

# The Diplommatinidae of Fiji – a hotspot of Pacific land snail biodiversity (Caenogastropoda, Cyclophoroidea)

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## Abstract

The minute (adult size 1.3–4.8 mm) land snail species of the family Diplommatinidae in the Fiji archipelago are revised based on historical material and modern (1998–99) collections targeting limestone outcrops on the largest island, Viti Levu, and several smaller islands in the Lau group. The forty-two species (including 30 new species) belong to the genera *Moussonina* Semper, 1865, *Palaina* Semper, 1865 and *Diancta* Martens, 1867, which are briefly characterized and keyed. The diagnostic structure of the inner lamellar system of each species is illustrated. All species except one are endemic to Fiji. In Viti Levu, the 12 localities surveyed each had 1–13 (average 5) species of Diplommatinidae; ten species were each found at a single site only. In the Lau islands, five islands were visited, with 1–4 species per island; four species are known from single islands. The number of historically known species not recollected in 1998–99 (7 species), the number of single-site occurrences (14 species), and the numerous islands — including limestone islands — that have not been surveyed at all, indicate that the 42 species of Diplommatinidae currently known from Fiji represent perhaps only half of the Fiji diplommatinid fauna. Such numbers approach the diplommatinid diversity of Palau (39 described and more than 60 undescribed species), and surpasses by far the diversity of other South Pacific archipelagos of comparable land area (New Caledonia, Vanuatu, Samoa).

Nomenclatural acts: Lectotypes designated: *Diplommatina fuscula*, *D. fuscula* var. *vitiana*, *D. godeffroyana*, *D. godeffroyana* var. *latecostata*, *D. tuberosa*, *D. martensi* var. *macrostoma*, all Mousson, 1870. Neotypes designated: *Diplommatina subregularis*, *D. ascendens*, *D. quadrata*, all Mousson, 1870. New species: *Diancta aurea* sp. n., *Diancta aurita* sp. n., *Diancta basi plana* sp. n., *Diancta controversa* sp. n., *Diancta densecostulata* sp. n., *Diancta dextra* sp. n., *Diancta dilatata* sp. n., *Diancta distorta* sp. n.,

*Diancta pulchella* sp. n., *Diancta rotunda* sp. n., *Diancta subquadrata* sp. n., *Diancta trilamellata* sp. n., *Moussonina acuta* sp. n., *Moussonina barkeri* sp. n., *Moussonina brodieae* sp. n., *Moussonina longipalatalis* sp. n., *Moussonina minutissima* sp. n., *Moussonina obesa* sp. n., *Moussonina polita* sp. n., *Moussonina uncinata* sp. n., *Moussonina vitianoides* sp. n., *Palaina alberti* sp. n., *Palaina flammulata* sp. n., *Palaina glabella* sp. n., *Palaina kitteli* sp. n., *Palaina labeosa* sp. n., *Palaina parietalis* sp. n., *Palaina sulcata* sp. n., *Palaina truncata* sp. n., *Palaina tuberosissima* sp. n.

## Keywords

Diplommatinidae, South Pacific, endemism, limestone outcrops, microgastropods, new species

## Introduction

For many of the Pacific islands, Captain Cook's voyages are the starting point of European scientific discovery of the local faunas and floras. However, although Cook stopped in Fiji in 1774, no land snails were collected or described from Fiji as a result of his voyages. In fact, the first land snail from Fiji was not described until 1834, quite a late date compared to the first discovery of land snails from New Zealand, New Caledonia or the Solomons, but a date comparable to the first discovery of the land snails of Tonga, Samoa, and the Society Islands. This may be a result of the land snails of the Pacific archipelagos from Fiji eastward being not very spectacular and thus escaping the attention of the untrained navy officers who were collecting all sorts of natural history items. The diplommatinids that form the focus of this paper are indeed small to minute, with adult sizes of 1.3–4.8 mm, the majority of species 2–3 mm. Until now, 12 species were known from Fiji, nearly all described by Zürich-based conchologist Albert Mousson, based on material collected by Eduard Graeffe, a young naturalist sent to explore Samoa, Uvea [= Wallis], Tonga and Fiji by the enlightened Hamburg merchant Cesar Godeffroy (see Bieler and Petit 2012). The two resulting contributions by Mousson (1865, 1870) constitute the foundation of Fiji malacology and contain the descriptions of approximately one-third of the Fiji land snail species today recognized as valid, among them *Diplommatina godeffroyana* [now *Palaina godeffroyana*]. The Godeffroy Museum, later incorporated in the Hamburg University Museum, was destroyed during the bombing of Hamburg at the end of World War II. However, the amount of material collected by Graeffe must originally have been enormous, and scattered lots survive in many European and North American museums, notably Zürich (which has the Mousson collection) and Paris (which has the specimens illustrated in Mousson's papers). Immediately after Graeffe, the Tahiti-based American conchologist Andrew Garrett started a two-years long exploration of the Fiji land snail fauna. Garrett's work was remarkable for his numerous observations on the habitats and ecology of the species but, although he visited many then malacologically unexplored islands, he surprisingly did not add a single species to the inventory of Fiji diplommatinids (Garrett 1887). In fact, after Mousson, a single new species of diplommatinid was added to the Fiji list (Liardet 1876) and nothing else for the following 140 years. Despite easier access by road to the mountain areas or by air to many islands, it is ironic



that, besides Gary Barker's still unpublished efforts (G. Barker, pers. com.), very little scientific collecting has taken place in Fiji in recent decades. The Fiji species were last reviewed by Kobelt (1902) and their systematics are in great need of revision. Several species were never illustrated, and some of the forms initially described as "varieties" in fact represent distinct species. Currently, ten species are recorded from Viti Levu, two from Ovalau and the Lau islands, and a single species from Taveuni. Of the 12 named taxa recorded from the Fiji archipelago, all but one are endemic.

The species of Diplommatinidae live in the leaf litter and can be extremely abundant — and diverse — in limestone regions. Twenty days of field work in 1998 and 1999 that sampled also spring snails (Haase et al. 2007) generated no less than 8,547 specimens of Diplommatinidae, representing 35 species. Segregating the Fiji diplommatinid fauna into species is relatively straightforward, but placing them in genera is problematic.

After being relegated for decades in the backwater of land snails systematics, the Diplommatinidae have recently hit the front line of molecular data, integrative taxonomy, and even cybertaxonomy. At the generic level, Webster et al. (2012) reconstructed a 5-genes molecular phylogeny of 71 specimens of Diplommatinidae from SE Asia and the West Pacific, representing 54 recognized species and 7 putative genera. Their results indicate that (1) monophyletic clades correspond with both coiling direction and biogeographic patterns; and (2) the ancestral state in the family is sinistrality, with several shifts (three in their dataset) to dextrality. At the species level, Tillier (1981) monographed the New Caledonia fauna. Based on anatomical characters, he concluded that species vary considerably in both shell size and shape, and that "in many cases the species can be distinguished only by their anatomy". According to Tillier, "species exhibit clinal variation in shell characters that are related to environmental conditions". Tillier's unconventional approach to diplommatinid taxonomy has not been repeated elsewhere, and obviously would be worth revisiting with molecular data. An integrative approach was followed by Yamazaki et al. (2013) who used shell, radula and molecular characters to revise the genus- and species-level systematics of the family Diplommatinidae in Palau. The "cybertaxonomy" approach of Liew et al (2014), based on 3D models and COI sequences, reviewed the species of *Plectostoma* H. Adams, 1865 from southeast Asia and treated 31 species (including 10 new species descriptions). Meanwhile, numerous other papers are still classically defining species based on shell characters only (e.g., Stanisic et al. 2010, Tongkerd et al. 2013, Simone 2013).

Vermeulen (1993) and Stanisic et al. (2010) used the genus name *Diplommata* Benson, 1849 in a very broad sense for an enormous number of species delimited solely by shell characters. However, Yamazaki et al. (2013) advised against the broad use of *Diplommata*. With the few exceptions reviewed above, modern concepts of the numerous genera of Diplommatinidae are still lacking. Irrespective of chirality, the Diplommatinidae of Fiji fall into three larger groups, based on shell characters, which here are considered to constitute genera (see discussion under the respective genus headings). The lesson from Webster et al. (2012) is that genera tend to be constrained to discrete geographical areas, and we have been guided by this conclusion in allocat-

ing the Fiji species to genera. Four nominal genera have their type species from islands in the South Pacific: *Moussonia* Semper, 1865 (Samoa), *Palaina* Semper, 1865 (Lord Howe Island), *Macropalaina* Möllendorff, 1897 (Fiji) and *Palmatina* Iredale, 1944 (Norfolk Island). The names *Moussonia* and *Palaina* (including *Macropalaina*, see below) are easily applicable to the Fiji fauna. For the third Fiji shell group, we have used *Diancta* Martens, 1864 (type species from the Moluccas). These working hypotheses will have to be validated in a broader geographical context and with anatomical and molecular characters, a goal far beyond that of the present paper.

## Material and methods

During two visits to Fiji by the second author (August 1998, and March 1999), the limestone outcrops of Viti Levu were specifically targeted, and opportunities to sample several of the lesser known and more remote islands in the Lau group arose during the BORDAU 1 oceanographic expedition (Richer de Forges et al. 2000). Standard methods for collecting microsnails in leaf litter were used, including a Winkler sieve, and rock faces and shrubs were inspected visually for rupicole and arboreal species. The dried leaf litter residues were sorted by Klaus Kittel, who immediately recognized that the magnitude of the Fiji diplommatinid radiation was considerably higher than had been recorded in the literature.

Diplommatinidae have a rich character set of the internal lamellae apparatus that can be used for species distinction. Names of the internal lamellae are here used in the sense of Vermeulen (1993), but a few additional terms have been created to accommodate the sometimes quite peculiar formation of some of these lamellae. The following definitions are used (Fig. 1):

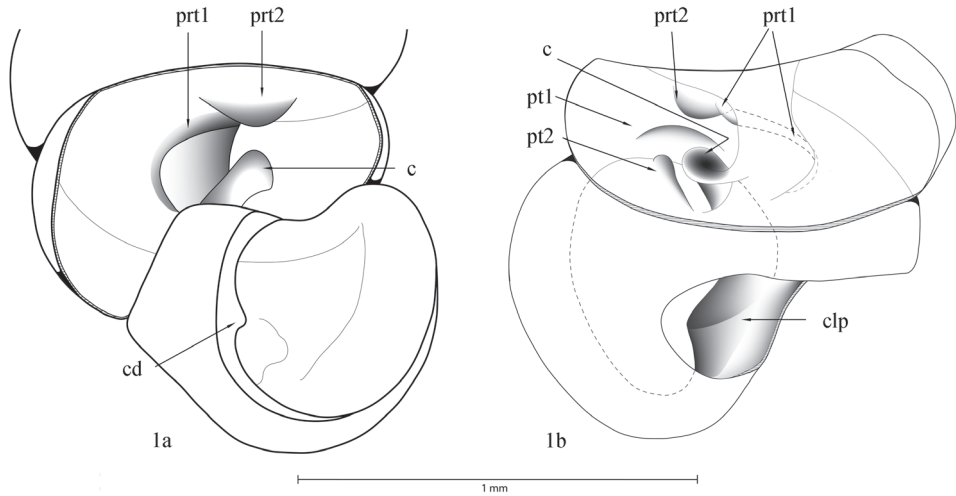
*columellaris*: a single lamella running on the columella into the interior of the shell; it may be visible as a basal columellar denticle in the aperture, it can have an interior undulation and secondary denticles on top of the lamella.

*columellar plate*: a basal broadening of the columella in the last whorl; it may be subdivided into two sections, the outer plate (pointing towards the aperture), and the internal plate (pointing towards the interior of the shell).

*parietal structures*: these may be either parietal denticles (i.e. single cone-like teeth visible in the aperture), or internal lamellae on the roof of the ultimate to penultimate whorls. In cases in which there are two parietal lamellae, the first (counted from the aperture) is usually a long lamella, the second very often a broad, spatulate lamella, which often runs at an angle to the first one.

*palatal structures*: there can be one to several lamella or small denticles, which may have either a spiral or axial orientation (i.e. perpendicular to the shell's axis); in constricted species, they may tend to be shifted also to the base of the penultimate whorl.

*constriction*: in certain species, the penultimate whorl suddenly decreases in diameter, with the last whorl continuing with the same growth increment as the whorls



**Figure 1.** Terminology of the lamellae apparatus of Diplommatinidae of Fiji.

before the constriction (and thus is consequently much larger than the constricted whorl). Vermeulen (1993: 6) used the name “tuba” for the post-constriction whorls, because in some diplommatinid genera this part detaches from the shell forming an irregular tube. This is not the case in any of the diplommatinid species from Fiji, and thus the term “tuba” is not used here.

*bulb*: a lateral voluminous protrusion of the ultimate whorl.

*bulb lamella*: an axial lamella inside the bulb that reinforces the shell at this particular place.

The lamellar system is usually placed ca. 0.5–1.5 whorls inside the shell, so many of these structures are placed in the whorl above the aperture, or even deeper inside the shell. The amount of constriction corresponds to the diameter of the operculum. While resting or as a reaction to other threats, the animal withdraws deeply behind the constriction, and has to pass all lamellae and teeth.

Preparation of shells showing the internal lamellar system requires some practice; the best way is to fix a specimen between two fingers, and use an insect needle (size 0) to break the dorsal wall of the shell through the aperture. After that, the shell fragment can quite easily be removed. At first glance, species may look very much alike, and in order to provide an overview and fast recognition of the species, a character matrix is provided (Table 1).

Size indications are relative to the size range of the species within the genera. In an absolute sense, a large species of *Moussonia* thus compares to small *Palaina* or *Diancta* species. In species with a double peristome, measurements of the aperture are from the inner peristomial lip.

**Table 1.** Character state matrix: 1 = present, 0 = absent. — Abbreviations used: bla = bulb lamella; bul = bulb; con = constriction; cpl = columella formed as a plate (with various states of reduction) (1) or as a lamella (2); oc = operculum thickened concentric; os = operculum simple; pal = number of palatal lamellae; prt = number of parietal lamellae; rp = ribbing pattern, with (1) = widely spaced throughout the whole shell, (2) densely spaced throughout the whole shell, (3) ribbing pattern changing in different parts of the shell.

Taxon//character	bla	bul	con	cpl	oc	os	pal	prt	rp
<i>Diancta aurea</i> sp. n.	0	0	1	1	0	1	0	0	3
<i>Diancta aurita</i> sp. n.	0	0	1	1	0	1	0	0	3
<i>Diancta basiplana</i> sp. n.	0	0	1	1	0	1	0	0	3
<i>Diancta controversa</i> sp. n.	0	0	1	1	0	1	1	0	2
<i>Diancta densecostulata</i> sp. n.	0	0	1	1	0	1	2	1	3
<i>Diancta dextra</i> sp. n.	0	0	1	1	—	—	1	0	1
<i>Diancta dilatata</i> sp. n.	0	0	1	1	0	1	0	0	2
<i>Diancta distorta</i> sp. n.	0	0	1	1	0	1	1	0	3
<i>Diancta macrostoma</i> (Mousson, 1870)	0	0	1	1	0	1	0	0	3
<i>Diancta martensi</i> (H. Adams, 1866)	0	0	1	1	0	1	1	0	3
<i>Diancta pulchella</i> sp. n.	0	0	1	1	0	1	0	0	3
<i>Diancta quadrata</i> (Mousson, 1870)	0	0	1	1	0	1	0	0	1
<i>Diancta rotunda</i> sp. n.	0	0	1	1	0	1	1	0	3
<i>Diancta subquadrata</i> sp. n.	0	0	1	1	0	1	0	0	3
<i>Diancta taviensis</i> (Liardet, 1876)	0	0	1	—	—	—	—	—	—
<i>Diancta trilamellata</i> sp. n.	0	0	1	1	0	1	1	1	3
<i>Moussonia acuta</i> sp. n.	0	0	0	2	—	—	0	2	0
<i>Moussonia barkeri</i> sp. n.	0	0	0	2	—	—	1	2	2
<i>Moussonia brodieae</i> sp. n.	0	0	0	2	—	—	1	2	1
<i>Moussonia fuscula</i> (Mousson, 1870)	0	0	0	2	—	—	1	2	1
<i>Moussonia longipalatalis</i> sp. n.	0	0	0	2	—	—	1	2	0
<i>Moussonia minutissima</i> sp. n.	0	0	0	2	—	—	1	2	1
<i>Moussonia obesa</i> sp. n.	0	0	0	2	—	—	1	2	1
<i>Moussonia polita</i> sp. n.	0	0	0	2	—	—	1	2	0
<i>Moussonia uncinata</i> sp. n.	0	0	0	2	—	—	1	2	1
<i>Moussonia vitiana</i> (Mousson, 1870)	0	0	0	2	—	—	1	2	2
<i>Moussonia vitianoides</i> sp. n.	0	0	0	2	—	—	2	2	2
<i>Palaina alberti</i> sp. n.	1	0	0	2	0	1	0	0	1
<i>Palaina ascendens</i> (Mousson, 1870)	—	1	0	—	—	—	—	—	1
<i>Palaina flammulata</i> sp. n.	1	1	0	2	0	1	0	0	1
<i>Palaina glabella</i> sp. n.	1	1	0	2	1	0	0	0	1
<i>Palaina godeffroyana</i> (Mousson, 1870)	0	0	0	2	1	0	0	0	1
<i>Palaina kitteli</i> sp. n.	1	1	1	2	0	1	0	1	3
<i>Palaina labeosa</i> sp. n.	0	1	0	2	1	0	0	0	3
<i>Palaina latecostata</i> (Mousson, 1870)	1	1	0	2	0	1	0	1	1
<i>Palaina parietalis</i> sp. n.	0	0	0	2	0	1	0	1	3
<i>Palaina pomatiaeformis</i> (Mousson, 1870)	0	1	0	2	1	0	0	0	3
<i>Palaina subregularis</i> (Mousson, 1870)	0	0	0	2	0	1	0	0	1
<i>Palaina sulcata</i> sp. n.	0	0	0	2	0	1	1	1	1
<i>Palaina truncata</i> sp. n.	1	1	0	2	—	—	0	1	1
<i>Palaina tuberosa</i> (Mousson, 1870)	0	1	0	2	—	—	0	1	3
<i>Palaina tuberosissima</i> sp. n.	1	1	0	2	0	1	1	1	3

We have tried to document the opercula of all species but not all species were collected alive and some opercula are thus not known. Usually, the opercula of Diplommatinidae are inadequately described (if at all) in the literature, probably because they are considered to be quite simple and uniform and of no taxonomic use. In fact, it is usually a flat, circular corneous plate, which internally may show a small lamella (here called apophysis). It is not fully clear whether the apophysis functions as the place where a kind of retraction muscle adheres, or whether the whole internal area is attached to the operculum-generating tissue and muscle. Our observations show that there obviously is some variation in the construction of opercula. Next to the simple form with the outer and inner surface being flat, opercula may have a structured outer surface with tightly arranged concentric periostracal lamellae. Often, these structures are not easily visible, because they are obscured by soil particles that are quite firmly fixed to them. It is not clear whether these structures are actively used by the animals as a surface to which such particles can be glued, or whether this is passive contamination that is stable simply because of the rough surface of this type of operculum. It must be stressed that this type of operculum occurs exclusively within the group we have identified here as genus *Palaina*.

Specimens are housed in MNHN unless otherwise stated, some are in NMBE; a reference collection will be deposited at the University of the South Pacific, Suva. All photos were taken with Leica DFC 425 multi-layered photography system. All measurements are in mm. The number following the slash after a catalogue number indicates the number of specimens in the lot. All localities are geo-referenced, the coordinates are supplied as decimal numbers; collecting dates are given as day.month.year.

### Museums acronyms

<b>NHMUK</b>	The Natural History Museum, London, United Kingdom
<b>MNHN</b>	Muséum National d'Histoire Naturelle, Paris, France
<b>NMBE</b>	Naturhistorisches Museum der Burgergemeinde Bern, Switzerland
<b>SMF</b>	Research Institute Senckenberg, Frankfurt am Main, Germany
<b>UMMZ</b>	Museum of Zoology, University of Michigan, USA
<b>ZMZ</b>	Zoological Museum of the University Zurich, Ichel, Switzerland

### Abbreviations

<b>bla</b>	bulb lamella
<b>bul</b>	bulb
<b>c</b>	columellaris
<b>cd</b>	columellar denticle
<b>con</b>	constriction
<b>cpl</b>	columellar plate

<b>D</b>	shell diameter
<b>H</b>	shell height
<b>oc</b>	operculum thickened concentric
<b>os</b>	operculum simple
<b>PD</b>	peristome diameter
<b>PH</b>	peristome height
<b>prt 1</b>	inner parietalis
<b>prt 2</b>	outer parietalis
<b>pt</b>	palatalis
<b>pt 1</b>	parallel palatalis
<b>pt 2</b>	perpendicular palatalis
<b>W</b>	number of whorls

## Systematic section

### *Diancta* Martens, 1864

1864 *Diancta* Martens, Monatsberichte der Königlichen Preussischen Akademie der Wissenschaften zu Berlin, (1864): 119. [Type species: *Diplommatina constricta* Martens, 1864, by monotypy; Moluccas, Indonesia].

**Diagnosis.** Shell dextral or sinistral, constriction easily visible to reduced, umbilicus always closed; protoconch usually with a pitted microsculpture; aperture shifted right or left of shell axis; no pleats visible in the aperture, columella reinforced by 1–2 plates situated right or left of the columella, often with a palatal callosity in opposition, parietalis can be present, often reduced; operculum corneous, multispiral, flat, with an elongate internal apophysis.

**Remark.** Martens (1864: 119) defined the genus *Diancta* by “penultimate whorl with a constriction”. Quadras and Möllendorff (1895) added the new subgenus *Paradiancta* (type species *Diancta philippinica* Quadras & Möllendorff, 1895, from the Philippines), which is characterised by dextral shells with a long palatalis and columellaris. Kobelt (1902: 419) added to the general definition that the shell of *Diancta* is oval and somewhat irregularly coiled. This short summary shows that the definition of these genera is based on taxonomically unimportant shell characters. Constriction of the shell is not an autapomorphic but a plesiomorphic character; for example, it is found in other genera like *Opisthostoma* Blandford, 1860 (Vermeulen 1991: 140) and *Diplommatina* Benson, 1849 (Vermeulen 1993, 1996: 116).

The diplommatinid species of Lord Howe Island were also placed in *Diancta* by Stanicic et al. (2010). The shells of these species show some resemblance to those from Fiji, and may be closely related to the Fiji radiation. An analysis of the inner lamellar system of these species would be desirable.

***Diancta macrostoma* (Mousson, 1870)**

Figs 2–4

1870 *Diplommatina martensi* var. *macrostoma* Mousson, Journal de Conchyliologie, 18: 184, pl. VIII, fig. 5. Type locality: “Ovalau, Vaini Loba et quelques autres points de Viti Levu”.

1897 *Diancta macrostoma* Möllendorff, Nachrichtenblatt der deutschen malakozoologischen Gesellschaft, 29 (1/2): 44.

**Type data.** *Diplommatina martensi* var. *macrostoma* Mousson: lectotype, here designated, ZMZ 526691a, paralectotypes ZMZ 526691/5, Ovalau, coll. Mousson ex Graeffe 1866. — *macrostoma* Möllendorff: lectotype designated by Zilch (1953: 18) SMF 104905/1, Fiji [“in insula Vitilevu”], coll. Möllendorff ex Mousson.

When establishing *Diancta macrostoma* as a new species, Möllendorff cited “*Diplommatina macrostoma* Mouss. ms.”, apparently unaware that Mousson had already described it as *Diplommatina martensi* var. *macrostoma*. The two names are homonyms but, as they are not based on the same name-bearing types, they are not objective synonyms.

**Diagnosis.** Shell sinistral, elongate, sculpture of widely spaced ribs, ribbing pattern constant throughout teleoconch.

**Description.** Shell sinistral, elongate oval, yellowish; last whorl constricted; protoconch broad, obtuse, with a fine pattern of granules; umbilicus closed, concave narrow periomphalum; teleoconch sculpture of coarse widely spaced ribs, ribbing pattern constant throughout the shell, somewhat denser on the dorsal side of penultimate whorl; aperture broadly subquadrate, peristome doubled, with the upper left edge slightly protruding; apertural rims connected by a thin, slightly detaching callus; aperture only just attached to the last whorl; no pleats visible in the aperture; inside the shell, two small columellar plates present.

Operculum corneous, flat, internally with a small lamella.

**Measurements.** Lectotype (Fig. 2): H = 2.86; D = 1.93; PH = 1.4; PD = 1.35; W = 5.

**Distribution** (not shown on map). Ovalau Island.

**Remarks.** Mousson also recorded this species from Viti Levu. The re-investigation of his specimens revealed that none of them is conspecific with the lectotype of *D. macrostoma*. For revised identification of these specimens, see Tab. 2.

***Diancta martensi* (H. Adams, 1866), comb. n.**

Figs 5–10

1866 *Diplommatina* (*Diancta*) *martensi* H. Adams, Proceedings of the Zoological Society of London, 1866: 446, t. 38 f. 11. Type locality: unknown.

1869 *Diplommatina distorta* “Mousson, 1869”, Schmeltz, Museum Godeffroy Catalog IV: 75 [nomen nudum].



1902 *Palaina (Palaina) martensi*, – Kobelt, Cyclophoridae: 400.

1959 *Palaina distorta*, – Solem, Fieldiana Zoology, 43: 191 [Fiji, Tonga; nomen nudum].

1959 *Palaina martensi*, – Solem, Fieldiana Zoology, 43: 191 [Fiji, Tonga].

2012 *Diplommatina distorta*, – Bieler & Petit, Zootaxa 3511: 45 [nomen nudum].

**Type data.** Possible syntype NHMUK 1867.3.22.4 [said to be from Australia, Lord Howe (error)].

**Material.** Fiji, Viti Levu, mouth of cave near Suva Bay, coll. Bryant Walker ex Ponsonby, UMMZ 88697 (Solem 1959 as *Palaina distorta*); Viti Levu, surroundings of Qauia village, secondary wet forest, 20–50 m, -18.0999 178.3999, leg. Bouchet & Warén, 15.03.1999, MNHN/394, NMBE 516879/25; Viti Levu, surroundings of Laselevu village, 80 m, rainforest, -17.7532 178.1416, leg. Bouchet, Warén & Dayrat, 14.02.1999, MNHN/92, NMBE 516880/10. — Tonga, Tongatabu, coll. Bryant Walker ex Ponsonby, UMMZ 87919.

**Diagnosis.** Shell medium sized, sinistral, last whorl strongly constricted, last whorl strongly ascending, apertural rims connected by a large polished callus, axial palatalis.

**Description.** Shell medium sized, sinistral, elongate oval, yellowish to whitish; last whorl strongly constricted; protoconch large, 1–1.5 whorls, bulbous obtuse, pitted; umbilicus closed, periomphalum narrow; teleoconch sculpture of widely spaced ribs on the initial and the central whorls, ribs becoming coarser and more widespread on the last third of the last whorl; last whorl strongly ascending; aperture quadrate, peristome connected to the last whorl; apertural rims connected by a large polished callus; aperture with a slightly enlarged process over the left edge; no pleats visible in the aperture; inside the shell, columellar plate split into two plates of equal size, with a small but strong axial palatal fold opposite.

Operculum corneous, flat, internally with a small lamella.

**Measurements.** Possible syntype (Fig. 5): H = 3.2; D = 2.57; PH = 1.51; PD = 1.48; W = 5.

**Distribution** (Fig. 170). Recorded from Fiji, Viti Levu, and Tonga, Tongatabu by Solem (1959: 191).

**Remarks.** The possible syntype matches well the figure of Adams (pl. 38, fig. 11). The museum's label records Lord Howe Island as origin, but there is no locality given in the original description. However, the possible syntype does not match the illustrations of Stanisic et al. (2010) of the Lord Howe Island species of *Diancta*. Thus, the NHMUK label is incorrect, the provenance of *D. martensi* remains unknown, and the status of NHMUK 1867.3.22.4 is doubtful (possible syntype). On the other hand, the specimens illustrated here from Fiji and Tonga (Figs 6–10) are almost identical with the possible syntype, which thus might originate from one or other of these island groups.

In their analysis of the Godeffroy sales catalogue, Bieler and Petit (2012: 45) listed “*Diplommatina distorta* Mousson” as a *nomen nudum*. To complete the history of this name, the Mousson collection in Zurich has been checked: the lots ZMZ 526698/7 (“*Dipl. martensi* H. Adams, *D. distorta* Mss, Viti Levu, Graeff. 68” in Mousson's handwriting), and ZMZ 526699/2 (“*Dipl. distorta*. Mss, Viti Levu, Graeffe 68” in



**Figures 2–4.** *Diancta macrostoma* (Mousson, 1870). **2** Lectotype ZMZ 526691 Fiji, Ovalau, H = 2.84 mm **3** paratype, last whorl opened to show internal lamellae (enlarged, not to scale) **4** operculum **4a** inner surface **4b** outer surface. Figure 2  $\times 10$ , Figure 3  $\times 40$  magnification.

Mousson's handwriting) were examined. It is clear that Mousson intended to separate these specimens under the name "*distorta*", but this remained a manuscript name. In fact, both lots contain typical specimens of *D. martensi*. It is not clear why Solem used "*Diplommatina distorta* Mousson", nor why he considered the two taxa as distinct.

We here identify the modern lots recorded above with this species. Although on average, specimens from these lots are somewhat smaller than the possible syntype, no other character justifies their separation.

### ***Diancta quadrata* (Mousson, 1870), comb. n.**

Figs 11–12

1870 *Diplommatina quadrata* Mousson, Journal de Conchyliologie, 18: 187, pl. VIII, fig. 1. Type locality: Viti Levu.

1902 *Palaina* (*Palaina*) *quadrata*, – Kobelt, Cyclophoridae: 404.

**Type data.** The holotype (by monotypy) could be found neither in MNHN nor in the Mousson collection in Zurich, the SMF, the collection of Charpentier in Lausanne or the Shuttleworth collection in NMBE. The species was not present in the 1989–1999 material. However, the Mousson collection contains a lot of one specimen, which agrees well with



**Figures 5–10.** *Diancta martensi* (H. Adams, 1866). **5** Possible syntype NHMUK 1867.3.22.4, err.: “Australia, Lord Howe”, H = 3.2 mm **6** UMMZ 88697 Fiji, Viti Levu, mouth of cave near Suva Bay, coll. Bryant Walker ex Ponsonby **7** UMMZ 87919 Tonga, Tongatabu, coll. Bryant Walker ex Ponsonby **8** Fiji, Viti Levu, Qauiā village, 20–50 m, H = 2.62 mm **9** last whorl opened to show internal lamellae (enlarged, not to scale). **10** operculum **10a** inner surface **10b** outer surface. All figures  $\times 10$ , Figure 10  $\times 40$  magnification.

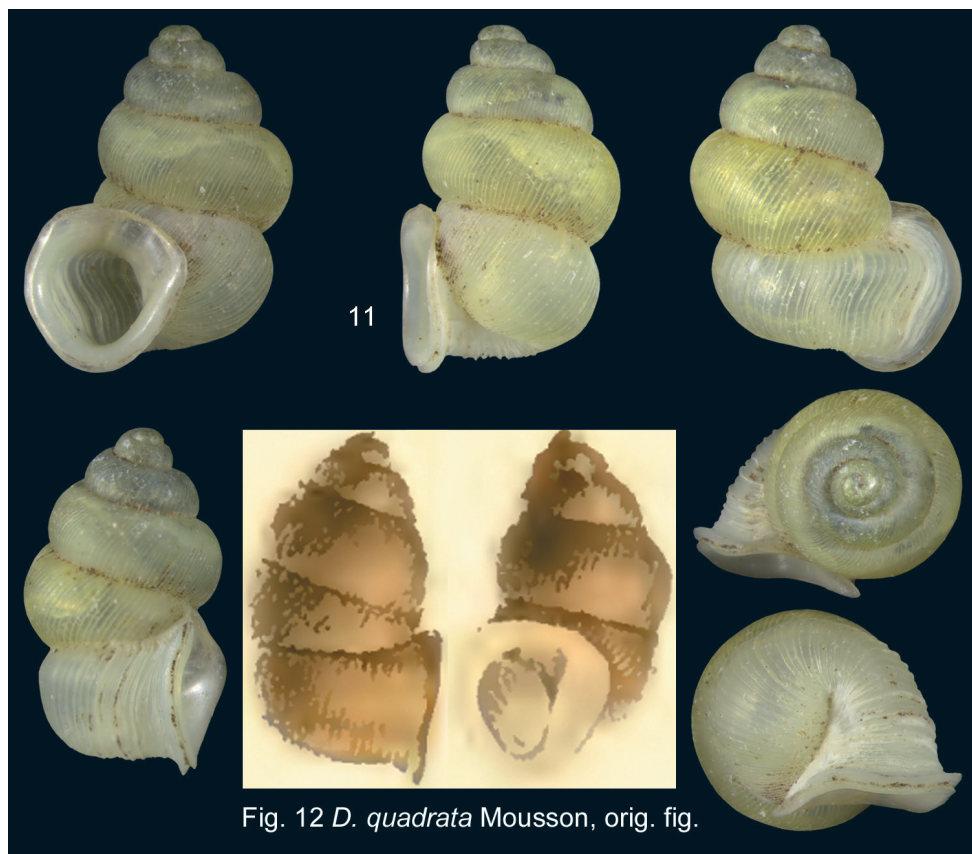


Fig. 12 *D. quadrata* Mousson, orig. fig.

**Figures 11–12.** *Diancta quadrata* (Mousson, 1870). **11** Neotype ZMZ 526690a, Viti Levu, H = 4.56 mm. **12** Original figure *Diplommatina quadrata* reproduced from Journal de Conchyliologie, 18: pl. VIII, fig. 1 All figures  $\times 10$  magnification.

the original description (see below). Because of the need to unambiguously stabilize the taxonomic extension of this nominal species, this specimen (ZMZ 526690a; Fig. 11) is here selected as neotype.

**Original description.** “*T. sinistrorsa*, oblique lineatim rimata, ovata, confertim costulato-striata, pallide flavula. Spira convexoconica; summo minuto, obtusulo; sutura vix profunda. Anfr. 5, celeriter accrescentes, convexi; primi laevigati; sequentes striati; tertius subinflatus; penultimus in dorso inflatus, in ventre retractus; ultimus fortiter ascendens, attenuatus, infra utrimque compressiusculus, cervice subangulata. Apert. verticalis, tangentialis, intus anguste elliptica, extus magna, subpatula, oblique et obtuse quadrata. Perist. expansum, vix incrassatum; marginibus lamina breviter solutu junctis, lateralibus super medium anfractus penultimi insertis, hic expansiusculis, antrorsum irregulariter undulatis. — Long, 4,6, diam. 2,9 mill. — Rat. apert. 1 : 1. Viti Levu ex Graeffe, one specimen”.

**Diagnosis.** Shell large, yellowish, teleoconch sculpture with narrowly spaced ribs on the entire shell, last whorl with shallow furrow, aperture quadrate to subrectangular, peristome disconnected from last whorl.

**Description** (based on neotype). Shell large, sinistral, oval, yellowish, partly translucent; last whorl only slightly constricted, with a broad and shallow furrow; protoconch large, 1–1.5 whorls, bulbous obtuse, pitted; umbilicus closed, periomphalum narrow; teleoconch sculpture of narrowly spaced ribs on the entire teleoconch; last whorl ascending; aperture quadrate to subrectangular, reinforced by a labial callus, peristome disconnected from the last whorl; apertural rims connected by a large polished callus; aperture with a slightly enlarged process over the left edge; no pleats visible in the aperture; internal lamellar structure not investigated.

Operculum unknown.

**Measurements.** Neotype (Fig. 11): H = 4.56; D = 3.53; PH = 2.24; PD = 2.16; W = 6.

**Distribution.** Viti Levu, precise locality unknown.

**Remarks.** This species is placed here in *Diancta*, because the neotype shows the typical contraction of the teleoconch, described by Mousson as “anfractus...penultimus in dorso inflatus, in ventre retractus”.

***Diancta taviensis* (Liardet, 1876), comb. n.**

Fig. 123

1876 *Diplommatina taviensis* Liardet, Proceedings of the Zoological Society of London, 1876: 101, pl. V fig. 9 (on the figure caption, the specific epithet is erroneously spelled *taviuviensis*). Type locality: Taviuni [= Taveuni Island, Fiji].

**Type material.** Not in NHMUK.

**Material.** No specimen available.

**Description** (original). “Shell with the penultimate whorl contracted in front, leaving the previous one and lip of the aperture joining regularly costated; lip double; aperture circular and entire. Animal with two tentacles, short and cylindrical, with an active arched motion, as in *Helicina*. Eyes situated at the base of tentacles inside [Hab. Taviuni, Fiji].”

**Remarks.** No specimen is available, but no collecting was done in Taveuni. This taxon was overlooked by Kobelt (1902). The original illustration is of a shell with an aperture shifted to the left of the shell axis, which indicates a generic placement in *Diancta* rather than *Moussonia* or *Palaina*.

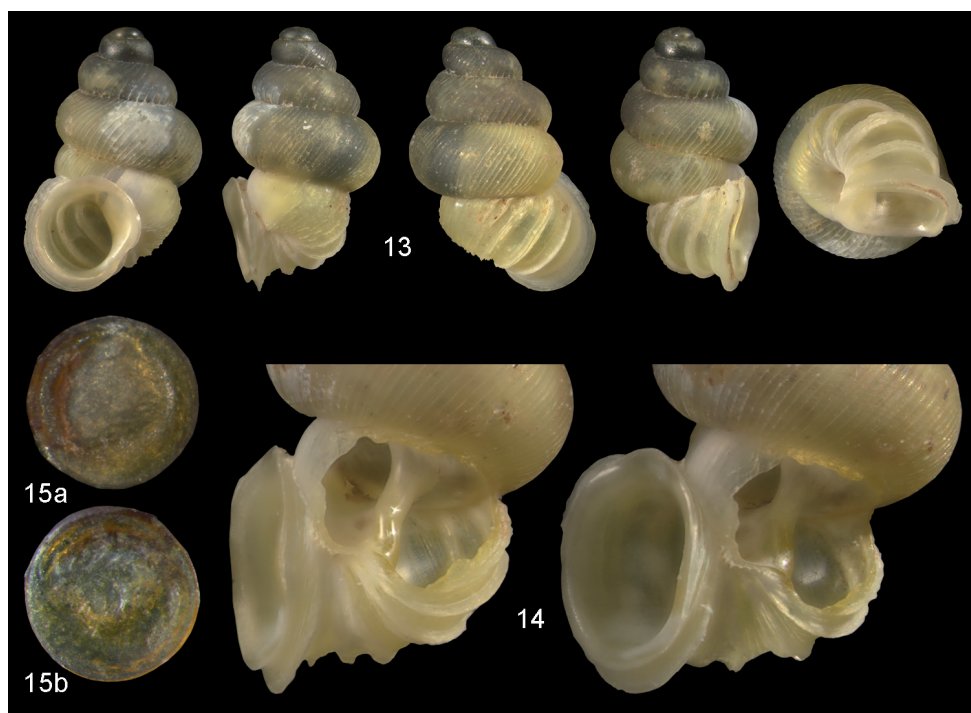
***Diancta aurea* sp. n.**

<http://zoobank.org/DCE948C6-F4CC-477F-8586-90738EBC1BD4>

Figs 13–15

**Type material.** Holotype MNHN IM-2000-27412, paratypes MNHN/15 IM-2000-27413, NMBE 516869/3. Type locality: Viti Levu, Wailotua karst, 50–80 m, rainforest, -17.7582 178.4166, leg. Bouchet, 25–27.08.1998.





**Figures 13–15.** *Diancta aurea* sp. n. **13** Holotype MNHN IM-2000-27412, Viti Levu, Wailotua karst; H = 3.48 mm **14** paratype, last whorl opened to show internal lamellae (enlarged, not to scale) **15** operculum **15a** inner surface **15b** outer surface. Figure 13  $\times 10$ , Figure 15  $\times 40$  magnification.

**Etymology.** Latin adjective *aureus*, -a, -um = golden; with reference to the peculiar colour of fresh shells of this species.

**Diagnosis.** Shell sinistral, yellow, narrow periomphalum, with a few very strong ribs on the last third of the last whorl, internal dentition almost completely reduced.

**Description.** Shell sinistral, small, of a bright yellow colour; last whorl constricted; protoconch broad, obtuse with a pitted microsculpture; umbilicus closed, very narrow periomphalum; teleoconch sculpture initially of coarse widely spaced ribs, changing to a more dense pattern on the next two whorls, almost smooth on the last whorl (particularly above the aperture), followed by a few very strong ribs on the last third of the last whorl; last whorl slightly ascending; aperture circular, not connected to the last whorl, peristome funnel-shaped, simple; apertural rims connected, with a small parietal shield; no dentition visible in the aperture in frontal view; columellar plate with a narrow internal part, outer part reduced to a basal knob.

Operculum corneous, flat, small apophysis, OD = 0.58.

**Measurements.** Holotype (Fig. 13): H = 3.48; D = 2.35; PH = 1.46; PD = 1.38; W = 4.5.

**Distribution** (Fig. 170). Only known from the type locality.

**Remarks.** *Diancta aurea* sp. n. differs from three species of similar size by the following character states: *D. basiplana* sp. n. differs in the remarkable form of its enlarged last whorl, *D. subquadrata* sp. n. in its much finer ribbing pattern on the teleoconch, and *D. aurita* sp. n. in its characteristic formation of the apertural process and the deep orange apertural shield.

***Diancta aurita* sp. n.**

<http://zoobank.org/6DF0DF46-9831-4193-BF26-10DB3A2C5E80>

Figs 16–17

**Type material.** Holotype MNHN IM-2000-27414, paratypes MNHN/4 IM-2000-27415, NMBE 516868/1. Type locality: Viti Levu, Wailotua karst, near summit Ulu-itova, 370–390 m, rainforest, -17.7582 178.4166, leg. Bouchet, 28.08.1998.

**Etymology.** Latin adjective *auritus*, *-a*, *-um* = with long ears.

**Diagnosis.** Large, sinistral shell, yellowish, aperture with an extraordinarily enlarged process over the left edge, aperture orange red.

**Description.** Shell large, sinistral, elongate oval, yellowish; last whorl slightly constricted; protoconch large, bulbous obtuse, pitted; umbilicus closed, narrow concave periomphalum; teleoconch sculpture of widely spaced ribs on the initial whorls, turning to a more densely spaced pattern on the central whorls, and becoming slightly coarser on the last third of the last whorl; last whorl slightly ascending; aperture circular, orange red, peristome doubled, not connected to the last whorl; apertural rims connected; aperture with an extraordinarily enlarged process over the left edge; no pleats visible in the aperture; inside the shell columellar plate with a reduced inner part, and a broad outer part.

Operculum corneous, flat, internally with a small lamella.

**Measurements.** Holotype (Fig. 16): H = 4.39; D = 2.7; PH = 1.78; PD = 1.79; W = 6.

**Distribution** (Fig. 170). Only known from the type locality.

**Remarks.** For a differential diagnosis, refer to *D. aurea* sp. n. There was no complete operculum available for an illustration or proper measurement.

***Diancta basiplana* sp. n.**

<http://zoobank.org/423E80A4-67B1-430D-95BE-DFC990CC1C9F>

Figs 18–20

**Type material.** Holotype MNHN IM-2000-27416, paratypes MNHN/44 IM-2000-27417, NMBE 516870/10. Type locality: Viti Levu, Wailotua karst, 50–80 m, rainforest, -17.7582 178.4166, leg. Bouchet, 25–27.08.1998.

**Material.** Viti Levu, Nakorosule limestone outcrop, 30 m, degraded forest, -17.7734 178.2517, leg. Bouchet & Dayrat, 16.02.1999, MNHN/180, NMBE 516881/20.



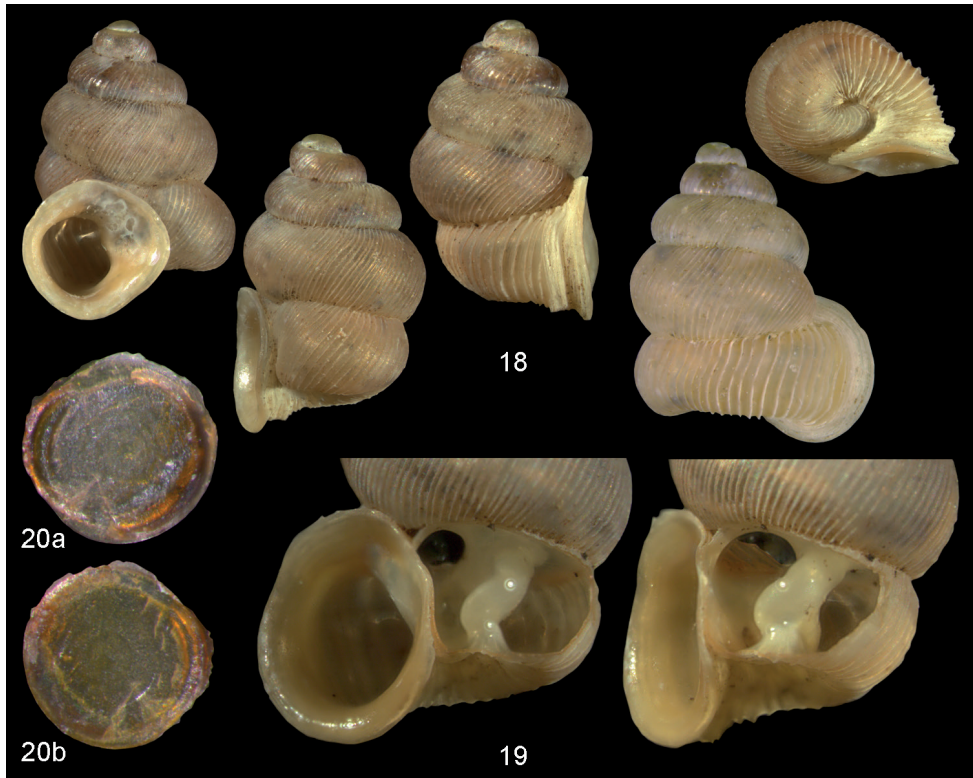


**Figures 16–17.** *Diancta aurita* sp. n. **16** Holotype MNHN IM-2000-27414, Viti Levu, Wailotua karst, H = 4.39 mm. **17** paratype, last whorl opened to show internal lamellae (enlarged, not to scale. Figure 16  $\times 10$  magnification.

**Etymology.** Latin noun *basis* = base, and adjective *planus*, *-a*, *-um* = flat.

**Diagnosis.** Large sinistral shell, last whorl with a broad bulbous expansion, columellar plate forming a twisted tooth-like lamella, periomphalum flat.

**Description.** Shell large, sinistral, shell colour dull brown; last whorl slightly constricted; protoconch big, bulbous obtuse with pitted microsculpture; umbilicus slit-like closed, periomphalum narrow, flat; last whorl with a broad bulbous expansion, aperture slightly shifted to the left and ascending, basis of the last whorl compressed; teleoconch sculpture of fine regularly spaced ribs, which become coarser on the last third of the last whorl; aperture almost rectangular, peristome doubled; apertural rims connected and detached from the last whorl, with a broad parietal shield; no pleats visible in the aperture; inside the shell with a columellar plate consisting of a twisted tooth-like lamella.



**Figures 18–20.** *Dianta basi plana* sp. n. **18** Holotype MNHN IM-2000-27416, Viti Levu, Wailotua karst, H = 3.94 mm. **19** paratype, last whorl opened to show internal lamellae (enlarged, not to scale) **20** operculum **20a** inner surface **20b** outer surface. Figure 18  $\times 10$ , Figure 20  $\times 40$  magnification.

Operculum corneous, with a small apophysis, OD = 0.63.

**Measurements.** Holotype (Fig. 18): H = 3.94; D = 2.81; PH = 1.85; PD = 1.96; W = 5.5.

**Distribution** (Fig. 170). Central and eastern part of Viti Levu.

**Remarks.** *Dianta basi plana* sp. n. is unmistakable because of its flat periomphalic base, and its twisted columellar plate.

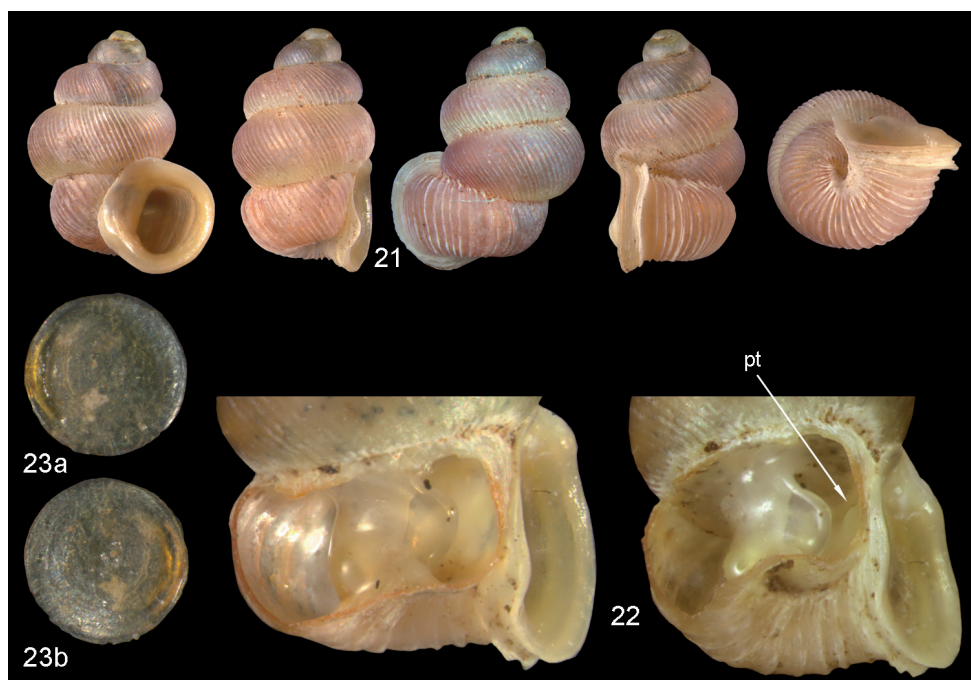
***Dianta controversa* sp. n.**

<http://zoobank.org/E3C3D011-62D3-4689-9E61-AFC1C49F3DB5>

Figs 21–23

**Type material.** Holotype MNHN IM-2000-27418, paratypes MNHN/8 IM-2000-27419, NMBE 516874/2. Type locality: Viti Levu, Wailotua karst, 50–80 m, rainforest, -17.7582 178.4166, leg. Bouchet, 25–27.08.1998.

**Material.** Viti Levu, Waivisa karst, 50–80 m, rainforest, -17.6879 178.4033, leg. Bouchet, 27.08.1998, MNHN/5; Viti Levu, Nakorosule limestone outcrop, 30 m,



**Figures 21–23.** *Diancta controversa* sp. n. **21** Holotype MNHN IM-2000-27418, Viti Levu, Wailotua karst, H = 3.2 mm **22** paratype, last whorl opened to show internal lamellae (enlarged, not to scale) **23** operculum **23a** inner surface **23b** outer surface). Figure 21  $\times 10$ , Figure 23  $\times 40$  magnification.

degraded forest, -17.7734 178.2517, leg. Bouchet & Dayrat, 16.02.1999, MNHN/1; Viti Levu, Saweni karst, 50–60 m, dry forest, -17.9032 177.7983, leg. Bouchet, 22.08.1998, MNHN/1.

**Etymology.** Latin adjective *controversus*, -a, -um = coiling in the opposite direction.

**Diagnosis.** Shell dextral, reddish to pinkish, regularly spaced ribs, last whorl slightly ascending, aperture connected to the last whorl, columellar plate with a strong inner plate, opposite a strong axial palatalis.

**Description.** Shell dextral, oval, medium sized, reddish to pinkish coloured; last whorl constricted; protoconch broad, obtuse; umbilicus slit-like, concave periomphalum; teleoconch sculpture of regularly spaced fine ribs, ribs become somewhat coarser on the last whorl; last whorl slightly ascending; aperture subrectangular, peristome funnel-shaped, doubled; aperture connected to the last whorl with a slight labial callus; no visible pleats in the aperture; inside, columellar plate with a strong inner plate, outer plate less developed, and a basal knob opposite to the inner plate with a strong axial palatalis.

Operculum corneous, flat, internally with a short apophysis, DO = 0.54.

**Measurements.** holotype (Fig. 21): H = 3.2; D = 2.47; PH = 1.53; PD = 1.55; W = 5.5.

**Distribution** (Fig. 170). Central to eastern Viti Levu.

**Remarks.** For a differential diagnosis, refer to *Diancta dextra* sp. n., the only other dextral species of *Diancta* species so far known in Fiji. Apart from the coiling direction,

*Diancta controversa* sp. n. resembles *D. martensi* in its aperture, which is attached to the last whorl. Both share a similar axial palatalis, but the columellar plate in *D. martensi* is not subdivided in two parts of differing size and shape.

***Diancta densecostulata* sp. n.**

<http://zoobank.org/A8FBE3F9-D8C6-4B0D-BEC6-B9DFE3B26FF3>

Figs 24–26

**Type material.** Holotype MNHN IM-2000-27420, paratypes MNHN/283 IM-2000-27421, NMBE 516873/20. Type locality: Viti Levu, Wailotua karst, 50–80 m, rainforest, -17.7582 178.4166, leg. Bouchet, 25–27.08.1998.

**Material.** Viti Levu, Tuvu karst, 50 m, dry forest, -17.9332 177.7067, leg. Bouchet, 23.08.1998, MNHN/11; Viti Levu, Wailotua, 115 m, -17.7664 178.4117, leg. Bouchet, 25.08.1998, MNHN/18.

**Etymology.** Latin adjectives *densus*, -a, -um = close, and *costulatus*, -a, -um = ribbed.

**Diagnosis.** Sinistral small shell, narrow periomphalum, fine regularly spaced teleoconch ribs, bipartite columellar plate, two palatal and one parietal lamella.

**Description.** Shell sinistral, oval, small, brownish; last whorl constricted; protoconch broad, obtuse with a pitted microsculpture; umbilicus closed, concave and narrow periomphalum; teleoconch sculpture of fine regularly spaced ribs, in a dense pattern on the upper whorl, pattern more spacious with more coarse ribs on the last whorl; last whorl strongly ascending; aperture circular, connected to the last whorl, peristome funnel-shaped, simple; apertural rims connected, with a broad parietal shield; no dentition visible in the aperture by frontal view; inside with bipartite columellar plate, external part of the plate reduced to a basal knob, internal part a broad lamella, opposite a palatalis (visible in the aperture of fresh shells as an internal knob), a second palatalis just right above the columellar angle, and a parietal lamella present.

Operculum corneous, flat, internally with a small apophysis, DO = 0.38.

**Measurements.** holotype (Fig. 24): H = 2.33; D = 1.46; PH = 1.14; PD = 1.13; W = 5.5.

**Distribution** (Fig. 170). Two localities quite far apart from each other on Viti Levu.

**Remarks.** *Diancta densecostulata* sp. n. differs from *D. macrostoma* by its slightly smaller shell, the regular dense pattern of the teleoconch ribs, and the internal dentition.

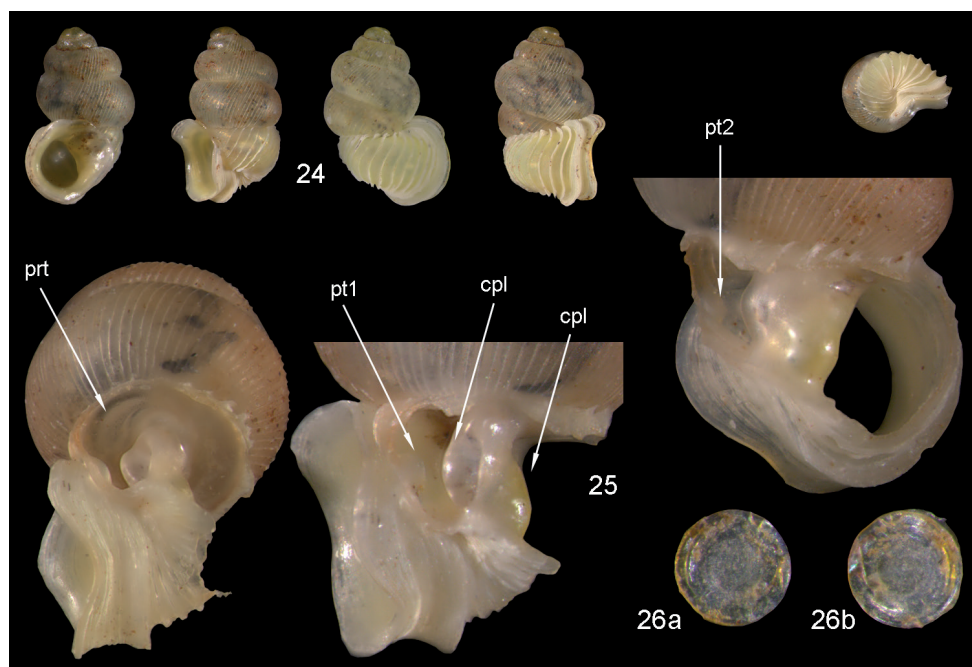
***Diancta dextra* sp. n.**

<http://zoobank.org/88339CDF-E1B2-4180-9D31-09F0E733F9C1>

Figs 27–28

**Type material.** Holotype MNHN IM-2000-27422. Type locality: Viti Levu, Wailotua karst, 50–80 m, rainforest, -17.7582 178.4166, leg. Bouchet, 25–27.08.1998.





**Figures 24–26.** *Diancta densecostulata* sp. n. **24** Holotype MNHN IM-2000-27420, Viti Levu, Wailotua karst, H = 2.33 mm; **25** paratype, last whorl opened to show internal lamellae (enlarged, not to scale) **26** operculum **26a** inner surface **26b** outer surface. Figure 24  $\times 10$ , Figure 26  $\times 40$  magnification.

**Material.** Viti Levu, Saweni karst, 50–60 m, dry forest, -17.9032 177.7983, leg. Bouchet, 22.08.1998, MNHN/1.

**Etymology.** Latin adjective *dexter*, *dextra*, -um = right.

**Diagnosis.** Shell dextral, quite large, reddish, regularly spaced fine ribs, columellar plate reduced, with a palatalis.

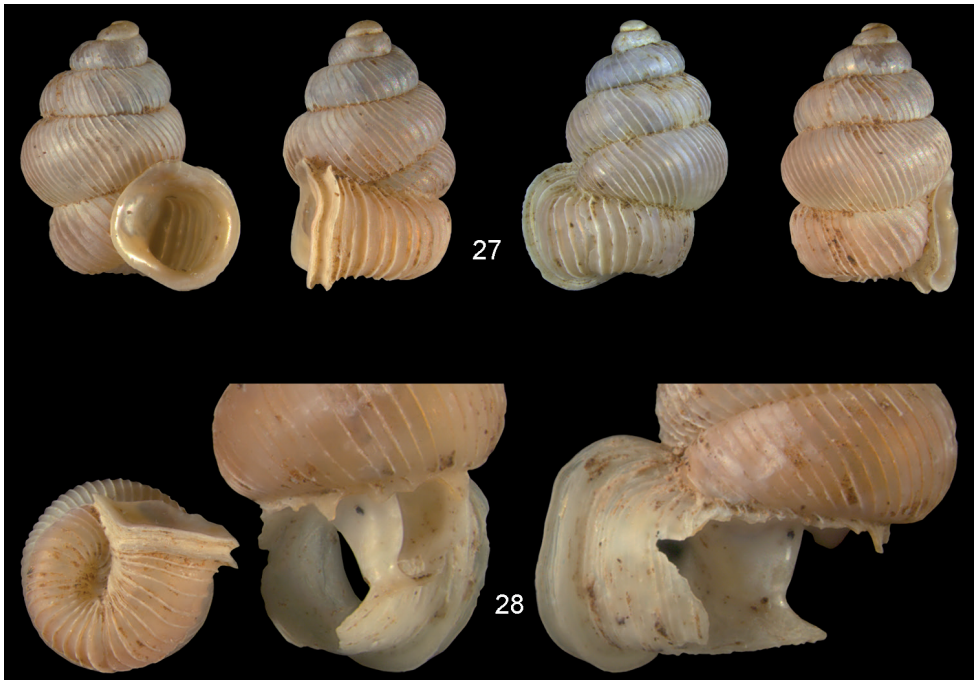
**Description.** Shell dextral, broadly oval, quite large, reddish; last whorl constricted; protoconch broad, obtuse; umbilicus slit-like, concave periomphalum; teleoconch sculpture of regularly spaced fine ribs, ribs slightly coarser on the last whorl; last whorl strongly ascending; aperture subrectangular, peristome funnel-shaped, simple; aperture connected to the last whorl; no visible pleats in the aperture; inside the shell, columellar plate reduced to an almost invisible callus, one palatalis present.

Operculum not recorded.

**Measurements.** Holotype (Fig. 27): H = 3.56; D = 2.9; PH = 1.74; PD = 1.73; W = 5.5.

**Distribution** (Fig. 170). Two localities in central and eastern Viti Levu.

**Remarks.** *Diancta dextra* sp. n. differs from the similar *D. controversa* sp. n. by the more coarse pattern of ribbing, the reduced columellar plate, and the missing palatalis. The two species co-occur in the Wailotua karst.



**Figures 27–28.** *Diancta dextra* sp. n. **27** Holotype MNHN IM-2000-27422, Viti Levu, Wailotua karst, H = 3.56 mm **28** paratype, last whorl opened to show internal lamellae (enlarged, not to scale). Figure 27  $\times 10$  magnification.

***Diancta dilatata* sp. n.**

<http://zoobank.org/67573DB0-423A-44DF-BF18-5ADE868AF414>

Figs 29–31

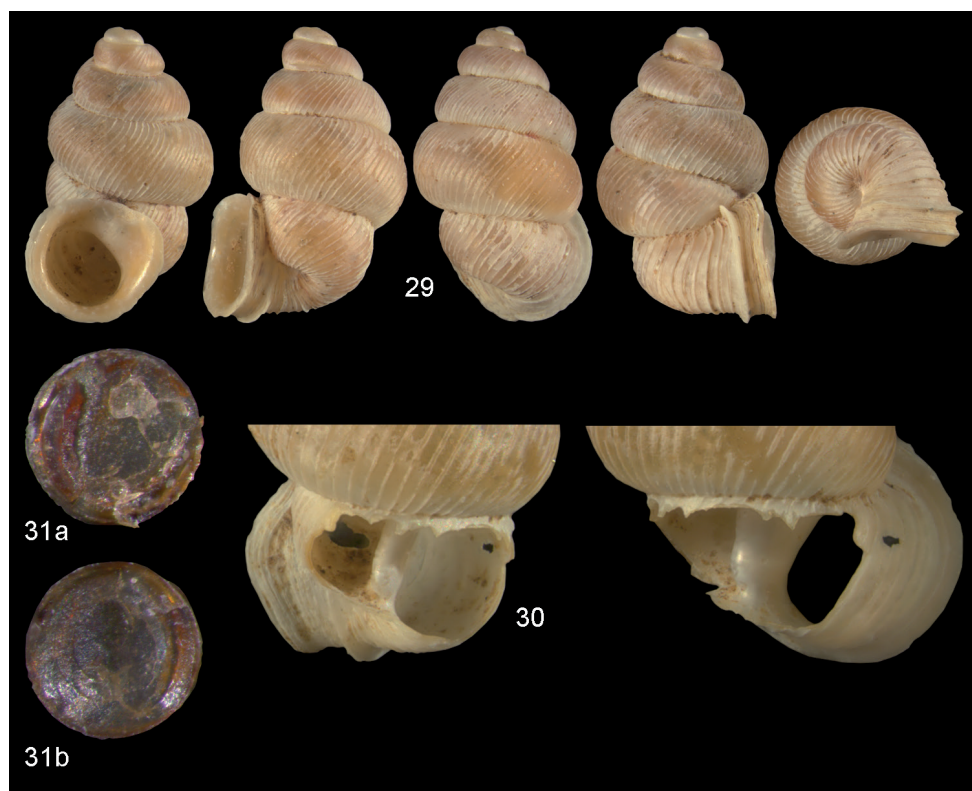
**Type material.** Holotype MNHN IM-2000-27423 paratypes MNHN/662 IM-2000-27424, NMBE 516878/50. Type locality: Viti Levu, Saweni karst, 50–60 m, dry forest, -17.9032 177.7983, leg. Bouchet, 22.08.1998

**Material.** Viti Levu, Tuvu karst, 50 m, dry forest, -17.9332 177.7067, 23.08.1998, leg. Bouchet, MNHN/301, NMBE 516882/20; Viti Levu, Qalimare karst, Toga village, 30–130 m, dry forest, -17.9953 177.5768, 21.08.1998, leg. Bouchet, MNHN/120, NMBE 516883/15; Viti Levu, Qalimare karst, East of Natawatawadi, 40 m, dry forest, -17.9816 177.6266, 21.08.1998, leg. Bouchet, MNHN/1.

**Etymology.** Latin adjective *dilatatus*, -a, -um = broadened.

**Diagnosis.** Shell sinistral, large, broad, aperture broad and circular, sculpture of coarse, widely spaced ribs, columellar plate reduced.

**Description.** Shell sinistral, large, stout and broad, of a dull brown colour; last whorl considerably constricted; protoconch broad, obtuse with a pitted microsculp-



**Figures 29–31.** *Diancta dilatata* sp. n. **29** Holotype MNHN IM-2000-27423, Viti Levu, Saweni karst, 50–60 m, H = 3.89 mm **30** paratype, last whorl opened to show internal lamellae (enlarged, not to scale) **31** operculum **31a** inner surface **31b** outer surface). Figure 29  $\times 10$ , Figure 31  $\times 40$  magnification.

ture; umbilicus closed, very narrow periomphalum; teleoconch sculpture of coarse, widely spaced ribs, with a few stronger ribs on the last third of the last whorl; last whorl ascending; aperture broad and circular, disconnected from the last whorl; peristome funnel-shaped, doubled; apertural rims connected; no dentition visible in the aperture by frontal view; columellar plate reduced, with a narrow basal almost denticle-like callus, no other lamellae present.

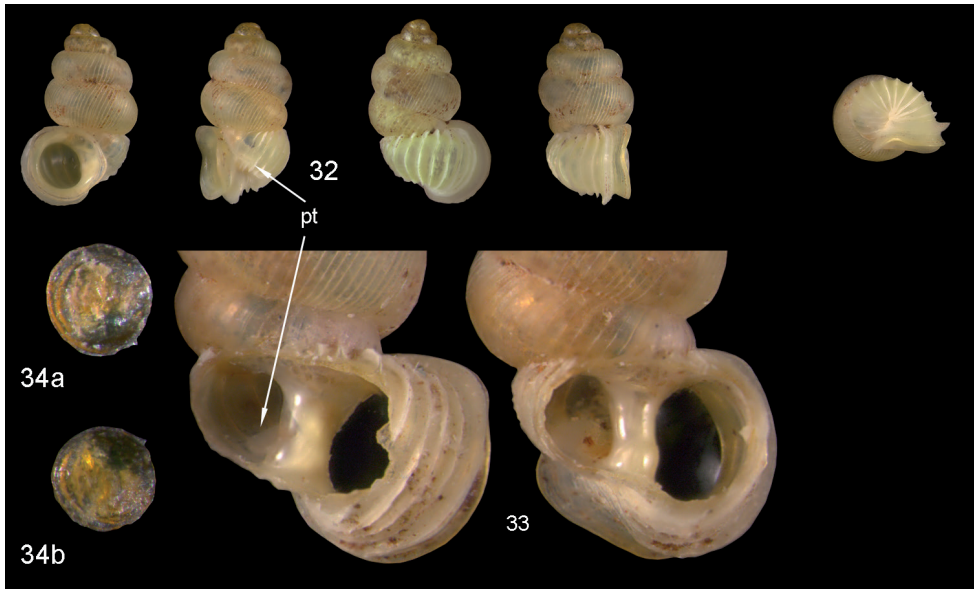
Operculum corneous, flat, with a long apophysis, OD = 0.59.

**Measurements** (Fig. 29). H = 3.89; D = 2.48; PH = 1.65; PD = 1.83; W = 6.

**Distribution** (Fig. 170). Four neighbouring localities in central Viti Levu.

**Remarks.** *Diancta dilatata* sp. n. differs from *D. subquadrata* sp. n. by its larger aperture and the much coarser ribbing pattern. In *D. martensi*, the aperture is subquadrated, and the peristome is connected to the penultimate whorl. *D. subquadrata* sp. n. and *D. martensi* differ from *D. dilatata* sp. n. by their well developed columellar plate.





**Figures 32–34.** *Dianta distorta* sp. n. **32** Holotype MNHN IM-2000-27425, Viti Levu, Qaia village, 20–50 m, H = 2.39 mm **33** paratype, last whorl opened to show internal lamellae (enlarged, not to scale) **34** operculum **34a** inner surface **34b** outer surface). Figure 32  $\times 10$ , Figure 34  $\times 40$  magnification.

***Dianta distorta* sp. n.**

<http://zoobank.org/13532952-45A7-4849-AE89-797A8429FD65>

Figs 32–34

**Type material.** Holotype MNHN IM-2000-27425, paratypes MNHN/112 IM-2000-27426, NMBE 516872/15. Type locality: Viti Levu, surroundings of Qaia village, secondary wet forest, 20–50 m, -18.0999 178.3999, leg. Bouchet & Warén, 15.03.1999.

**Material.** Viti Levu, Wailotua karst, 50–80 m, rainforest, -17.7582 178.4166, leg. Bouchet, 25–27.08.1998, MNHN/49, NMBE 516884/5; Viti Levu, surroundings of Laselevu village, 80 m, rainforest, -17.7532 178.1416, leg. Bouchet, Warén & Dayrat, 14.02.1999, MNHN/57, NMBE 516885/5; Viti Levu, Waivisa karst, 50–80 m, rainforest, -17.6879 178.4033, leg. P. Bouchet, 27.08.1998, MNHN/33, NMBE 516886/5.

**Etymology.** Latin adjective *distortus*, *-a*, *-um* = distorted.

**Diagnosis.** Shell sinistral, very small, teleoconch sculpture of regular fine ribs, last whorl only slightly ascending, aperture circular, detached, internally with strong palatal lamella, columellar plate reduced.

**Description.** Shell sinistral, very small, elongate, yellowish; last whorl strongly constricted; protoconch broad, obtuse with a pitted microsculpture; umbilicus closed, concave periomphalum; teleoconch sculpture of regularly spaced fine ribs, with an abrupt change on the last whorl with ribs becoming very coarse and widely spaced;

last whorl only slightly ascending; aperture circular, detached from the last whorl; peristome funnel-shaped, doubled; no dentition visible in the aperture by frontal view; internally with strong palatal lamella visible through fresh translucent shells, columellar plate reduced to a knob-like basal denticle.

Operculum corneous, flat, with a relatively long apophysis, OD = 0.35.

**Measurements.** holotype (Fig. 32): H = 2.39; D = 1.54; PH = 0.89; PD = 0.91; W = 5.5.

**Distribution** (Fig. 170). eastern part of Viti Levu.

**Remarks.** *Diancta distorta* sp. n. differs from all the other small *Diancta* species by its elongate shell and the unique combination of reduced columellar plate and opposing palatal lamella. In its outer shell morphology it resembles *D. densecostulata*, but in the latter the aperture is always attached to the penultimate whorl (and differs completely in its inner lamellae).

### *Diancta pulchella* sp. n.

<http://zoobank.org/F812CDE3-0E4F-4240-AC75-5771ACAD770A>

Figs 35–37

**Type material.** Holotype MNHN IM-2000-27427, paratypes MNHN/136 IM-2000-27428, NMBE 516875/50. Type locality: Viti Levu, Wailotua karst, 50–80 m, rainforest, -17.7582 178.4166, leg. Bouchet, 25–27.08.1998.

**Etymology.** Latin adjective *pulchellus*, -a, -um = handsome.

**Diagnosis.** Sinistral, large shell, last whorl shifted to the left, periomphalum perspective broadened, broad basal columellar plate.

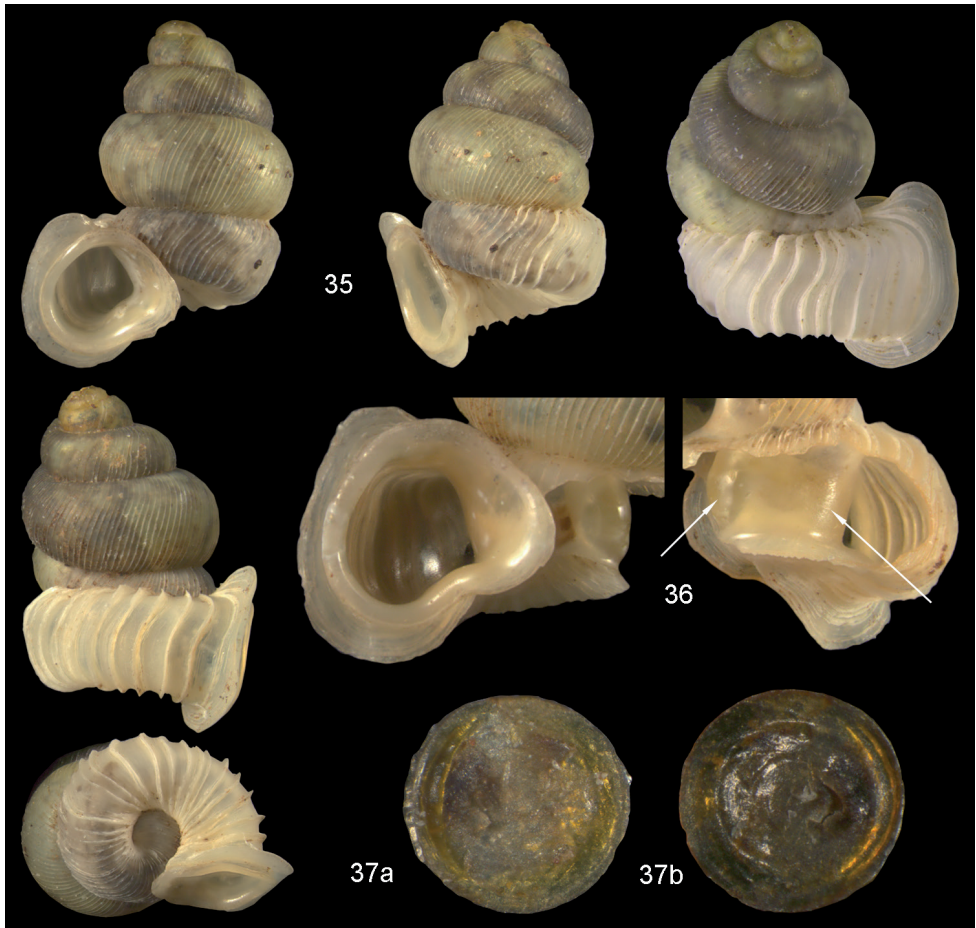
**Description.** Shell large, sinistral, oval, light brown to yellowish; last whorl constricted; protoconch big, bulbous obtuse with microsculpture of minute granules; umbilicus slit-like, closed, periomphalum perspective broadened; last whorl considerably shifted to the left, only slightly ascending; teleoconch sculpture of fine, regularly spaced ribs, much coarser on the last third of the last whorl and more widely spaced; aperture almost rectangular, peristome doubled; apertural rims connected; aperture shortly detaching from the last whorl with an extraordinarily enlarged ear-like process over the left edge; no pleats visible in the aperture; inside the shell with a single, broad basal columellar plate (Fig. 36, arrows).

Operculum corneous, flat, internally with a broad apophysis, DO = 0.75.

**Measurements.** holotype (Fig. 35): H = 4.56; D = 3.59; PH = 1.66; PD = 1.61; W = 5.

**Distribution** (Fig. 170). Only known from the type locality.

**Remarks.** *Diancta pulchella* sp. n. is the largest diplommatinid so far known from Fiji. It cannot be confused with any other *Diancta* species because of its aperture, which is completely shifted to the left side of the shell. *Diancta aurita* sp. n. has a similar ear-shaped apertural process, but differs in all other respects including the orange colouration of its aperture. *Diancta basi plana* sp. n. differs by its bulbous extension on the last whorl, the attached aperture, the ribbing pattern, and the simple peristomial rim.



**Figures 35–37.** *Diancta pulchella* sp. n. **35** Holotype MNHN IM-2000-27427, Viti Levu, Wailotua karst, H = 4.56 mm **36** paratype, last whorl opened to show internal lamellae (arrows showing the limits of the columellar plate; enlarged, not to scale) **37** operculum **37a** inner surface **37b** outer surface. Figure 35  $\times 10$ , Figure 37  $\times 40$  magnification.

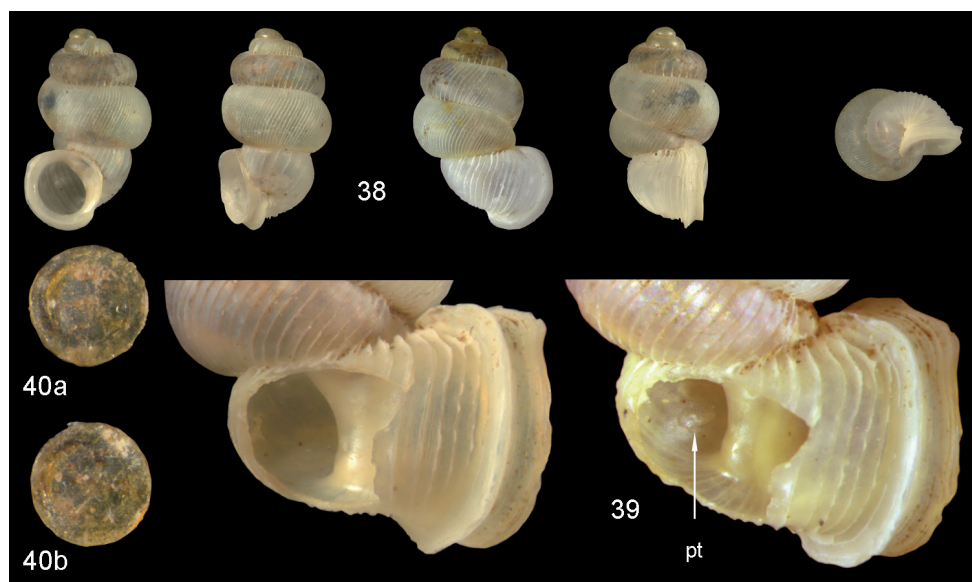
***Diancta rotunda* sp. n.**

<http://zoobank.org/61A5E745-97F3-4B36-8C6C-FB7B04F91613>

Figs 38–40

**Type material.** Holotype MNHN IM-2000-27429, paratypes MNHN/213 IM-2000-27430, NMBE 516876/20. Type locality: Viti Levu, Saweni karst, 50–60 m, dry forest, -17.9032 177.7983, leg. Bouchet, 22.08.1998.

**Material.** ZMZ 526682c/2, Viti Levu, leg. Graeffe 1872.



**Figures 38–40.** *Diancta rotunda* sp. n. **38** Holotype MNHN IM-2000-27429, Viti Levu, Saweni karst, H = 2.65 mm. **39** paratype, last whorl opened to show internal lamellae (enlarged, not to scale) **40** operculum **40a** inner surface **40b** outer surface. Figure 38  $\times 10$ , Figure 40  $\times 40$  magnification.

**Etymology.** Latin adjective *rotundus*, -a, -um = rounded; with reference to the shape of the aperture.

**Diagnosis.** Shell sinistral, small, whitish, penultimate whorl enlarged, change in ribbing pattern of teleoconch, columellar plate reduced, a small palatal fold.

**Description.** Shell sinistral, elongate oval, small, whitish to translucent; last whorl strongly constricted; protoconch small, smooth; umbilicus slit-like open to completely closed, periomphalum concave; teleoconch sculpture of coarse spacious ribs on the upper whorl, fine and dense on the medium and coarse and spacious on the last whorl; penultimate whorl enlarged; last whorl slightly ascending; aperture circular, peristome funnel-shaped, doubled; aperture slightly detaching from last whorl; no pleats visible in the aperture; inside the shell, columellar plate reduced, with a small palatal fold opposite.

Operculum corneous, flat, internally with a small lamella, OD = 0.4.

**Measurements.** holotype (Fig. 38): H = 2.65; D = 1.68; PH = 1.07; PD = 1.03; W = 5.5.

**Distribution** (Fig. 170). Only known from the type locality.

**Remarks.** *Diancta rotunda* sp. n. is one of the smallest species of the genus in Fiji, along with *D. distorta* sp. n., *D. densecostulata* sp. n., *D. macrostoma*, and *D. trilamellata* sp. n., but it can be distinguished from these by its enlarged penultimate whorl. Its teleoconch sculpture is similar to that in *D. trilamellata* sp. n., but the latter species possesses a palatalis and parietalis.

***Diancta subquadrata* sp. n.**

<http://zoobank.org/39D5B7BD-C20E-4988-8B40-C68AAEAC744A>

Figs 41–43

**Type material.** Holotype MNHN IM-2000-27431, paratypes MNHN/21 IM-2000-27432, NMBE 516877/5. Type locality: Viti Levu, limestone outcrop SE of Nambukulevu, 230 m, rainforest, -18.1366 177.8149, leg. Bouchet, Warén & Dayrat, 20.02.1999.

**Etymology.** Latin prefix *sub* = somewhat, and adjective *quadratus*, *-a*, *-um* = squared; with reference to the shape of the aperture.

**Diagnosis.** Shell sinistral, broad, small, brownish, ribbing pattern changing from coarse on the upper whorls to fine on the medium and coarse on the last whorl, aperture circular, columellar plate broad.

**Description.** Shell sinistral, broadly oval, small, brownish; last whorl considerably constricted; protoconch large, 1–1.5 whorls, pitted; umbilicus closed, periomphalum narrowly concave; ribbing pattern on teleoconch of coarse and spacious ribs on the upper whorl, fine and dense on the intermediate whorls, and coarse and widely spaced again on the last whorl; last whorl slightly ascending and detaching from the last whorl; aperture circular, peristome funnel-shaped, doubled, peristomial rims connected by a broad parietal shield; no pleats visible in the aperture; columellar plate broad, not subdivided, no inner lamellae present.

Operculum corneous, flat, with a long apophysis, OD = 0.59.

**Measurements.** Holotype (Fig. 41): H = 3.29; D = 2.02; PH = 1.35; PD = 1.55; W = 5.

**Distribution.** Only known from the type locality.

**Remarks.** *Diancta subquadrata* sp. n. is very similar to *D. densecostulata*, but differs by its broadly expanded peristome, reduced columellar plate, and complete absence of internal lamellae.

***Diancta trilamellata* sp. n.**

<http://zoobank.org/3AE7EA86-5BEA-4D24-B74A-7825087BE481>

Figs 44–46

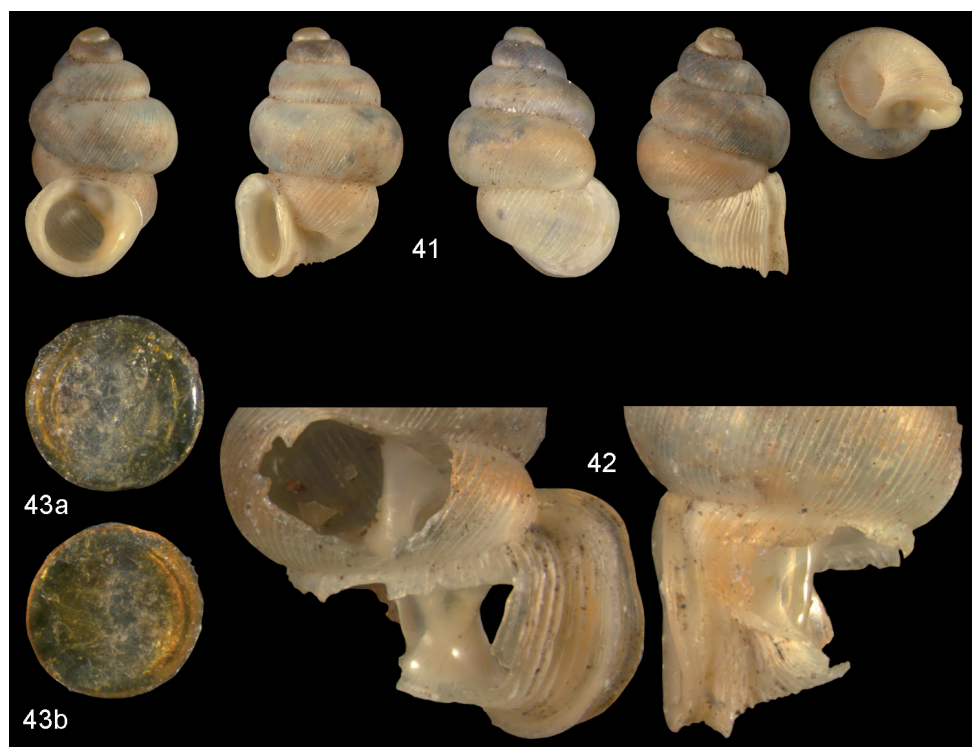
**Type material.** Holotype MNHN IM-2000-27433, paratypes MNHN/62 IM-2000-27434, NMBE 516871/10. Type locality: Viti Levu, Waivisa karst, 50–80 m, rainforest, -17.6879 178.4033, leg. Bouchet, 27.08.1998.

**Etymology.** Latin numeral *tres* = three, and adjective *lamellatus*, *-a*, *-um* for possessing lamellae.

**Diagnosis.** Shell sinistral, very small, teleoconch sculpture of coarse ribs, initially widely , then densely, spaced, last whorl ascending, aperture circular, detached from last whorl, with a palatal and a parietal lamella and broad columellar plate.

**Description.** Shell sinistral, very small, whitish to yellowish; last whorl strongly constricted; protoconch broad, obtuse with a pitted microsculpture; umbilicus closed, very narrow periomphalum; teleoconch sculpture initially of coarse widely spaced ribs,





**Figures 41–43.** *Diancta subquadrata* sp. n. **41** Holotype MNHN IM-2000-27431, Viti Levu, limestone outcrop SE of Nambukulevu, H = 3.29 mm. **42** paratype, last whorl opened to show internal lamellae (enlarged, not to scale) **43** operculum **43a** inner surface **43b** outer surface. Figure 41  $\times 10$ , Figure 43  $\times 40$  magnification.

changing to a more dense pattern on the central whorls, with a few very strong ribs on the last whorl; last whorl strongly ascending; aperture almost circular, not connected to the last whorl, peristome doubled and funnel-shaped, apertural rims connected; no dentition visible in the aperture by frontal view; internally with a palatal and a parietal lamella, columellar plate broad, subdivided into an inner and outer part, inner part with a slight notch.

Operculum corneous, flat, with a short apophysis, OD = 0.39.

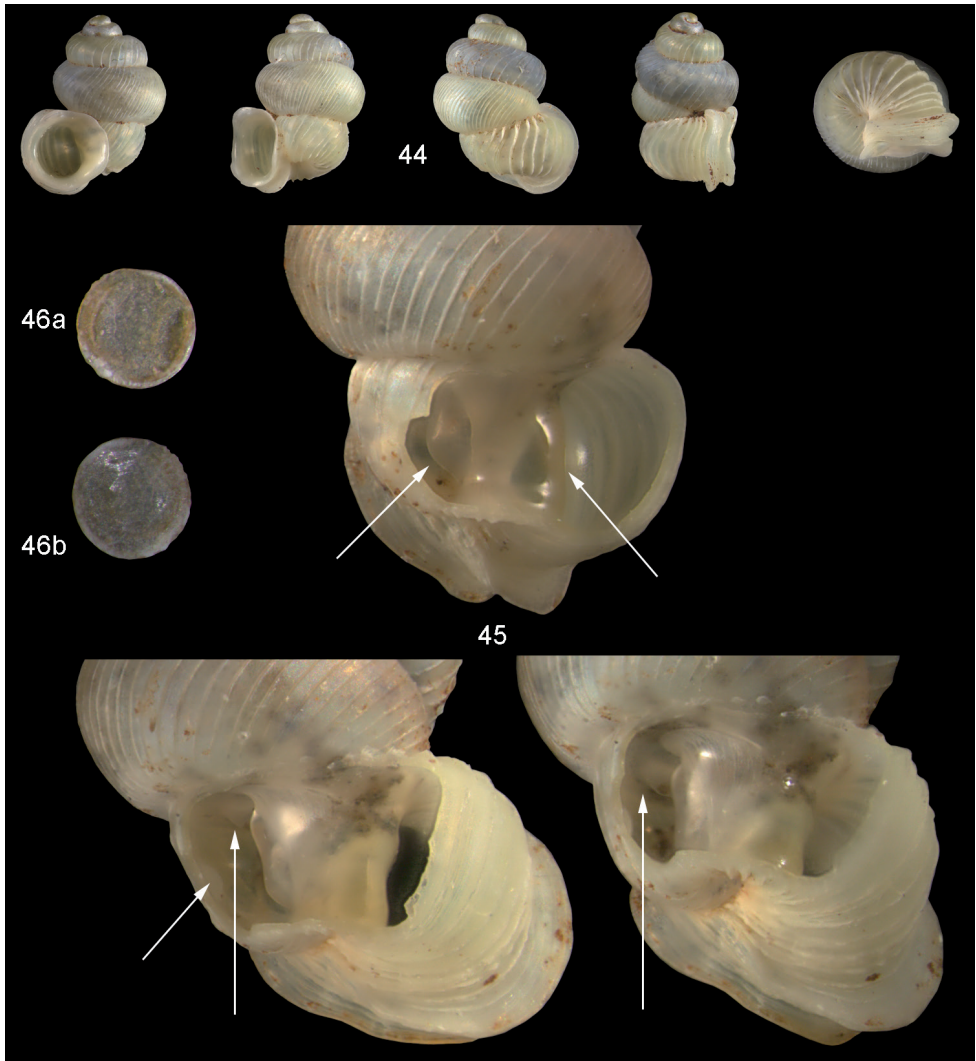
**Measurements.** holotype (Fig. 44): H = 2.37; D = 1.91; PH = 1.13; PD = 1.17; W = 5.

**Distribution** (Fig. 170). only known from the type locality.

**Remarks.** *Diancta trilamellata* sp. n. superficially resembles *D. martensi*, but differs from it by its smaller size, the detached aperture, and the presence of a parietal lamella.

### *Moussonina* Semper, 1865

1865 *Moussonina* Semper, Journal de Conchyliologie, 13: 296. Type species: *Pupa problematica* Mousson, 1865, by original designation.

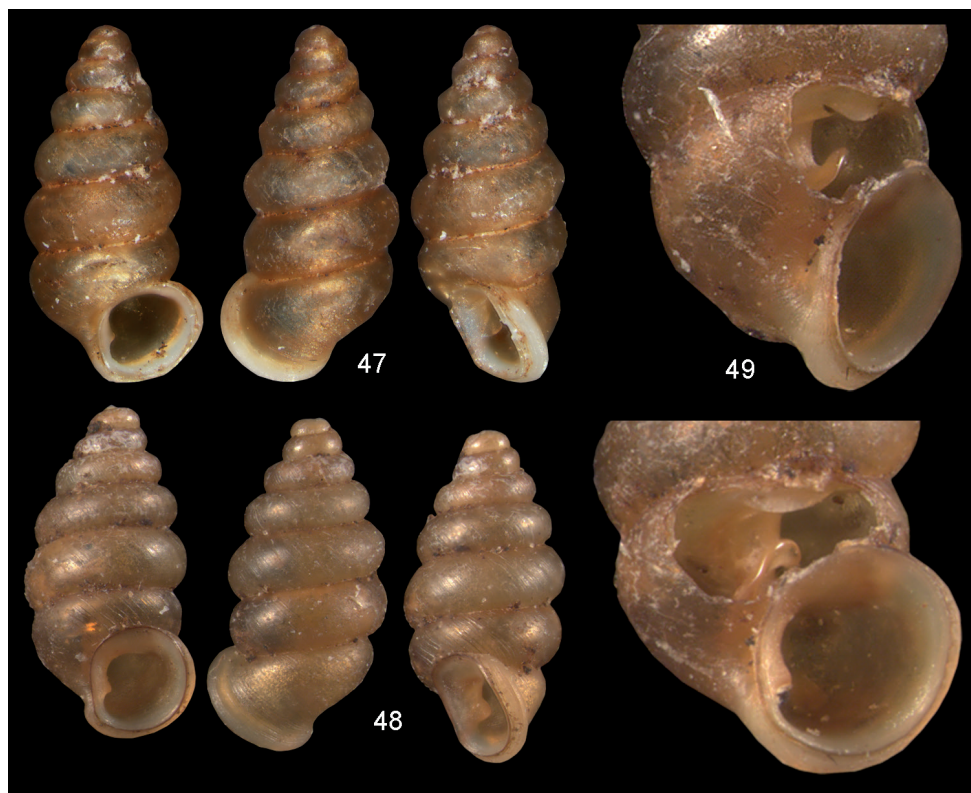


**Figures 44–46.** *Diancta trilamellata* sp. n. **44** Holotype MNHN IM-2000-27433, Viti Levu, Waivisa karst, 50–80 m, H = 2.37 mm **45** paratype, last whorl opened to show internal lamellae (enlarged, not to scale) **46** operculum, 46a inner surface, 46b outer surface). Figure 44  $\times 10$ , Figure 46  $\times 40$  magnification.

**Diagnosis.** Shell elongate conical, dextral, oval, almost non-umbilicate; protoconch whorls smooth; teleoconch whorls usually with a blunt keel; whorls completely smooth to finely ribbed, sometimes with fine thread-like spirals; last whorl narrowed; columellaris ends as a tooth-like lamella in a central to basal position in the aperture; internal lamellar system with one columellaris, two parietal lamellae and one to two palatal lamellae. The operculum was not observed.

**Remarks.** The Samoan *Pupa problematica* Mousson, 1865, the type species of *Moussonia*, is illustrated here for comparison (Fig. 140, Syntype ZMZ 526751,





**Figures 47–49.** *Moussonia fuscula* (Mousson, 1870). **47** Lectotype ZMZ 526754, Fiji, Lau Islands, Oneata, coll. Mousson ex Graeffe 1868, H = 2.35 mm **48** Lau Islands, Yagasa Levu, south point of island, H = 2.19 mm **49** last whorl opened to show internal lamellae. All figures  $\times 20$  magnification.

Samoa, Upolu, H = 1.9 mm). Unfortunately, there are not enough specimens of the type species available to document its inner lamellar system.

### *Moussonia fuscula* (Mousson, 1870)

Figs 47–49

1870 *Diplommatina fuscula* Mousson, Journal de Conchyliologie, 18: 188, pl. VIII, fig. 9. Type locality: Oneata [Lau Is, Fiji].

1902 *Diplommatina* (*Moussonia*) *fuscula*, – Kobelt, Cyclophoridae: 478.

1978 *Moussonia fuscula*, – Solem, Pacific Science, 32 (1): 40 [Karoni, Lakemba].

**Type material.** Lectotype, here designated, ZMZ 526754/a, Fiji, Iles de Lau, Oneata, coll. Mousson ex Graeffe, 1868. — Paralectotypes: ZMZ 526754/20, SMF 105171/2, coll. Möllendorff ex Mousson.

**Material.** Lau Islands: Aiwa, stunted forest on limestone, 5–20 m, -18.3316 -178.6825, leg. Bouchet, 07.03.1999, MNHN/153, NMBE 516888/15; Yacata (=Yathata), forest on limestone, 5–10 m, -17.2584 -179.5096, leg. Bouchet, 05.03.1999, MNHN/35, NMBE 516889/5; Yagasa Levu, south point of island, forest on limestone, 20–50 m, -18.952 -178.4533, leg. Bouchet, 11.03.1999, MNHN/1174, NMBE 516887/70.

**Diagnosis.** Shell dextral, small, dark brown, teleoconch sculpture of widely spaced ribs with fine periostracal threads, whorls inconspicuously keeled, palatalis short, tooth-like.

**Description.** Shell dextral, small, last whorl not constricted, translucent light to dark brown; protoconch consisting of 2 whorls, granulated; teleoconch of > 5 whorls with an almost inconspicuous keel, sculpture consisting of faint, widely spaced ribs with fine periostracal threads; suture deep; last whorl slightly ascending before aperture; aperture attached to last whorl, rounded, peristomial rim reinforced by a strong white labial callus, columellar side with a strong columellaris; umbilicus closed; internal lamellar system with one columellaris, two parietal lamellae and one palatalis; columellaris a strong lamella, with a well-developed undulation at its end above the aperture; inner parietalis a long thread-like lamella, outer parietalis large, spatulate; palatalis a short lamella, directly above the aperture (can be seen from the outside as a reflecting callus).

**Measurements.** Lectotype (Fig. 47): H = 2.35; D = 0.59; PH = 0.73; PD = 1.39; W = 7.5.

**Distribution** (Fig. 171). several islands of the central Lau group.

### *Moussonia vitiana* (Mousson, 1870), comb. n.

Figs 50–52

1870 *Diplommatina fuscula* var. *vitiana* Mousson, Journal de Conchyliologie, 18: 188.

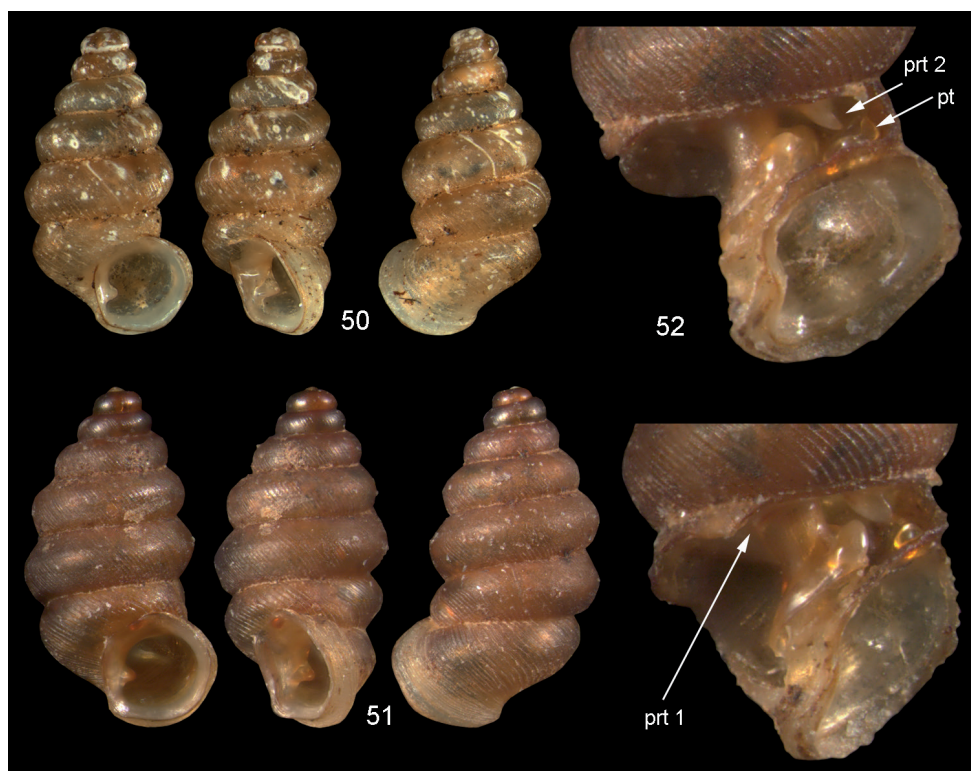
Type locality: Viti Levu, Ovalau.

1902 *Diplommatina* (*Moussonia*) *vitiana*, – Kobelt, Cyclophoridae: 479.

**Type material.** Lectotype, here designated, ZMZ 526756/a, Fiji, Ovalau, coll. Mousson ex Graeffe 1868. — Paralectotypes ZMZ 526756/20; ZMZ 526755/6, Viti Levu, coll. Mousson ex Graeffe 1868.

**Material.** Limestone outcrop SE of Nambukulevu, 230 m, rainforest, -18.1366 177.8149, leg. Bouchet, Warén & Dayrat, 20.02.1999, MNHN/95, NMBE 516890/15; Nakorosule limestone outcrop, 30 m, degraded forest, -17.7734 178.2517, leg. Bouchet & Dayrat, 16.02.1999, MNHN/432, NMBE 516891/40. Lau Islands: Aiwa, stunt forest on limestone, 5–20 m, -18.3316 -178.6825, leg. Bouchet, 07.03.1999, MNHN/124; Lau Islands: Evuevu Island, NW Vanua Balavu, forest on limestone, 5–50 m, -17.0591 -179.0209, leg P. Bouchet, 01.03.1999, MNHN/2.

**Diagnosis.** shell dextral, medium sized, yellowish to red-brown, bluntly keeled teleoconch whorls, palatalis an elongate undulate lamella.



**Figures 50–52.** *Moussonina vitiana* (Mousson, 1870). **50** Lectotype ZMZ 526756, Fiji, Ovalau, coll. Mousson ex Graeffe 1868, H = 2.02 mm. **51** Viti Levu, Nakorosule limestone outcrop, 30 m, H = 2.24 mm **52** whorl opened to show internal lamellae. Figures 50–51  $\times 20$ , Figure 52  $\times 40$  magnification.

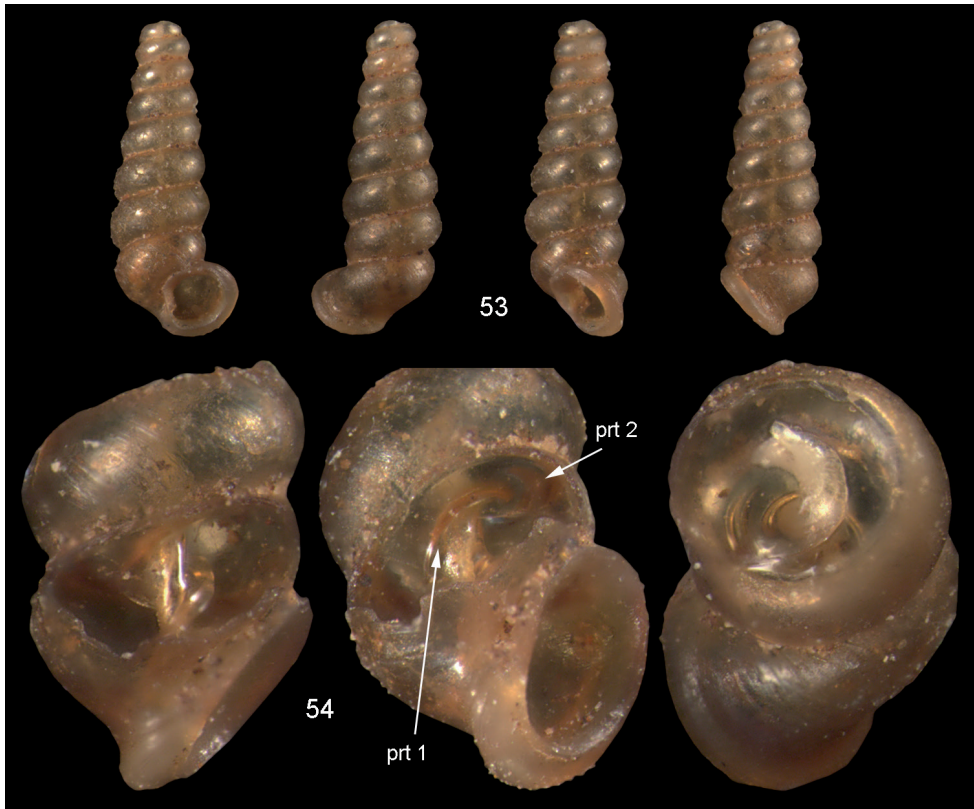
**Description.** shell dextral, medium sized, last whorl slightly constricted, yellowish to red-brown; protoconch of 2 whorls, smooth; teleoconch of  $> 5$  bluntly keeled whorls; sculpture of fine, densely spaced ribs; suture deep; last whorl not or only slightly ascending before aperture; umbilicus almost closed; aperture attached to last whorl, subrectangular, peristomial rim doubled, reinforced by a labial callus, columella with a strong columellaris; internal lamellar system with one columellaris, two parietal lamellae and one palatalis; columellaris a thin lamella, slightly undulating at its end above the aperture, where it is reinforced by a callus; inner parietalis a long lamella, outer parietalis spatulate and oblique; palatalis in a central position above aperture, formed like an undulate lamella and ending in a knob-like tooth visible as a red-brown callus from the outside.

Operculum unknown.

**Measurements.** Lectotype (Fig. 50): H = 2.02; D = 1.14; PH = 0.63; PD = 0.65; W = 7.

**Distribution** (Fig. 170). Eastern part of Viti Levu and the neighbouring island of Ovalau.

**Remarks.** For a differential diagnosis, refer to *M. vitianoides* sp. n.



**Figures 53–54.** *Moussonia acuta* sp. n. **53** Holotype MNHN IM-2000-27435, Fiji, Lau Islands, Yacata (= Yathata), H = 2.08 mm **54** paratype, last whorl opened to show internal lamellae. Figure 53  $\times 20$ , Figure 54 ca.  $\times 50$  magnification.

***Moussonia acuta* sp. n.**

<http://zoobank.org/39D8828A-D5C7-474E-8053-CDAE4E06154C>

Figs 53–54

**Type material.** Holotype MNHN IM-2000-27435, paratypes MNHN/35 IM-2000-27436, NMBE 516853/5. Type locality: Fiji, Lau Islands, Yacata (= Yathata), forest on limestone, 5–10 m, -17.2584 -179.5096, leg. Bouchet, 05.03.1999.

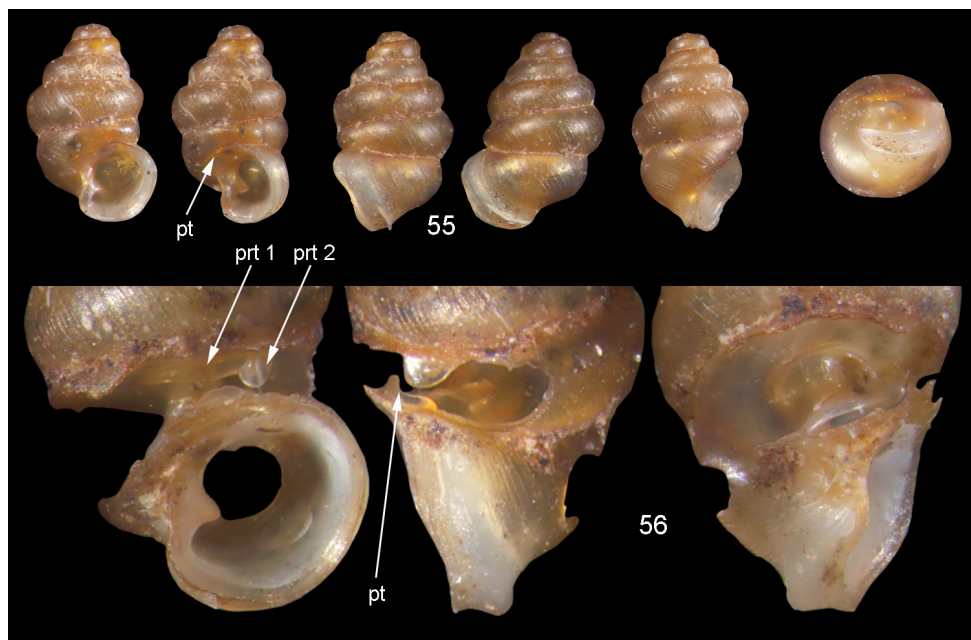
**Material.** Lau Islands, Yagasa Levu, south point of island, forest on limestone, 20–50 m, -18.952 -178.4533, leg. Bouchet, 11.03.1999, MNHN/2.

**Etymology.** Latin adjective *acutus*, -a, -um = pointed.

**Diagnosis.** Elongate acute shell, very small aperture, > 8 rounded whorls, both parietal lamellae thread-like, palatalis missing.

**Description.** Shell dextral, small, elongate turreted, deep reddish brown; protoconch of 2 whorls, smooth; teleoconch of > 8 well rounded whorls, almost smooth, only a few faint, widely spaced riblets; suture deep; last whorl not ascending before





**Figures 55–56.** *Moussonia barkeri* sp. n. **55** Holotype MNHN IM-2000-27437, Viti Levu, surroundings of Qauia village, H = 1.3 mm **56** paratype, last whorl opened to show internal lamellae. Figure 55  $\times 20$ , Figure 56  $\times 40$  magnification.

aperture; aperture very small, attached to last whorl, obliquely rounded, peristomial rim reinforced by a strong labial callus, columellar side with a strong columellaris; umbilicus slightly open; internal lamellar system with one columellaris, two parietal lamellae and one palatalis; columellaris a thin lamella, without undulation at its end above the aperture; inner parietalis a long thread-like lamella, slightly overlapping with the second low parietalis; palatalis missing.

Operculum unknown.

**Measurements.** Holotype (Fig. 53): H = 2.08; D = 0.85; PH = 0.49; PD = 0.51; W = 8.5.

**Distribution** (Fig. 171). Two islands in the Lau archipelago.

**Remarks.** *Moussonia acuta* sp. n. is unmistakable because of its very narrow shell form, which is unique among Fiji Diplommatinidae.

***Moussonia barkeri* sp. n.**

<http://zoobank.org/09C4DCEC-EDE4-4106-A633-A194053F58E5>

Figs 55–56

**Type material.** Holotype MNHN IM-2000-27437, paratypes MNHN/46 IM-2000-27438, NMBE 516859/10. — Type locality: Viti Levu, surroundings of Qauia vil-

lage, secondary wet forest, 20–50 m, -18.1001 178.3999, leg. Bouchet & Warén, 15.03.1999.

**Etymology.** This species is named after Gary Barker, formerly of Landcare Research, Hamilton, New Zealand, in recognition for his efforts to get the land snails of Fiji onto the local conservation agenda.

**Diagnosis.** Shell minute, dextral, light brown, inner parietalis long, outer parietalis spatulate, palatalis long, directly above the aperture, undulating.

**Description.** Shell minute, dextral, biconical, last whorl slightly constricted, light brown to yellowish; protoconch consisting of 2 whorls, smooth; teleoconch of > 4 well rounded whorls, sculpture consisting of fine and widely spaced riblets; last whorl only slightly ascending before aperture; aperture attached to last whorl, subquadrate, relatively large, peristomial rim reinforced by a thick white labial callus, columellar side with a strong columellaris; internal lamellar system with one columellaris, two parietal lamellae and one palatalis; columellaris a thin lamella, with a strong undulation at its end above the aperture; inner parietalis a thin lamella, not connected to the second spatulate parietalis; very long palatalis directly above the aperture (can be seen from the outside as a long fine thread), with a central undulation.

Operculum unknown.

**Measurements.** Holotype (Fig. 55): H = 1.3; D = 0.66; PH = 0.53; PD = 0.51; W = 5.5.

**Distribution** (Fig. 170). Only known from the type locality.

**Remarks.** *Moussonia barkeri* sp. n. is unique in its combination of a minute shell with an aperture the size of that of larger species. It differs from the similar sized *M. minutissima* sp. n. by its more obese shell, its long undulating palatalis, and the larger outer parietalis.

### ***Moussonia brodieae* sp. n.**

<http://zoobank.org/90D975CD-5268-4CC4-9F77-1CCF01BFF8C2>

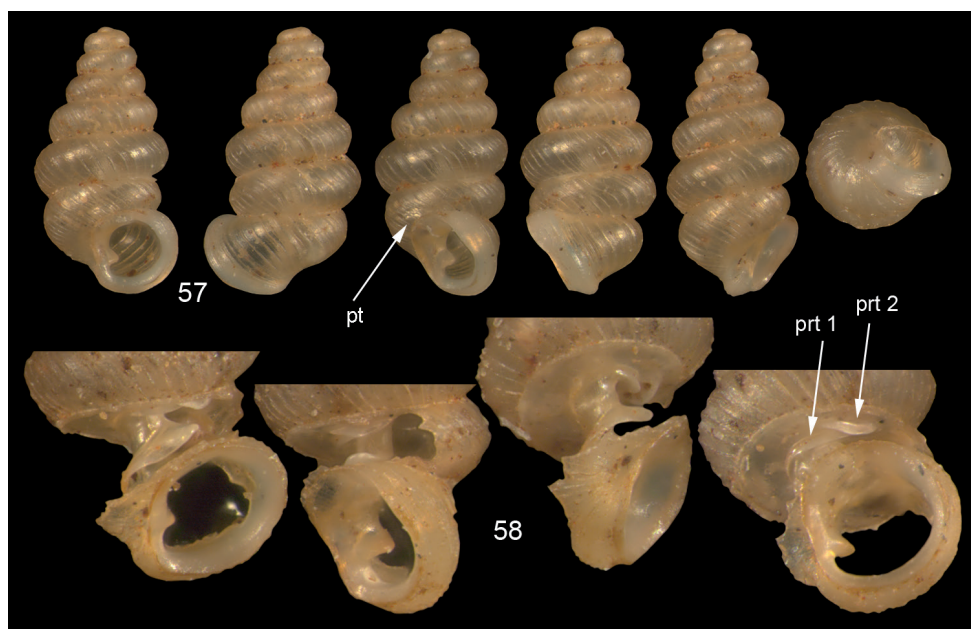
Figs 57–58

**Type material.** Holotype MNHN IM-2000-27439, paratypes MNHN/33 IM-2000-27440, NMBE 516856/5. Type locality: Lau Islands, Cikobia-i-Lau (= Thikombia), forest on limestone, 10–60 m, -17.2857 -178.7944, leg. Bouchet, 03.03.1999.

**Etymology.** This species is named after Giliane Brodie, lecturer at the University of the South Pacific, to acknowledge and encourage her conversion from nudibranch taxonomy to land snail conservation.

**Diagnosis.** Shell dextral, small, translucent light yellow, teleoconch sculpture of strong, widely spaced ribs, aperture rounded, inner parietalis short, outer parietalis low, palatalis short tooth-like.

**Description.** Shell dextral, small, last whorl slightly constricted, translucent light yellow; protoconch consisting of 2 whorls, smooth; teleoconch of > 5 bluntly keeled



**Figures 57–58.** *Moussonia brodieae* sp. n. **57** Holotype MNHN IM-2000-27439, Lau Islands, Cikobia-i-Lau (= Thikombia), H = 1.75 mm **58** paratype, last whorl opened to show internal lamellae. Figure 57  $\times 20$ , Figure 58  $\times 40$  magnification.

whorls, sculpture consisting of strong, widely spaced ribs, which can bear a periostracal bristle at the periphery (only in really fresh shells); suture deep; last whorl slightly ascending before aperture; aperture attached to last whorl, rounded, peristomial rim reinforced by a strong labial callus, columellar side with a strong columellaris; internal lamellar system with one columellaris, two parietal lamellae and one palatalis; columellaris a thin lamella, with a strong undulation at its end above the aperture; inner parietalis a short lamella, overlapping with the outer parietalis, which is a low lamella; very short palatalis directly above the aperture (can be seen from the outside as a small reflecting callus).

Operculum unknown.

**Measurements.** Holotype (Fig. 57): H = 1.75; D = 0.95; PH = 0.56; PD = 0.58; W = 6.5.

**Distribution** (Fig. 171). the Lau island Cikobia-i-Lau.

**Remarks.** *Moussonia brodieae* sp. n. is conchologically close to *M. polita* sp. n., but the latter has only faint ribs, a glossy shell surface, and a very long palatalis, which terminates in a small knob.

Solem (1978) recorded from Mothe Island a shell briefly characterized as “a form with heavy radial sculpture, [...] differing clearly from the smooth-shelled *M. fuscula*” and that he suspected to probably represent an undescribed species. This may have been *M. brodieae* sp. n.



***Moussonia longipalatalis* sp. n.**

<http://zoobank.org/7382F617-C278-4D3D-9A22-33537ECE1908>

Figs 59–60

**Type material.** Holotype MNHN IM-2000-27441, paratypes MNHN/630 IM-2000-27442, NMBE 516852/50. Type locality: Lau Islands, Navutu-i-Loma (= Nasau), forest on limestone, 5–30 m, -18.9659 -178.4798, leg. Bouchet, 11.03.1999.

**Etymology.** Latin adjective *longus*, -a, -um = long, and noun *palatalis* for the palatal fold; used as a noun in apposition.

**Diagnosis.** Shell dextral, very small, translucent light yellowish-brownish, bluntly keeled whorls, reduced sculpture, palatalis a very long lamella.

**Description.** Shell dextral, very small, last whorl not constricted, translucent light yellowish-brownish; protoconch of 2 whorls, granulated; teleoconch of > 7 bluntly keeled whorls, sculpture of faint periostracal threads; suture very deep; last whorl not ascending before aperture; aperture attached to last whorl, rounded, peristomial rim reinforced by a weak labial callus, columellar side with a strong columellaris; umbilicus closed; internal lamellar system with one columellaris, two parietal lamellae and one palatalis; columellaris a thin lamella, with a strong undulation at its end above the aperture; inner parietalis long, outer parietalis spatulate; palatalis a very long lamella, situated on the left side above the aperture (can be seen from the outside as a reflecting callus).

**Measurements.** Holotype (Fig. 59): H = 2.13; D = 1.09; PH = 0.65; PD = 0.69; W = 7.5.

**Distribution** (Fig. 171). Only known from the type locality.

**Remarks.** Although very similar to *M. fuscula*, *Moussonia longipalatalis* sp. n. is treated here as a different species because the latter has a smaller shell, bluntly keeled whorls, and a long and very readily visible palatalis, which is only a short knob-like callus in *M. fuscula*.

***Moussonia minutissima* sp. n.**

<http://zoobank.org/281CF762-DC02-43AA-8387-C6406F703A30>

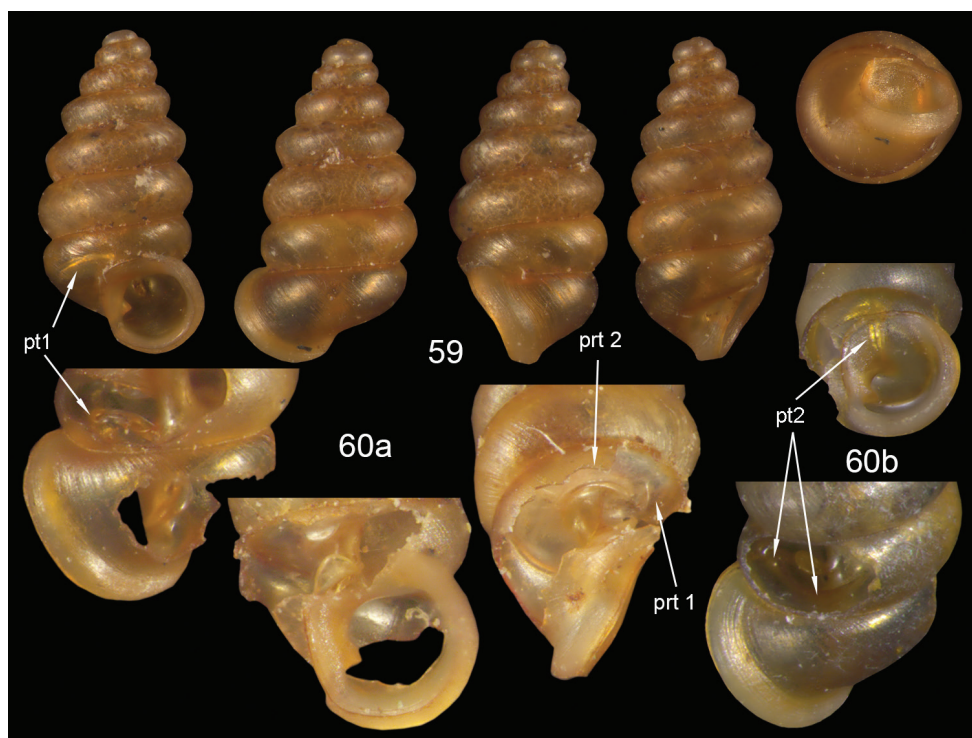
Figs 61–62

**Type material.** Holotype MNHN IM-2000-27443, paratypes MNHN/169 IM-2000-27444, NMBE 516854/20. Type locality: Lau Islands, Yacata (= Yathata), forest on limestone, 5–10 m, -17.2584 -179.5096, leg. Bouchet, 05.03.1999.

**Etymology.** Latin adjective *minutissimus*, -a, -um = very small.

**Diagnosis.** Shell dextral, small, light brownish, protoconch granulated, ribs with periostracal threads, inner parietalis very short, palatalis tooth-like directly above aperture.

**Description.** Shell dextral, small, last whorl not constricted, translucent light brownish; protoconch of 2 whorls, granulated; teleoconch of > 5 whorls with an



**Figures 59–60.** *Moussonia longipalatalis* sp. n. **59** Holotype MNHN IM-2000-27441, Lau Islands, Yacata (= Yathata), H = 1.68 mm **60** paratype, last whorl opened to show internal lamellae. Figure 59  $\times 20$ , Figure 60  $\times 40$  magnification.

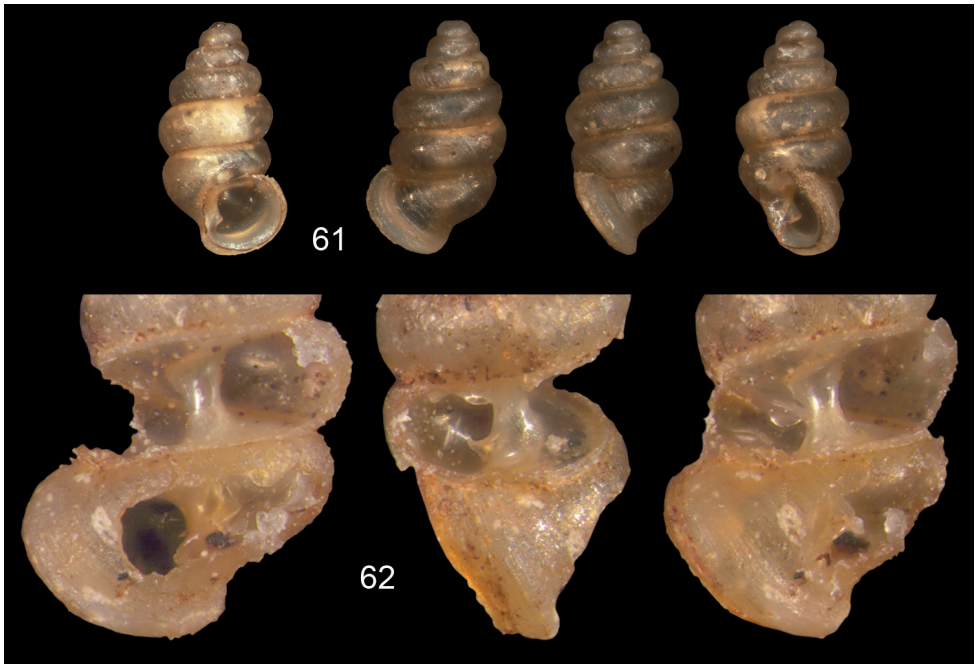
almost inconspicuous keel, sculpture of faint, widely spaced ribs with fine periostracal threads; suture deep; last whorl slightly ascending before aperture; aperture attached to last whorl, rounded, peristomial rim reinforced by a strong labial callus, columellar side with a strong columellaris; umbilicus slightly open; internal lamellar system with one columellaris, two parietal lamellae and one palatalis; columellaris a thin lamella, with a strong undulation at its end above the aperture; inner parietalis a very short thread-like lamella, outer parietalis small, spatulate; palatalis tooth-like, directly above the aperture (can be seen from the outside as a reflecting callus).

Operculum unknown.

**Measurements.** holotype (Fig. 61): H = 1.54; D = 0.85; PH = 0.54; PD = 0.57; W = 5.5.

**Distribution** (Fig. 171). Only known from the type locality.

**Remarks.** *Moussonia minutissima* sp. n. is remarkable because of its granulated protoconch. It differs from *M. barkeri* sp. n. by its reduced tooth-like palatalis and very short inner parietalis, and from *M. fuscula* by its smaller size and the short inner parietalis.



**Figures 61–62.** *Moussonina minutissima* sp. n. **61** Holotype MNHN IM-2000-27443, Fiji, Lau Islands, Yacata (=Yathata), H = 1.54 mm **62** paratype, last whorl opened to show internal lamellae. Figure 61  $\times 20$ , Figure 62  $\times 40$  magnification.

***Moussonina obesa* sp. n.**

<http://zoobank.org/D37F19AA-4D12-4D55-B6C4-AB88CA478E19>

Figs 63–64

**Type material.** Holotype MNHN IM-2000-27445, paratypes MNHN/9 IM-2000-27446, NMBE 516860/2. Type locality: Fiji, Viti Levu, Wailotua karst, 50–80 m, rainforest, -17.7582 178.4166, leg. Bouchet, 25–27.08.1998.

**Material.** Viti Levu, Wailotua, 115 m, in washings from freshwater seeps, -17.7664 178.4117, leg. Bouchet, 25.08.1998, MNHN/5.

**Etymology.** Latin adjective *obesus*, -a, -um = fat.

**Diagnosis.** Shell dextral, broad, bluntly keeled, with widely spaced ribs, inner parietalis long, outer parietalis spatulate, long palatalis, situated above aperture.

**Description.** Shell dextral, relatively large and broad, last whorl not constricted, deep red-brownish; protoconch of 2 whorls, smooth; teleoconch of > 5 bluntly keeled whorls, sculpture of strong, densely spaced ribs with a fine sculpture of spiral threads (high magnification needed); suture deep; last whorl slightly ascending before aperture; aperture attached to last whorl, subrectangular, peristomial rim slightly reinforced by a weak labial callus, columellar side with a strong columellaris; internal lamellar system with one columellaris, two parietal lamellae and one palatalis; columellaris a thin lamella, with a strong undulation at its end above the aperture with a small denticle on top of the undulating part; inner parietalis a long lamella, which increases in height



**Figures 63–64.** *Moussonia obesa* sp. n. **63** Holotype MNHN IM-2000-27445, Viti Levu, Wailotua karst, H = 2.54 mm **64** paratype, last whorl opened to show internal lamellae. Figure 63  $\times 20$ , Figure 64  $\times 40$  magnification.

towards its end, outer parietalis large, spatulate; palatalis above the aperture forming a long and strong lamella.

Operculum unknown.

**Measurements.** Holotype (Fig. 63): H = 2.54; D = 1.46; PH = 0.92; PD = 0.86; W = 6.5.

**Distribution** (Fig. 170). Only known from the type locality.

**Remarks.** *Moussonia obesa* sp. n. is instantly recognized by its broad shell. It differs from the similar *M. uncinata* sp. n., which has an axial palatalis, situated deep in the shell.

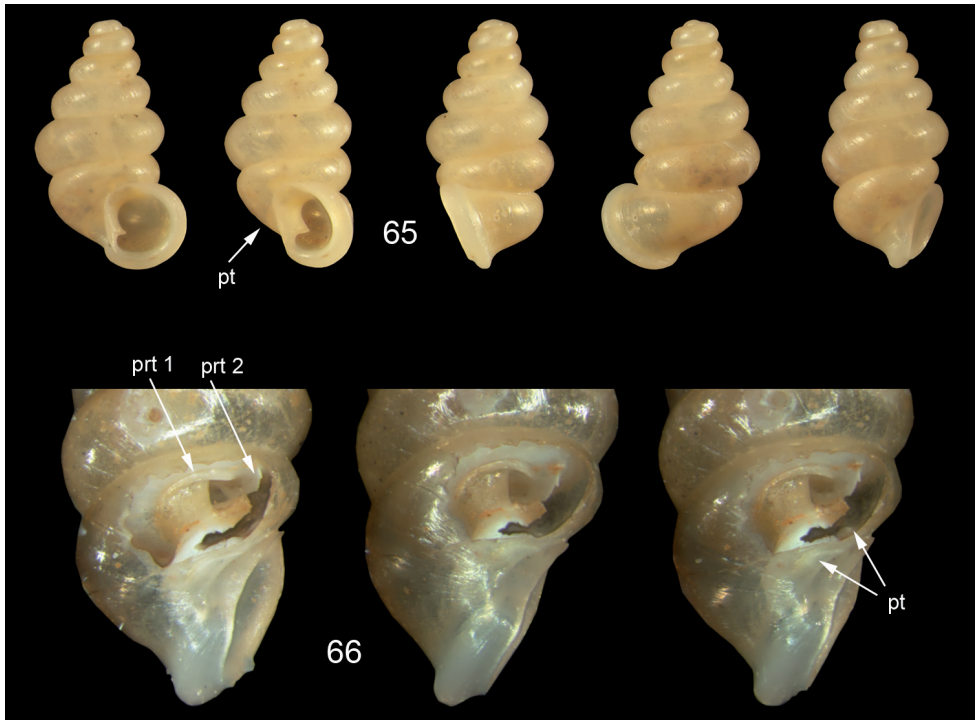
### *Moussonia polita* sp. n.

<http://zoobank.org/7A2185A1-4D56-423B-8DA4-A58FC405BB53>

Figs 65–66

**Type material.** Holotype MNHN IM-2000-27447, paratypes MNHN/49 IM-2000-27448, NMBE 516855/7. Type locality: Lau Islands, Yacata (= Yathata), forest on limestone, 5–10 m, -17.2584 -179.5096, leg. Bouchet, 05.03.1999.





**Figures 65–66.** *Moussonia polita* sp. n. **65** Holotype MNHN IM-2000-27447, Lau Islands, Yacata (=Yathata), H = 1.64 mm **66** paratype, last whorl opened to show internal lamellae. Figure 65  $\times 20$ , Figure 66  $\times 40$  magnification.

**Etymology.** Latin adjective *politus*, -a, -um = smooth, shining.

**Diagnosis.** Shell dextral, translucent light yellow, glossy shining, almost smooth, inner parietalis thread-like, outer parietalis spatulate, palatalis extremely long ending above the angular edge of the peristome.

**Description.** Shell dextral, small, last whorl well constricted, translucent light yellow; protoconch of 2 whorls, smooth; teleoconch of > 5 well rounded whorls, sculpture of a few faint, widely spaced ribs, shell glossy shining; suture deep; last whorl slightly ascending before aperture; aperture attached to last whorl, rounded, peristomial rim reinforced by a strong labial callus, columellar side with a strong columellaris; umbilicus slightly open; internal lamellar system with one columellaris, two parietal lamellae and one palatalis; columellaris a thin lamella, with a strong undulation at its end above the aperture; inner parietalis a long thread-like lamella, slightly overlapping with the second spatulate parietalis; palatalis extremely long, directly above the aperture, starting as a lamella besides the columellar side of the aperture, ending above the angular edge of the peristome with a small denticle. Operculum unknown.

**Measurements.** Holotype (Fig. 65): H = 1.64; D = 1.01; PH = 0.57; PD = 0.54; W = 6.

**Distribution** (Fig. 171). Yacata (=Yathata) in the Lau Is.

**Remarks.** For a differential diagnosis, refer to *M. brodieae* sp. n.





**Figures 67–68.** *Moussonina uncinata* sp. n. **67** Holotype MNHN IM-2000-27449, Viti Levu, surroundings of Qauia village, H = 2.43 mm **68** paratype, last whorl opened to show internal lamellae (enlarged). Figure 67  $\times 20$ , Figure 68  $\times 40$  magnification.

***Moussonina uncinata* sp. n.**

<http://zoobank.org/AD0D5F93-530D-4DD3-9A29-89B9F02BD3F8>

Figs 67–68

**Type material.** Holotype MNHN IM-2000-27449, paratypes MNHN/257 IM-2000-27450, NMBE 516858/30. Type locality: Viti Levu, surroundings of Qauia village, secondary wet forest, 20–50 m, -18.1001 178.3999, leg. Bouchet & Warén, 15.03.1999.

**Material.** Viti Levu, surroundings of Laselevu village, 80 m, rainforest, -17.7532 178.1416, leg. Bouchet, Warén & Dayrat, 14.02.1999, MNHN/13, NMBE 516893/3.

**Etymology.** Latin adjective *uncinatus*, -a, -um = hooked; with reference to the hook-like palatalis of this species.

**Diagnosis.** Shell dextral, deeply red-brown; teleoconch sculpture of fine, widely spaced riblets, suture with deep incision dorsolaterally on the last whorl, inner parietalis inconspicuous, outer parietalis spatulate, palatalis above angular edge of peristome.

**Description.** Shell dextral, spindle-shaped, last whorl slightly constricted, deeply red-brown; protoconch of 2 whorls, smooth; teleoconch of > 6 slightly shouldered whorls, sculpture of fine, widely spaced riblets; suture deep, with a deep notch dorsolaterally on the last whorl indicating the inner end of the palatalis (see arrows); last whorl slightly ascending before aperture; aperture attached to last whorl, subquadrate, peristomial rim reinforced, doubled, white, columellar side with a strong columellaris; internal lamellar system with one columellaris, two parietal lamellae and one palatalis; columellaris a lamella with a large brown denticle on top of the lamellar area just above the aperture, extending into the interior of the shell, where it abruptly bends upwards; inner parietalis an inconspicuous broad and flat callus, not connected to the outer parietalis, which is a thin, spatulate lamella; palatalis deep inside the shell above the angular edge of the peristome forming a strong, hook-like lamella with a moderately deep corresponding furrow on the outer side of the shell, its inner end indicated by a sutural incision.

Operculum unknown.

**Measurements.** Holotype (Fig. 67): H = 2.46; D = 1.29; PH = 0.8; PD = 0.84; W = 7.5.

**Distribution** (Fig. 170). two localities on Viti Levu.

**Remarks.** *Moussonia uncinata* sp. n. can be identified by the hook-like palatalis and the small furrow on the last whorl, indicating its end. It has some similarities with *M. obesa* sp. n., but the latter has stronger ribs, a palatalis parallel to the suture, and non-spathulate prt2. Among the Fiji *Moussonia* species, *M. uncinata* sp. n. is one of the largest. It shares the axial and deeply situated palatalis with *M. vitianoides* sp. n.; for differences, refer to that species.

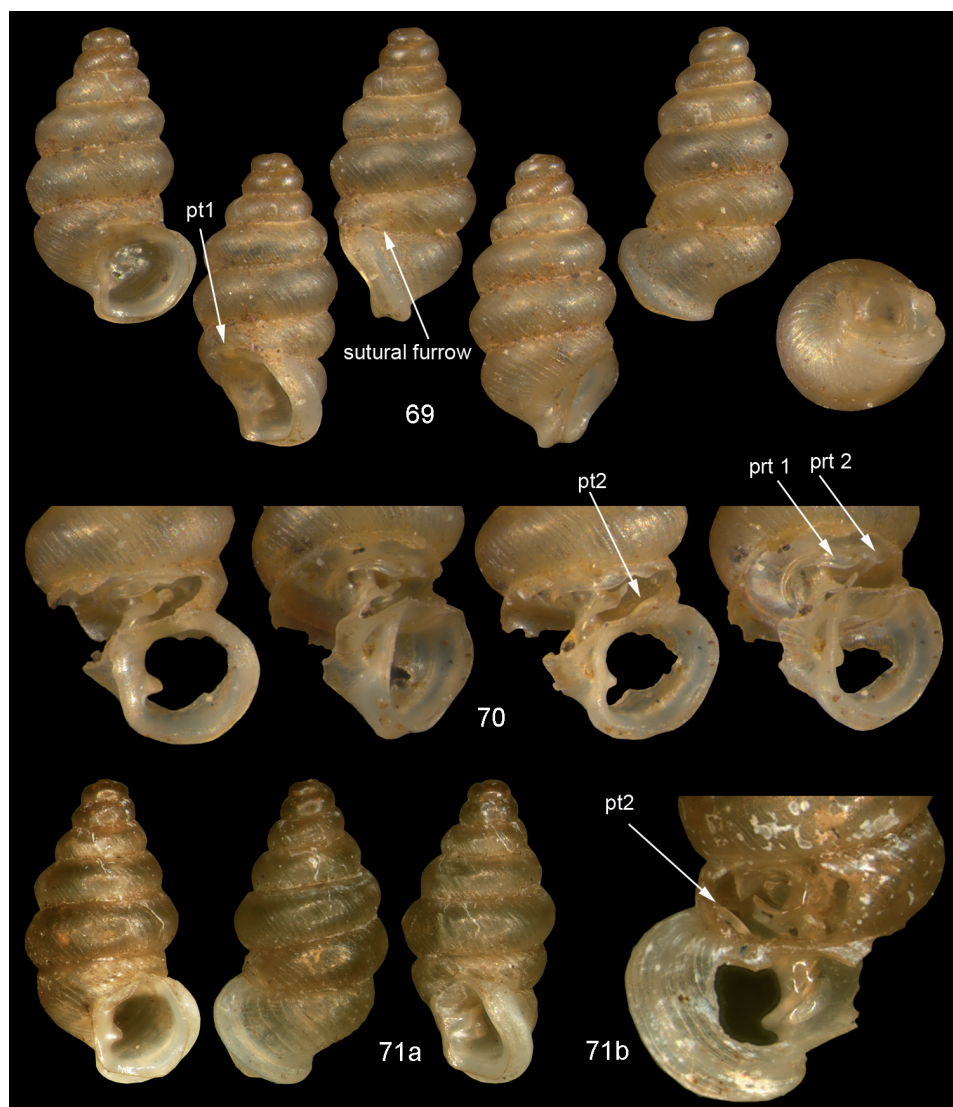
### *Moussonia vitianoides* sp. n.

<http://zoobank.org/2351240A-AE02-4366-B443-057A70971278>

Figs 69–71

**Type material.** Holotype MNHN IM-2000-27451, paratypes MNHN/127 IM-2000-27452, NMBE 516857/20. Type locality: Viti Levu, Nakorosule limestone outcrop, 30 m, degraded forest, -17.7734 178.2517, leg. Bouchet & Dayrat, 16.02.1999.

**Material.** Fiji, Viti Levu, Waivisa karst, 50 m, in washings from karstic spring, -17.6879 178.4033, leg. Bouchet, 27.08.1998, MNHN/25, NMBE 516904/5; Viti Levu, Waivisa Karst, 50–80 m, rainforest, -17.6879 178.4033, leg. Bouchet, 27.08.1998, MNHN/58, NMBE 516892/7.



**Figures 69–71.** *Moussonina vitianoides* sp. n. **69** Holotype MNHN IM-2000-27451, Viti Levu, limestone outcrop SE of Nambukulevu, H = 1.98 mm **70** paratype, last whorl opened to show internal lamellae **71** Fiji, Viti Levu, Waivisa Karst, H = 2.03 mm. Figures 69, 71a  $\times 20$ , Figures 70, 71b  $\times 40$  magnification.

**Etymology.** *Vitiana* and suffix *-oides*, meaning similar to *M. vitiana*.

**Diagnosis.** Shell dextral, yellow brownish, teleoconch with bluntly keeled whorls, densely spaced ribs, both parietal lamellae simple, two palatal lamellae, first palatalis above aperture, second palatalis above angular edge of peristome.

**Description.** Shell dextral, small, last whorl almost not constricted, yellow brownish; protoconch of 2 whorls, smooth; teleoconch of  $> 5$  bluntly keeled whorls, sculp-

ture of strong, densely spaced ribs; suture deep; last whorl slightly ascending before aperture; umbilicus, slit-like open; aperture attached to last whorl, subrectangular, peristomial rim doubled, reinforced by a strong labial callus, columellar side with a strong columellaris; internal lamellar system with 1 columellaris, two parietal and two palatal lamellae; columellaris a thin lamella, with a strong undulation at its end above the aperture; inner parietalis a long lamella, which increases in height towards its end, shortly overlapping with the outer parietalis, which is a low lamella; first palatalis a fine elongate lamella above the aperture, the second palatalis deep inside the shell above the angular edge of the peristome forming a strong almost axially orientated lamella running from the palatum to the inner basal surface of the whorl, corresponding to a small sutural furrow on the outer side of the shell.

Operculum unknown.

**Measurements.** Holotype (Fig. 69): H = 1.98; D = 1.14; PH = 0.67; PD = 0.68; W = 6.5.

**Distribution** (Fig. 170). Two karstic outcrops in eastern central Viti Levu.

**Remarks.** The first palatalis is not present in all specimens. *M. vitianoides* sp. n. can superficially be confused with *M. vitiana*. It differs from it by the presence of two palatal lamellae, with the second one in an almost axial position. This remarkable feature can also be observed in *M. uncinata* sp. n., but the latter has a larger, deep brown shell, and lacks the first palatalis.

### ***Palaina* Semper, 1865**

1865a *Palaina* Semper, Journal de Conchyliologie, 13: 291, 292. Type species: *Diplommatina macgillivrayi* Pfeiffer, 1854 [from Lord Howe Island], by subsequent designation of Iredale (1944: 303). Thiele (1929: 109) and Wenz (1939: 481) cited “*Palaina patula* Crosse” as type species, but this was a *nomen nudum* in 1865, later published as *Palaina patula* Semper, 1866.

1897 *Macropalaina* Möllendorff, Nachrichtenblatt der deutschen malakozoologischen Gesellschaft, 29: 43. Type species: *Diplommatina pomatiaeformis* Mousson, 1870, by original designation.

**Diagnosis.** Shell elongate oval, last whorl not constricted, usually with a bulbous last whorl, aperture in a rather central position in relation to the shell longitudinal axis, without apertural dentition; internal dentition mainly concerns formation of the columellaris, which may be toothed to completely unarmed; operculum with or without concentric lamellae; with a low arcuate ridge on the inner surface.

Semper established the name *Palaina* without providing a description. Kobelt’s (1902: 394) definition is undiagnostic, as this author included under this header many species from the Pacific diplommatinid radiation, which can be considered a polyphyletic assemblage: “Shell ovate cone-shaped, in most cases sinistral, with a diverse sculpture. Last whorl constricted at the beginning or the first quarter; aperture without

teeth, operculum deeply sunken, uncalcified, circular, with several whorls. Shell elongate oval; no dentition; operculum corneous, with thick concentric ridges” [translated from German].

A re-definition of *Palaina* was provided by Yamazaki et al. (2013: 16), who considered *Eupalaina* Kobelt & Moellendorff, 1898 as a subgenus of *Palaina* (subsequent type designation *Palaina patula* Crosse, 1866). The type species of *Palaina* is *Diplommatina macgillivrayi* Pfeiffer, 1854, from Lord Howe Island, from which island several species of *Palaina* are recorded (Stanisic et al. 2010). Comparing their shells to those from Palau and to those from Fiji that we include in *Palaina*, they differ by their quite compact and stout outline (the Fiji species are more variable in shape). The inner lamellar system of the Lord Howe radiation is unknown. However, Tillier (1981) illustrated the operculum of *P. macgillivrayi*, which seems to have a bilobed ridge on the inner surface, and thus differs from what is seen in the Palau species, which have a single strong ridge (Yamazaki et al. 2013: Figs 10A–D), and in the Fiji species, which have a low, inconspicuous ridge. In shell shape and formation of the opercula, the Fiji “*Palaina*” are close to those from New Caledonia, but unfortunately, Tillier (1981) did not investigate the internal lamellar system in the latter, so potentially useful information is lacking. The species in the New Caledonia radiation have no penis, while the Palau species possess one. Yamazaki et al. (2013) claimed that Tillier (1981) found *P. macgillivrayi* to also have no penis, a statement that, however, is not explicit in Tillier’s text. For Fiji, no information is available in this regard at present. This short review shows that knowledge of this group is patchy. It seems possible that all the different island radiations will have to be separated at the generic level once the full set of characters is known. For the time being, we conservatively apply *Palaina* in a broad sense to the Fiji radiation, although we anticipate a separation at the generic level (for which the name *Macropalaina* is available) from the Lord Howe and Palau radiations. The Fiji species might not even be monophyletic.

### ***Palaina ascendens* (Mousson, 1870), comb. n.**

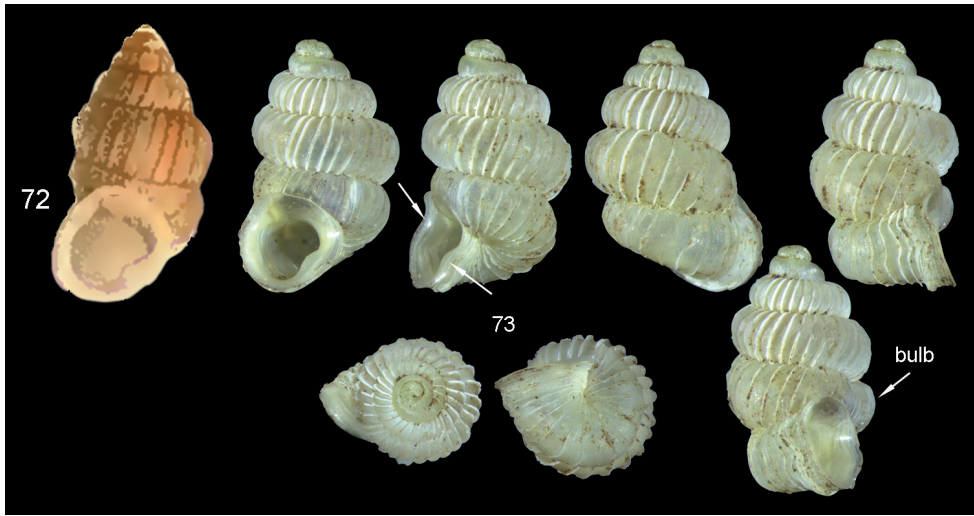
Figs 72–73

1870 *Diplommatina ascendens* Mousson, Journal de Conchyliologie, 18: 184, pl. VIII, fig. 5. Type locality: “Ile de Viti-Levu”.

1902 *Diplommatina* (*Pseudopalaina*) *ascendens*, – Kobelt, Cyclophoridae: 451.

**Type material.** The 2 specimens originally mentioned by Mousson could not be traced in the collection of Mousson in Zurich nor in the collection of the Journal de Conchyliologie in Paris. In a lot in ZMZ, however, originally identified by Mousson as “*D. martensi*”, a specimen similar to the - somewhat sketchy - original illustration of *D. ascendens* is present. This specimen cannot be considered type material, because it was acquired by Mousson in his collection in 1872, i.e. two years after the description of the species. To stabilize the use of the name, this specimen is here selected as neotype.





**Figures 72–73.** *Palaina ascendens* (Mousson, 1870). **72** original figure from Journal de Conchyliologie, 18: pl. VIII, fig. 5: H = 3.8 mm **73** neotype ZMZ 526689d, Viti Levu, “Tatatan”, H = 3.31 mm. All figures  $\times 10$  magnification.

Neotype: ZMZ 526689d, here designated, Viti Levu, “Tatatan”, coll. Mousson ex Graeffe 1872 (Fig. 72). The locality “Tatatan” could not be identified with certainty; possibly it is Cautata, NE of Suva.

**Original description.** “T. sinistrorsa, longe rimata, acute ovata, lamellosocostulata, carneo-albescens. Spira convexo-conica; summo obtusulo, graniformi; sutura subprofunda. Anfr. 5  $1/2$ , celeriter accrescentes, convexi; nucleolares laevigati; sequentes ventrosi, lamelliferi; penultimus in ventre retractus et compressus, tenuiter costulatus, lateraliter ruga transversa proeditus; ultimus attenuatus, lente et valde usque ad suturam anfr. tertii fere ascendens, ad rimam paulo impressus. Apert. tangentialis, sursum versa [40° cum axi], transverse perobliqua, subpatula, intus et extus obtuse quadrata. Perist. subexpansum, antice duplicatim incrassatum; marginibus convergentibus, lamina sinistrorsa junctis; columellari et externo supra antrorsum productis, infra sinuatis. Columella obtuse nodulata, interdum lamina producta circumdata. — Long. 3,8, diam. 2,2 mill. — Rat. anfr. 5 : 1. — Rat. apert. 5 : 4. Hab. Ile de Viti-Levu.”

**Diagnosis.** Shell whitish, moderately large bulb, sculpture of widely spaced ribs, aperture subquadrate, with two denticles.

**Description.** Shell sinistral, medium sized, oval, whitish; protoconch acute, granulated; last whorl not constricted with a moderately large bulb; last whorl strongly ascending; teleoconch sculpture of coarse widely spaced ribs; umbilicus slit-like, periomphalum narrow; aperture subquadrate, peristome reinforced by a lip, with two denticles on each side (Fig. 73, arrows), broadly attached to last whorl; no pleats visible in the aperture; internal lamellar system not studied.

Operculum unknown.

**Measurements.** Neotype (Fig. 73): H = 3.31; D = 2.13; PH = 1.32; PD = 1.40; W = 5.

**Distribution.** Uncertain.

**Remarks.** The lot ZMZ 526689 contained a larger number of *Diancta martensi* (ZMZ 526689c), but also one specimen of *P. tuberosa* (ZMZ 526689a) and a specimen of *P. latecostata* (ZMZ 526689b).

*Diplommatina ascendens* is here classified in *Palaina* because it has a well-developed bulb. It is unmistakable by the formation of the aperture: usually, species of *Palaina* have a rounded aperture, and not a subquadrate oblique aperture, which is probably why Mousson may have merged it with the superficially similar *Diancta martensi*. However, the latter is a true species of *Diancta* as evidenced by the lack of a bulb and the internal lamellar system.

### *Palaina godeffroyana* (Mousson, 1870)

Figs 74–78

1870 *Diplommatina godeffroyana* Mousson, Journal de Conchyliologie, 18: 182, pl. VIII, fig. 4. Type locality: Nagara, southern Viti Levu, and Ovalau.

1870 *Diplommatina godeffroyana* var. *fracta* Mousson, Journal de Conchyliologie, 18: 183. Type locality: Viti Levu.

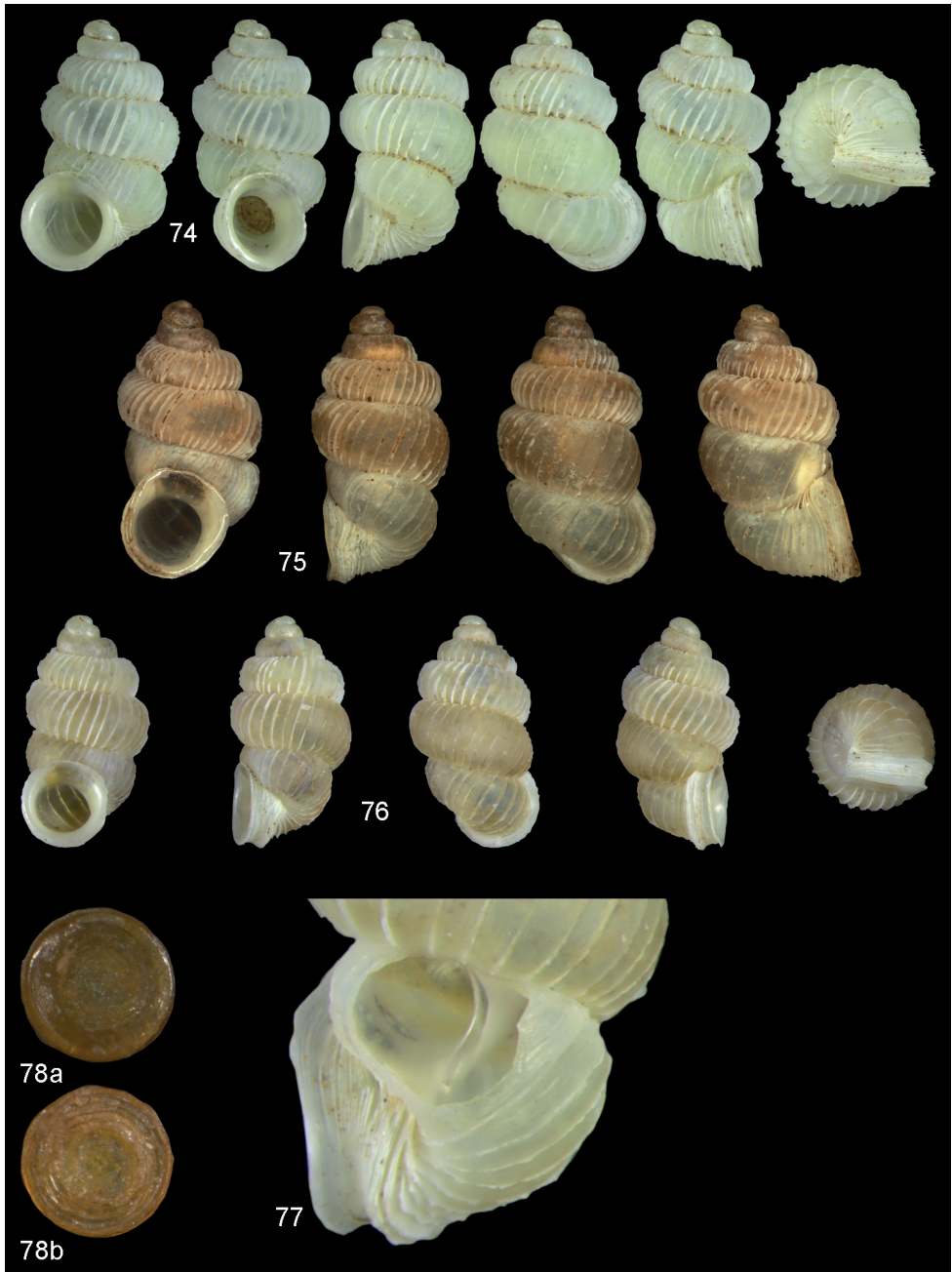
1902 *Palaina* (*Palaina*) *godeffroyana*, – Kobelt, Cyclophoridae: 399.

**Type material.** *godeffroyana* lectotype, here designated, ZMZ 526678/a, Fiji, Viti Levu, Island of Nagara [probably now Naqara; also spelled Nanggara, south-east of Viti Levu], Graeffe 1868; paralectotypes ZMZ 526678/4; probable paralectotypes SMF 105089/4, Fiji, Viti Levu, coll. Möllendorff ex Mousson. — *fracta* syntypes: ZMZ 526681/4, Fiji, Viti Levu.

**Material.** SMF 105091/1, Viti Levu, coll. O. Boettger ex Schlüter 1887; ZMZ 526686a/9, Viti Levu, “Tatatan” [a place name we could not identify], Graeffe 1872; ZMZ 526684/15, Viti Levu, Graeffe 1872; ZMZ 526688/1, Viti Levu, Vaini Loba, Graeffe 1872; ZMZ 526682a, Viti Levu, Graeffe 1872; Viti Levu, Waivisa karst, 50–80 m, rainforest, -17.6879 178.4033, leg. Bouchet, 27.08.1998, MNHN/24, NMBE 516894/5; Viti Levu, Saweni karst, 50–60 m, dry forest, -17.9032 177.7983, leg. Bouchet, 22.08.1998, MNHN/1; Viti Levu, Wailotua karst, 50–80 m, rainforest, -17.7582 178.4166, leg. Bouchet, 25–27.08.1998, MNHN/1.

**Diagnosis.** Shell sinistral, elongate oval, white, bulb reduced, last whorl ascending, lamellar system reduced.

**Description.** Shell sinistral, elongate oval, white to light yellowish; protoconch acute, granulated, consisting of 2 whorls; last whorl not constricted, bulb reduced, inconspicuous; teleoconch sculpture of widely spaced ribs, ribbing pattern slightly wider on the last two whorls; last whorl strongly ascending; aperture circular, in



**Figures 74–78.** *Palaina godeffroyana* (Mousson, 1870). **74** lectotype of *Diplommatina godeffroyana* ZMZ 526678 Fiji, Viti Levu, Island of Nagara, Graeffe 1868, H = 3.4 mm **75** syntype of *Diplommatina godeffroyana* var. *fracta* ZMZ 526681, Viti Levu, H = 3.76 mm **76** Viti Levu, Waivisa karst, 50–80 m, H = 3.14 mm **77** ditto, last whorl opened to show internal lamellae (enlarged, not to scale) **78** ditto, operculum **78a** inner surface **78b** outer surface. Figures 74–77  $\times 10$ , Figure 78  $\times 40$  magnification.

a central position, broadly adhered to the last whorl, peristomial rims connected; umbilicus closed, periomphalum narrow; lamellar system completely reduced; bulb lamella very weak.

**Operculum.** Outer surface with concentric rings of lamellae, internal surface concave and smooth inside, OD = 0.52.

**Measurements.** Lectotype *godeffroyana* (Fig. 74): H = 3.4; D = 1.84; PH = 1.36; PD = 1.29; W = 5.5.

**Distribution** (Fig. 170). Many sites on Viti Levu.

**Remarks.** *Palaina godeffroyana* resembles *P. pomatiaeformis*, which, however, differs by its larger and elongate shell, denser ribbing pattern, and the presence of a basal columellar denticle.

### *Palaina latecostata* (Mousson, 1870), comb. n.

Fig 79–81

1870 *Diplommatina godeffroyana* var. *latecostata* Mousson, Journal de Conchyliologie, 18: 183. Type locality: Viti Levu.

1902 *Palaina* (*Palaina*) *godeffroyana latecostata*, – Kobelt, Cyclophoridae: 399.

**Type material.** Lectotype, here designated, ZMZ 526679/a, Fiji, Viti Levu, coll. Mousson ex Graeffe 1868. — Paralectotypes ZMZ 526679/6.

**Material.** ZMZ 526686b/5, Viti Levu, “Tatatan” [a place name we could not identify], Graeffe 1872; ZMZ 526685/8, Fiji, Island of Ovalau, Graeffe 1866; ZMZ 526682b/7, Viti Levu, Graeffe 1872 [as *D. godeffroyana*].

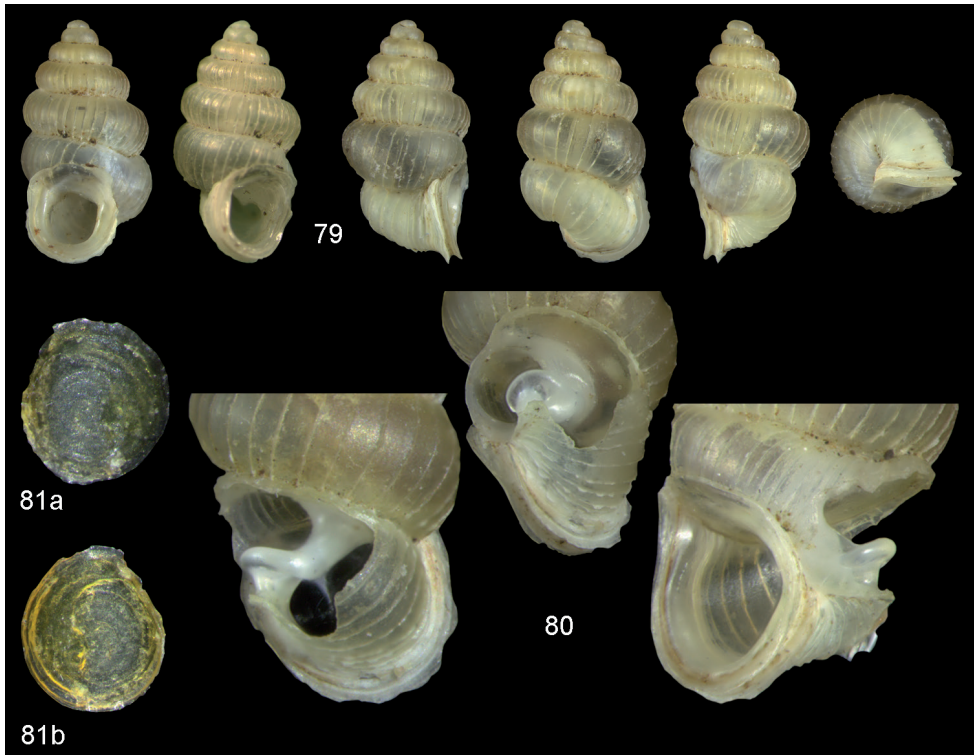
**Diagnosis.** Shell sinistral, small, bulb well developed, periomphalum compressed, aperture circular, peristome with a faint labial callus, columella obliquely twisted, bulb lamella present.

**Description.** Shell sinistral, small, broadly oval, whitish to greenish; protoconch acute, granulated; last whorl not constricted, slightly ascending; bulb well developed; umbilicus closed, periomphalum compressed; sculpture of teleoconch whorls with widely spaced ribs; aperture circular, simple, adhered to the last whorl; peristome with a faint labial callus; oblique view into the aperture revealing a strong columellaris; internally, columella obliquely twisted, forming a horizontal lamella in its lower third; a moderately strong bulb lamella present, in some specimens entering the parietum as a thick lamella; small parietalis present.

Operculum corneous, with a long lamella on the outer surface, internally smooth, OD = 0.55.

**Measurements.** Lectotype (Fig. 79): H = 3.2; D = 1.73; PH = 1.35; PD = 1.22; W = 6.5.

**Distribution.** Ovalau and the hitherto mysterious locality “Tatatan” (or Tatatau?) on Viti Levu (possible Cautata, NE of Suva).



**Figures 79–81.** *Palaina latecostata* (Mousson, 1870). **79** Lectotype ZMZ 526679a, Viti Levu, H = 3.20 mm **80** paralectotype, last whorl opened to show internal lamellae (enlarged, not to scale) **81** operculum **81a** inner surface **81b** outer surface. Figure 79  $\times 10$ , Figure 81  $\times 40$  magnification.

***Palaina pomatiaeformis* (Mousson, 1870)**

Figs 82–85

1870 *Diplommatina pomatiaeformis* Mousson, Journal de Conchyliologie, 18: 180, pl.

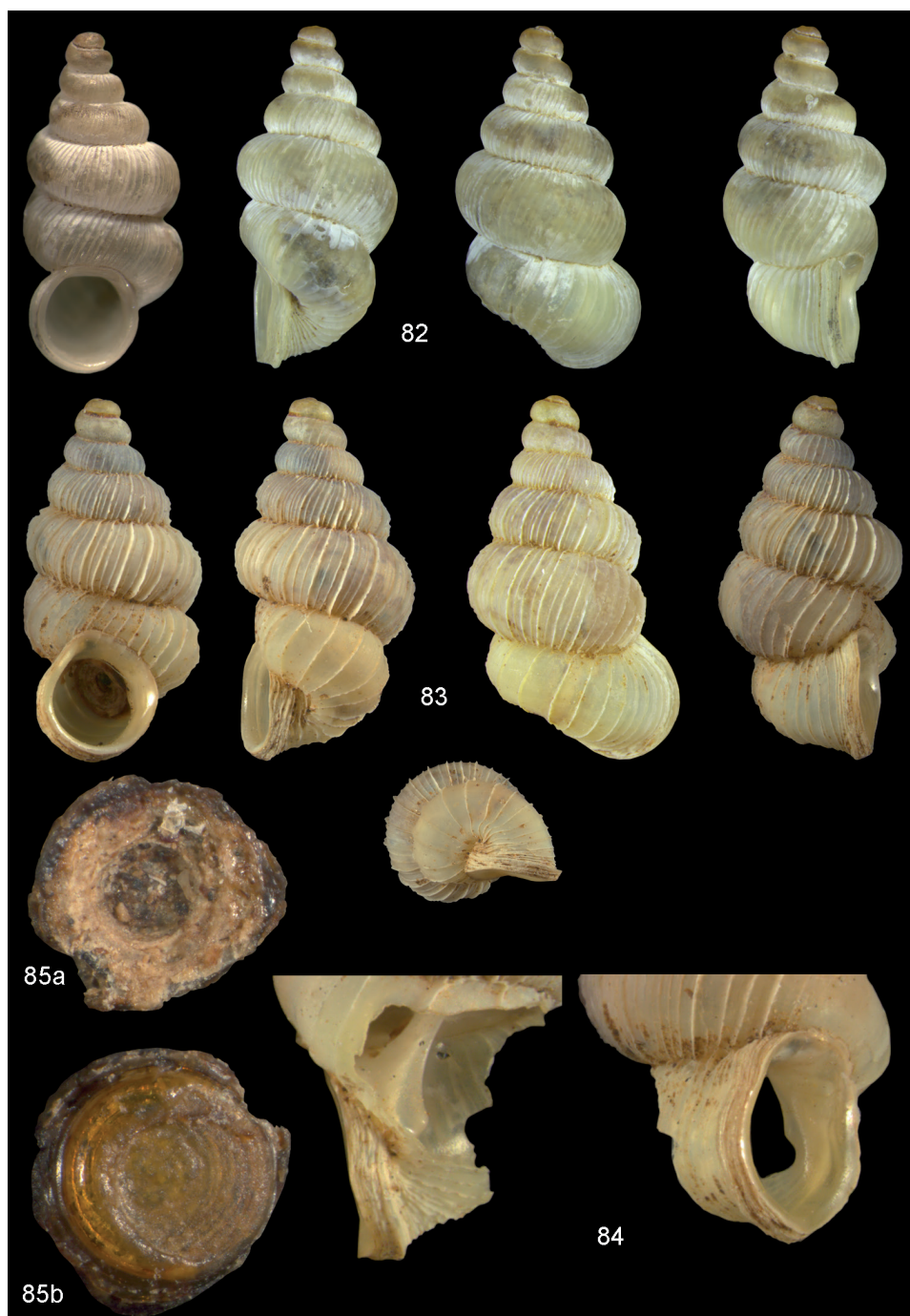
VIII, fig. 2. Type locality: Vaini-Loba, in the southern part of Viti Levu.

1902 *Palaina* (*Macropalaina*) *pomatiaeformis*, – Kobelt, Cyclophoridae: 411.

**Type material.** Possible syntypes ZMZ 526676/4. This lot contains 4 specimens from two places, as can be seen from the labels: 1. Viti Levu, “Vai Loban” [= Vaini-Loba], Graeffe [18]68 and 2. Viti Levu (S coast) Graeffe [18]72. The specimens from Vaini-Loba, the type locality, are mixed with those from the S coast, which reached Mousson after the description, and are not part of the type series. The Vaini-Loba material cannot be recognized; nonetheless, all specimens are conspecific. — Possible syntypes SMF 105141/2, Fiji, Viti Levu, coll. Möllendorff ex Mousson.

**Material.** Viti Levu, surroundings of Qauia village, secondary wet forest, 20–50 m, -18.1001 178.3999, leg. Bouchet & Warén, 15.03.1999, MNHN/28, NMBE





**Figures 82–85.** *Palaina pomatiaeformis* (Mousson, 1870). **82** Possible syntype ZMZ 526676, Vaini-Loba (?), H = 4.8 mm **83** Viti Levu, surroundings of Qauia village, 20–50 m, H = 5.09 mm **84** ditto, last whorl opened to show internal lamellae (enlarged, not to scale). **85** ditto, operculum **85a** inner surface **85b** outer surface. Figures 82, 83  $\times 10$ , Figure 85  $\times 40$  magnification.

516895/7; Viti Levu, surroundings of Laselevu village, 80 m, rainforest, -17.7532 178.1416, leg. Bouchet, Warén & Dayrat, 14.02.1999, MNHN/5.

**Diagnosis.** Shell sinistral, large, elongate spire, light yellowish, widely spaced ribs with occasionally interspersed smaller ribs, central teleoconch whorls rapidly increasing in diameter suture deep, columella with a small knob-like denticle.

**Description.** Shell sinistral, large, elongate spire, white to light yellowish; protoconch acute, granulated, consisting of 2 whorls; initial teleoconch whorls narrow, subsequent whorls rapidly increasing in diameter; last whorl not constricted, bulb of moderate size; teleoconch sculpture of widely spaced ribs with occasionally interspersed smaller ribs, rib pattern constant throughout the whole shell; deep suture and well-rounded whorls; last whorl ascending; aperture circular, in a central position, broadly adhered to the last whorl, peristomial rims connected; umbilicus closed, periomphalum narrow; internally, columella not reinforced with a small knob-like denticle at the base; bulb lamella very weak.

**Operculum.** Outer surface with concentric rings of lamellae, internal surface concave and smooth inside, OD = 0.91.

**Measurements.** Possible syntype (Fig. 82): H = 4.8; D = 2.26; PH = 1.53; PD = 1.57; W = 6.

**Distribution** (Fig. 170). several localities on Viti Levu.

**Remarks.** This is the type species of *Macropalaina*. The character states in this species compare very well with those in *Palaina* as defined here, the only difference being the remarkable lamellate operculum. Until the diagnostic value of the operculum has been investigated there is no reason to separate *Macropalaina* from *Palaina*, and they are here treated as synonyms, as did previous authors before us.

*Palaina pomatiaeformis* is the largest *Palaina* species so far known from Fiji. It differs from all other *Palaina* species by its narrow initial teleoconch whorls and the last whorls that rapidly increase in diameter. This characteristic “*Cochlostoma*-like” feature prompted Möllendorff to separate it in its own genus. However, an acute protoconch with somewhat narrower upper teleoconch whorls can also be found in *P. godeffroyana* and other species. Size and shell form make *P. pomatiaeformis* a species that cannot be confused with any other *Palaina* species.

### *Palaina subregularis* (Mousson, 1870)

Figs 86–92

1870 *Diplommatina subregularis* Mousson, Journal de Conchyliologie, 18: 181, pl. VIII, fig. 3. Type locality: “Nagara, petite île située près de la côte sud de Viti-Levu”.

1897 *Diplommatina graeffei* Möllendorff, Nachrichtenblatt der deutschen malakozoologischen Gesellschaft, 29 (1/2): 44 [name attributed by Möllendorff to Mousson].

Type locality: Vitilevu. New synonym.

1902 *Palaina* (*Palaina*) *subregularis*, – Kobelt, Cyclophoridae: 405.

1902 *Diancta* (*Diancta*) *graeffei*, – Kobelt, Cyclophoridae: 420.

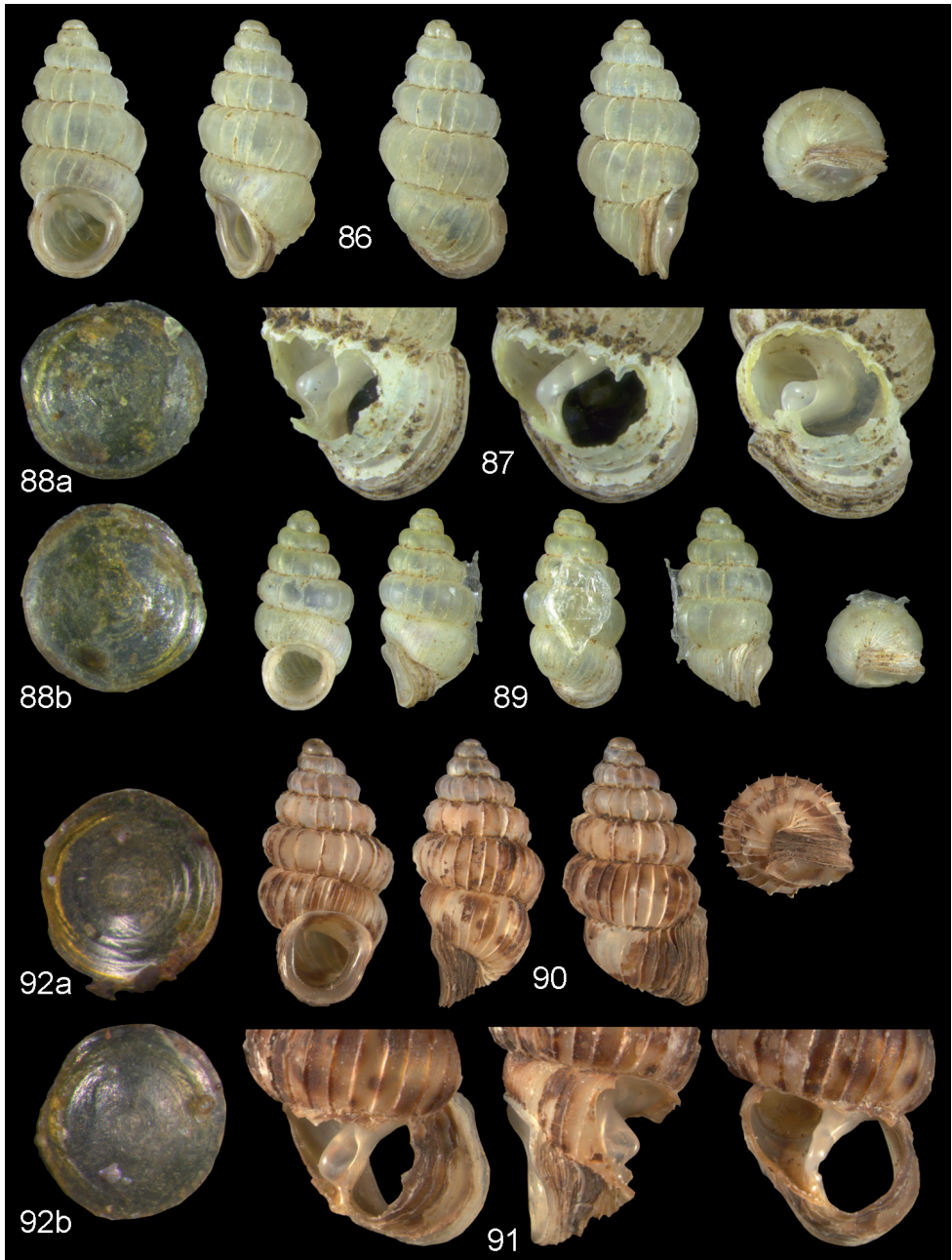
**Type data.** No type specimens of *D. subregularis* could be traced in MNHN or in ZMZ. Under the name *D. subregularis*, the Mousson collection houses the lot ZMZ 526677 which, according to the handwritten label, originates from “Viti Levu, Graeffe 1872”. Although identified by Mousson himself as his *D. subregularis*, this lot is not type material, because it reached Mousson two years after the description of the taxon, and it does not originate from the type locality. From the same locality “Viti Levu”, four specimens in SMF 105079/4 (coll. Möllendorff ex Mousson, also as *D. subregularis*), had been identified as “cotypes” by A. Zilch. It is highly probable that these specimens also come from ZMZ 526677, and thus were not originally part of the type series. Moreover, SMF 105079/4 consists of three shells that do match with “*subregularis*” in the sense of Mousson, and one that does not, but is *P. godeffroyana*. In order to stabilize the application of this name, we here designate a neotype from ZMZ 526677, because the specimens from this lot match the description of Mousson very well. Neotype: *subregularis* ZMZ 526677a, Viti Levu, coll. Mousson ex Graeffe 1872 (Fig. 86).

*D. graeffei*: lectotype, designated by Zilch (1953: 17, pl. 6 fig. 89), SMF 104903/1, Fiji, Viti Levu, coll. Möllendorff ex Mousson. The name *graeffei* had already been used by Mousson in his collection (ZMZ 526702/many, “*Dipl. graeffei* Mss., Viti Levu (Graeffe)”), but had remained a manuscript name. The lectotype of *graeffei* matches the shells in this lot so well that the SMF specimen most probably originates from this lot; however, there is no evidence that Möllendorff ever saw the specimens in the Mousson collection when he published the name *Diplommatina graeffei*, and the specimens in ZMZ 526702 are not regarded by us as paralectotypes.

**Material.** SMF 105079/4, Fiji, Viti Levu, coll. Möllendorff ex Mousson; Viti Levu, Voli Voli limestone outcrop, 10–30 m, secondary open forest, -17.3374 178.1831, leg. Bouchet, Warén & Dayrat, 18.02.1999, MNHN/8; Viti Levu, limestone outcrop SE of Nambukulevu, 230 m, rainforest, -18.1366 177.8149, leg. Bouchet, Warén & Dayrat, 20.02.1999, MNHN/6; Viti Levu, Qalimare karst, Toga village, 30–130 m, dry forest, -17.9953 177.5768, leg. Bouchet, 21.08.1998, MNHN/255, NMBE 516896/20; Viti Levu, Tuvu karst, 50 m, dry forest, -17.9332 177.7067, leg. Bouchet, 23.08.1998, MNHN/172, NMBE 516897/20.

**Diagnosis.** Shell sinistral, elongate oval, teleoconch whorls with widely spaced ribs, brown axial flames or blotches between the ribs, aperture circular, bulb reduced, columella a broad lamella, basally with columellar tooth.

**Description.** Shell sinistral, elongate oval, eroded shells purely white, well preserved specimens with a pattern of brown axial flames or blotches between the ribs; protoconch acute, granulated; last whorl not constricted, slightly ascending; bulb reduced, demarcated by a faint bulb lamella; umbilicus closed, periomphalum narrow; sculpture of teleoconch whorls with widely spaced ribs, ribbing pattern above the aperture somewhat denser; aperture circular, sometimes with a double lip demarcated by a brown line, adhered to the last whorl; oblique view into the aperture revealing a strong columellaris; internally, columella forming a broad lamella extending towards the interior of shell, basally forming a columellar tooth.



**Figures 86–92.** *Palaina subregularis* (Mousson, 1870). **86** Neotype ZMZ 526677a, Viti Levu, H = 3.5 mm **86** specimen ex ZMZ 526677, last whorl opened to show internal lamellae (enlarged, not to scale) **88** ditto, operculum **88a** inner surface, **88b** outer surface) **89** *Diplommatina graeffei* (Möllendorff, 1897), lectotype SMF 104903 Viti Levu, H = 2.7 mm. **90** Viti Levu, Tuvu karst, H = 3.62 **91** ditto, last whorl opened to show internal lamellae (enlarged, not to scale). **92** ditto, operculum, **92a** inner surface, **92b** outer surface. Figures 86, 89, 90  $\times 10$ , Figures 88, 92  $\times 40$  magnification.



Operculum corneous, outer surface with several concentric lamellae and a single, short raised lamella; internal surface concave, smooth.

**Measurements.** Neotype of *subregularis* (Fig. 86): H = 3.5; D = 1.71; PH = 1.24; PD = 1.26; W = 7; lectotype of *graeffei* (Fig. 89): H = 2.7; D = 1.35; PH = 0.99; PD = 0.89; W = 7.

**Distribution** (Fig. 170). Quite widespread on Viti Levu.

**Remarks.** After a careful comparison of the lectotype of *D. graeffei* with the rest of the material attributed to *P. subregularis*, it was not possible to find any discriminating characters between the two taxa besides shell size, and we conclude that the former is a small specimen of the latter.

For a differential diagnosis, refer to *P. flammulata* sp. n., *P. truncata* sp. n., and *P. parietalis* sp. n.

### *Palaina tuberosa* (Mousson, 1870)

Figs 93–94

1870 *Diplommatina tuberosa* Mousson, Journal de Conchyliologie, 18: 185. Type locality: “Viti Levu (Vai-Loba) Südküste” [Vaini-Loba, south coast of Viti Levu].

1902 *Palaina (Palaina) tuberosa*, – Kobelt, Cyclophoridae: 406.

**Type material.** Lectotype MNHN IM-2000-26707 [number of specimens not originally mentioned; the original specimen deposited in the collection of Journal de Conchyliologie is herewith designated as lectotype].

**Material.** ZMZ 526687/3, “Viti Levu (Vai-Loba) Südküste”, coll. Mousson ex Graeffe 1872; ZMZ 526689a/1, Viti Levu, “Tatatan”, coll. Mousson ex Graeffe, 1872 [identified by Mousson as “*D. martensi*”].

**Diagnosis.** Shell sinistral, small, bulb well developed, whorls widely ribbed, area above aperture fine and densely ribbed, labial callus weak, columella obliquely twisted, truncate with a thick bi-lobed tooth, parietalis a long slightly raised lamella.

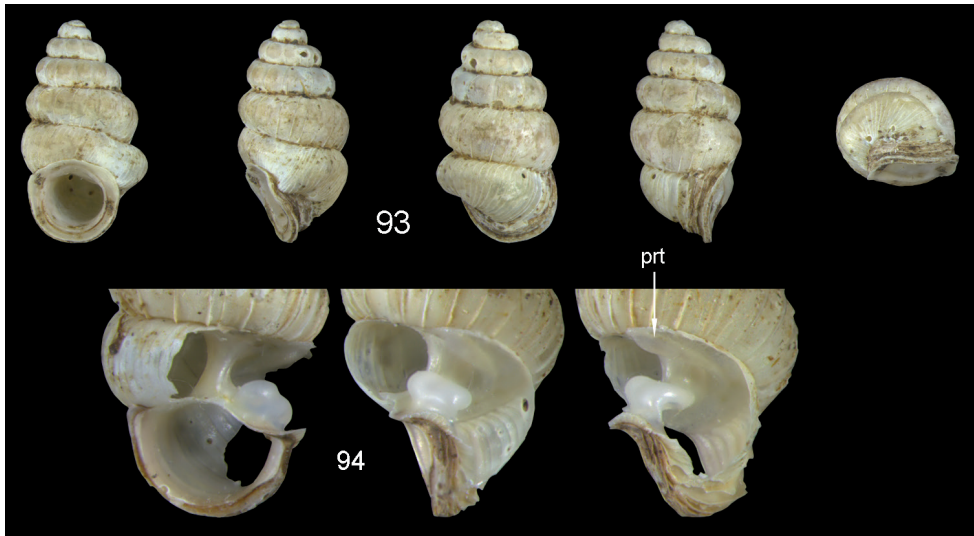
**Description.** Shell sinistral, small, broadly oval, faint yellowish; protoconch acute, granulated; last whorl not constricted, slightly ascending; bulb well developed; umbilicus closed, periomphalum narrow; sculpture of teleoconch whorls with widely spaced ribs, area above the aperture with fine and densely arranged ribs; aperture circular, simple, adhered to the last whorl; aperture with a weak labial callus, two small ear-like processes on the upper edges of the peristome; by oblique view into the aperture columellaris visible; internally, columella obliquely twisted, truncate in the lower half forming a thick bi-lobed tooth; parietum with a long slightly raised parietalis in front of the bulb.

Operculum unknown.

**Measurements.** Lectotype (Fig. 93): H = 2.93; D = 1.68; PH = 1.11; PD = 1.21; W = 6.

**Distribution.** Vaini-Loba (or Vai-Loba?) on the southern coast of Viti Levu (modern name not identified); not found during the 1998–99 field work.





**Figures 93–94.** *Palaina tuberosa* (Mousson, 1870). **93** Lectotype MNHN IM-2000-26707, Vaini-Loba, south coast of Viti Levu, H = 2.93 mm **94** ZMZ 526687, last whorl opened to show internal lamellae (enlarged, not to scale). Figure 93  $\times 10$  magnification.

**Remarks.** *Palaina tuberosa* can easily be confused with *P. tuberosissima* sp. n., which is similar in shell size and shape. *P. tuberosa* differs from it by having the dense ribbing pattern of the area above the aperture, the weak labial callus, and the reduced ear-like processes on the peristome. In the internal lamellar system, *P. tuberosa* has only a bilobed columellar tooth, its parietalis is not spatulate, and a palatalis and second columellaris are missing altogether.

***Palaina alberti* sp. n.**

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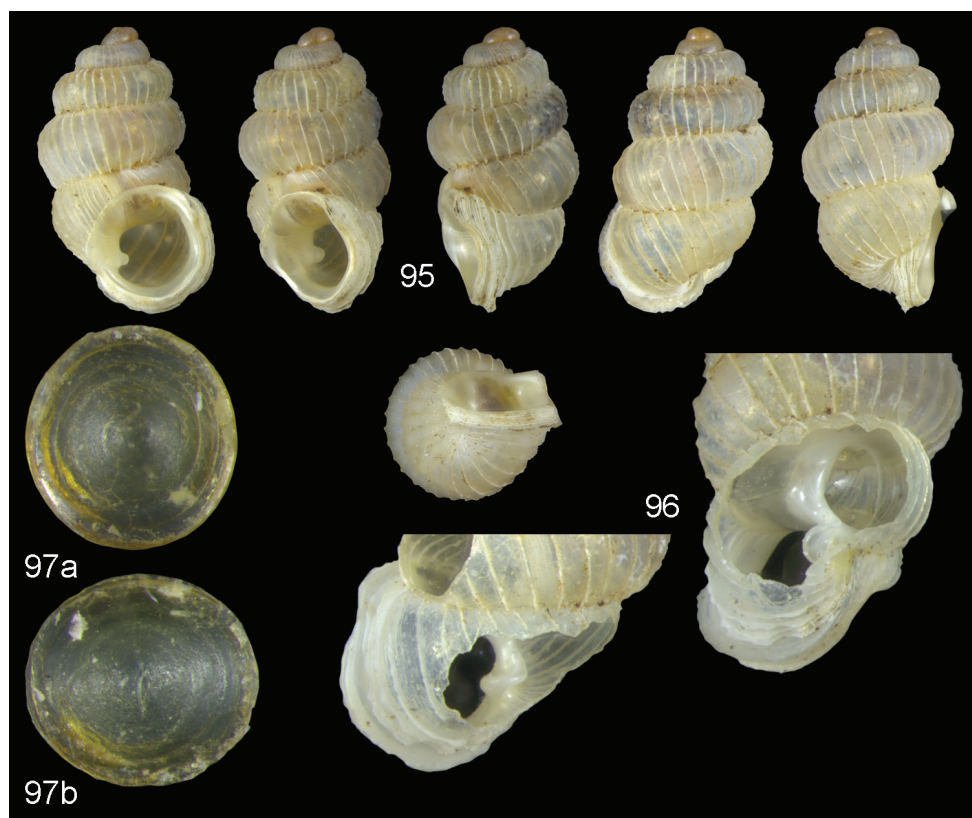
Figs 95–97

**Type material.** Holotype ZMZ 526680, paratypes ZMZ 526680/3. Type locality: Viti Levu, Nagar[r]a [probably now Naqara; also spelled Nanggara, south-east of Viti Levu], coll. Mousson ex Graeffe, 1868.

**Etymology.** This species is named in honour of Albert Mousson who pioneered the description of the Fiji diplommatinid fauna.

**Diagnosis.** Shell dextral, small, bulb inconspicuous, columellaris visible in frontal view forming a short horizontal lamella, bulb lamella visible as a fine white line in frontal apertural view.

**Description.** Shell dextral, small, broadly oval, whitish to greenish; protoconch acute, granulated; last whorl not constricted, slightly ascending; bulb inconspicuous;



**Figures 95–97.** *Palaina alberti* sp. n. **95** Holotype ZMZ 526680, Viti Levu, Nagara Island, H = 3.76 mm **96** paratype, last whorl opened to show internal lamellae (enlarged, not to scale) **97** operculum **97a** inner surface **97b** outer surface. Figure 95  $\times 10$ , Figure 97  $\times 40$  magnification.

umbilicus slit-like, periomphalum narrow; sculpture of teleoconch whorls with widely spaced ribs; aperture subquadrate, with two ear-like processes, simple, adhered to the last whorl; peristome with a labial callus; columellaris visible in frontal view; internally, columellaris forming a short horizontal lamella coiling into the interior of the shell; bulb lamella present, visible as a fine white line in frontal apertural view.

Operculum corneous, strongly concave, with a long lamella on the outer surface, internally smooth, OD = 0.7.

**Measurements.** Holotype (Fig. 95): H = 3.76; D = 2.3; PH = 1.69; PD = 1.72; W = 6.

**Distribution.** only known from the type locality.

**Remarks.** *Palaina alberti* sp. n. was identified by Mousson as “*Dipl. Godeffroyana* var. *latecostata*”, but can easily be separated from that species by its dextral shell. Additionally, it differs from *P. latecostata* by the columellaris, which in *P. alberti* is visible in the aperture, and forms a horizontal lamella. No dextral *Palaina* species is currently known from Fiji.



**Figures 98–100.** *Palaina flammulata* sp. n. **98** Holotype MNHN IM-2000-27453, Viti Levu, Qalimare karst, east of Natawatawadi, 40 m, H = 3.45 mm **99** paratype, last whorl opened to show internal lamellae (enlarged, not to scale) **100** operculum **100a** inner surface **100b** outer surface. Figure 98  $\times 10$ , Figure 100  $\times 40$  magnification.

***Palaina flammulata* sp. n.**

<http://zoobank.org/D2C4D356-323B-4CE6-83AE-880E514C6581>

Figs 98–100

**Type material.** Holotype MNHN IM-2000-27453, paratypes MNHN/173 IM-2000-27454, NMBE 516861/20. Type locality: Viti Levu, Qalimare karst, East of Natawatawadi, 40 m, dry forest, -17.9816 177.6266, leg. Bouchet, 21.08.1998.

**Etymology.** Adjective formed from the Latin noun *flamma* = fire, diminutive *flammula*, to describe the colour pattern of this species.

**Diagnosis.** Shell sinistral, broadly oval, with a pattern of brown axial flames, large bulb, whorls with widely spaced ribs and occasionally interspersed smaller ribs, columella twisted with a truncate basal tooth.

**Description.** Shell sinistral, broadly oval, protoconch acute, granulated; basic shell colour yellowish to white, with a pattern of brown axial flames between the ribs; last whorl not constricted, with a large bulb; teleoconch sculpture of widely spaced ribs with occasionally interspersed smaller ribs, rib pattern constant throughout the whole shell;

fine spiral threads visible on the upper teleoconch whorls (high magnification required); last whorl slightly ascending; aperture circular, sometimes with a double lip, broadly adhered to the last whorl; umbilicus closed, periomphalum narrow; columella twisted, forming a narrow lamella, and ending in a truncate basal tooth; bulb lamella present.

Operculum flat, corneous, multispiral, with a short apophysis, OD = 0.61.

**Measurements.** Holotype (Fig. 98): H = 3.45; D = 1.81; PH = 1.25; PD = 1.31; W = 7.

**Distribution** (Fig. 170). Only known from the type locality.

**Remarks.** *Palaina flammulata* sp. n. is very similar to *P. subregularis*, but differs from it by having a large bulb with a strong bulb lamella, irregular ribbing pattern, and a narrow columellar lamella. *P. parietalis* sp. n. and *P. truncata* sp. n. differ by possessing a parietalis.

### *Palaina glabella* sp. n.

<http://zoobank.org/586F4739-9E46-43B2-8C87-A9C23627D067>

Figs 101–103

**Type material.** Holotype MNHN IM-2000-27455, paratypes MNHN/174 IM-2000-27456, NMBE 516862/20. — Viti Levu, Nakorosule limestone outcrop, 30 m, degraded forest, -17.7734 178.2517, leg. Bouchet & Dayrat, 16.02.1999.

**Material.** ZMZ 526686a/9, Viti Levu, Tatatau, Graeffe 1872; Viti Levu, Saweni karst, 50–60 m, dry forest, -17.9032 177.7983, leg. Bouchet, 22.08.1998, MNHN/265, NMBE 516898/20; Viti Levu, Wailotua karst, 50–80 m, rainforest, -17.7582 178.4166, leg. Bouchet, 25–27.08.1998, MNHN/13, NMBE 516899/5; surroundings of Laselevu village, 80 m, rainforest, -17.7532 178.1416, leg. Bouchet, Warén & Dayrat, 14.02.1999, MNHN/8.

**Possible material.** Vanua Levu, surroundings of Waivunia village, 100 m, from washing of vegetation in spring/seeps at head of creek, -16.7866 179.4117, leg. Bouchet, 31.08.1998, MNHN/1. Voli Voli limestone outcrop, 10–30 m, secondary open forest, -17.3374 178.1831, leg. Bouchet, Warén & Dayrat, 18.02.1999, MNHN/1.

**Etymology.** Latin adjective *glabellus*, -a, -um = without hairs.

**Diagnosis.** Shell sinistral, medium sized, light brownish, teleoconch sculpture of widely spaced ribs, above the aperture, ribs weak or missing; columella only slightly reinforced.

**Description.** Shell sinistral, medium sized, broadly oval, light yellowish brownish; protoconch acute, granulated; last whorl not constricted, bulb of moderate size; teleoconch sculpture of widely spaced ribs, rib pattern constant throughout the whole shell; above the aperture, ribs becoming weak or are missing; last whorl slightly ascending; aperture circular, with a double lip, broadly adhered to the last whorl; umbilicus closed, periomphalum narrow; columella only slightly reinforced, bulb lamella weak.

Operculum flat, corneous, outer surface with thick concentric lamellae, inner surface smooth, concave, with a short apophysis, OD = 0.78.

**Measurements.** Holotype (Fig. 101): H = 3.48; D = 1.95; PH = 1.24; PD = 1.21; W = 6.



**Figures 101–103.** *Palaina glabella* sp. n. **101** Holotype MNHN 455, Nakorosule limestone outcrop, 30 m, H = 3.48 mm **102** paratype, last whorl opened to show internal lamellae (enlarged, not to scale) **103** operculum **103a** inner surface **103b** outer surface. Figure 101  $\times 10$ , Figure 103  $\times 40$  magnification.

**Distribution** (Fig. 170). Central to eastern area of Viti Levu. The specimens from Vanua Levu and Voli Voli (Viti Levu) are not fully characteristic and may belong to another yet undescribed species.

**Remarks.** *P. glabella* sp. n. is very close to *P. labeosa* sp. n. and *P. ascendens*, but the latter differ by their reinforced lip, subquadrate aperture and the dense ribbing pattern of the area above the aperture.

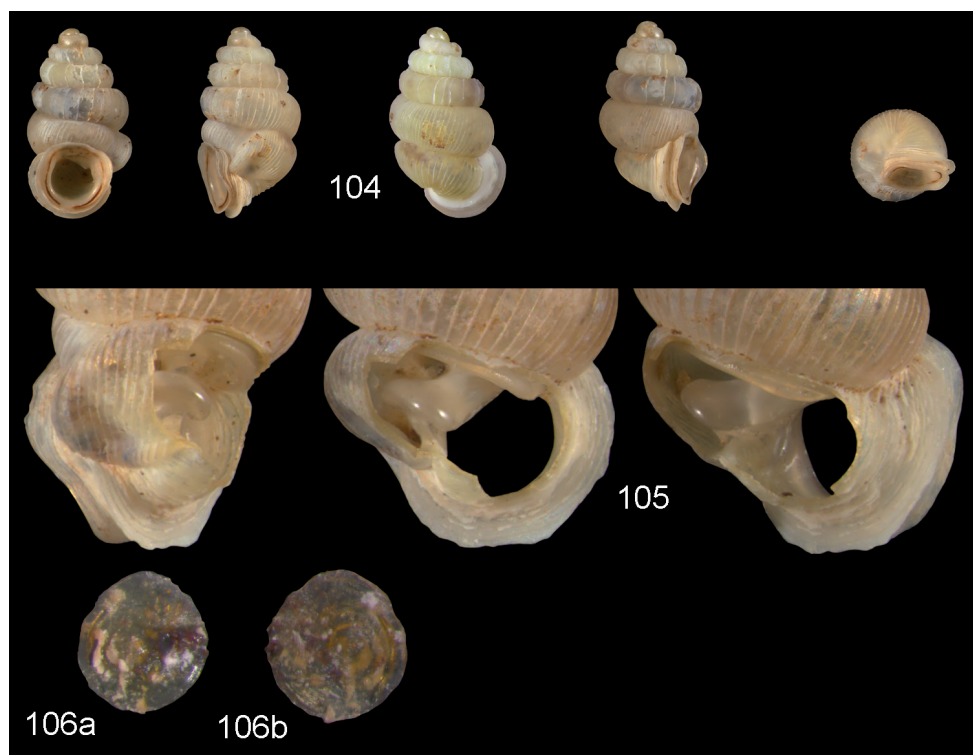
***Palaina kitteli* sp. n.**

<http://zoobank.org/931AC85A-38C7-4E1A-AF79-1C3EFB85EBE5>

Figs 104–106

**Type material.** Holotype MNHN IM-2000-27457, paratypes MNHN/169 IM-2000-27458, NMBE 516863/20. — Viti Levu, Wailotua karst, 50–80 m, rainforest, -17.7582 178.4166, leg. Bouchet, 25–27.08.1998.





**Figures 104–106.** *Palaina kitteli* sp. n. **104** Holotype MNHN 457, Viti Levu, Wailotua karst, H = 2.51 mm **105** paratype, last whorl opened to show internal lamellae (enlarged, not to scale) **106** operculum **106a** inner surface **106b** outer surface. Figure 104  $\times 10$ , Figure 106  $\times 40$  magnification.

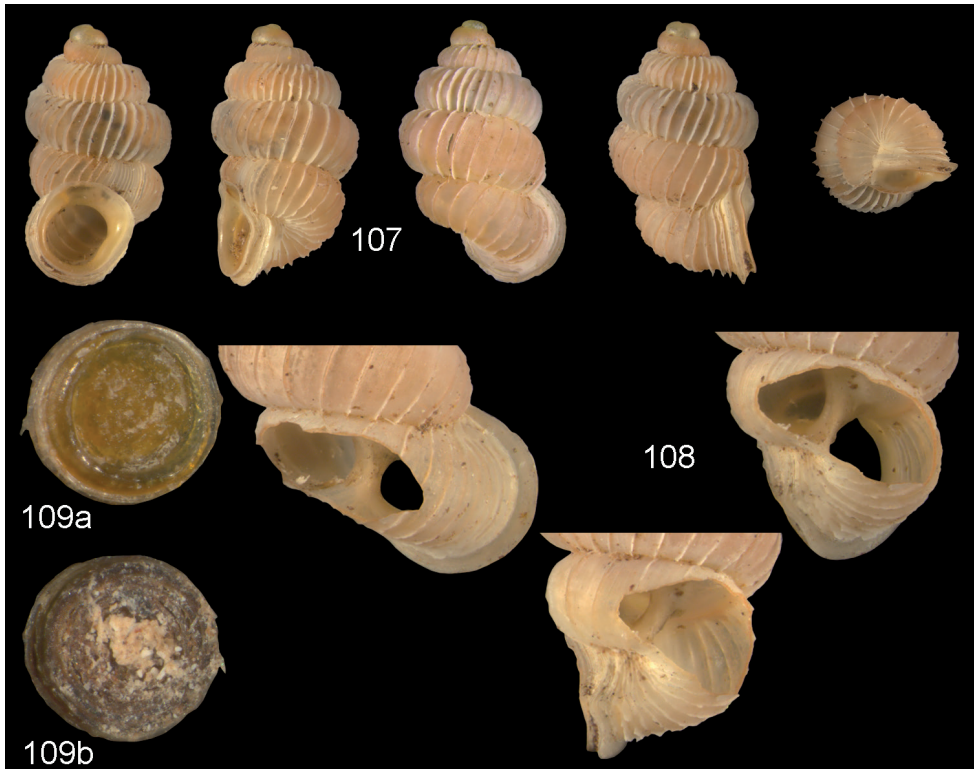
**Material.** Viti Levu, Waivisa karst, 50–80 m, rainforest, -17.6879 178.4033, leg. Bouchet, 27.08.1998, MNHN/77, NMBE 516900/15.

**Etymology.** This species is dedicated to Klaus Kittel, who sorted the micro land snails from the Fiji leaf litter, and recognized the extent of the diplommatinid radiation.

**Diagnosis.** Shell sinistral, small, yellowish, bulb laterally compressed, oblique to the shell's axis, columella obliquely twisted, with a basal lamellar callus.

**Description.** Shell sinistral, small, oval, whitish to yellowish; protoconch acute, granulated; last whorl not constricted, ascending; bulb well developed, laterally compressed, oblique to the shell's axis with a deep basal depression; suture very deep, whorls well rounded; umbilicus closed, periomphalum narrow; sculpture of teleoconch whorls with widely spaced ribs, ribbing pattern denser on the last 1.5 whorls; aperture circular, with a double lip, adhered to the last whorl, but parietal callus slightly detaching; oblique view into the aperture revealing a strong columellaris; internally, columella obliquely twisted, truncate in the lower half forming a basal lamellar callus, parietum with a very long parietalis in front of the bulb; a strong bulb lamella present.

Operculum corneous, flat, smooth, with a small apophysis, OD = 0.47.



**Figures 107–109.** *Palaina labeosa* sp. n. **107** Holotype MNHN IM-2000-27459, Viti Levu, Waivisa Karst, 50–80 m, H = 3.45 mm **108** paratype, last whorl opened to show internal lamellae (enlarged, not to scale) **109** operculum **109a** inner surface **109b** outer surface. Figure 107  $\times 10$ , Figure 109  $\times 40$  magnification.

**Measurements.** Holotype (Fig. 104): H = 2.51; D = 1.39; PH = 0.94; PD = 1.02; W = 6.5.

**Distribution** (Fig. 170). eastern area of Viti Levu.

**Remarks.** *P. kitteli* sp. n. is unique in having an almost lamellar bulb, which is well rounded in all other species, particularly in *P. tuberosissima*, which is otherwise very close in many other shell characters. The latter species differs by its spatulate parietalis, and its bifid columellaris.

***Palaina labeosa* sp. n.**

<http://zoobank.org/9230CA2E-3711-431C-8BB3-1365BB8D04FC>

Figs 107–109

**Type material.** Holotype MNHN IM-2000-27459, paratypes MNHN/16 IM-2000-27460, NMBE 516864/2. — Viti Levu, Waivisa karst, 50–80 m, rainforest, -17.6879 178.4033, leg. Bouchet, 27.08.1998.

**Material.** Viti Levu, surroundings of Laselevu village, 80 m, rainforest, -17.7532 178.1416, leg. Bouchet, Warén & Dayrat, 14.02.1999, MNHN/4.

**Etymology.** Latin adjective *labeosus*, -a, -um = with a thick lip.

**Diagnosis.** Shell sinistral, medium sized, brownish, whorls with moderately spaced ribs, ribbing pattern above the aperture much denser, aperture subquadrate, peristome reinforced by a strong labial callus, operculum with several concentric lamellae.

**Description.** Shell sinistral, medium sized, broadly oval, brownish to yellowish; protoconch acute, granulated; last whorl not constricted, slightly ascending; bulb well developed; umbilicus closed, periomphalum narrow; sculpture of teleoconch whorls with moderately spaced ribs, ribbing pattern above the aperture much denser; aperture subquadrate, double lipped, adhered to the last whorl; peristome reinforced by a strong labial callus; by oblique view into the aperture columellaris invisible; internally, columella only slightly reinforced; bulb demarcated by a faint bulb lamella.

Operculum corneous, outer surface with several concentric lamellae and a single, short raised lamella; internal surface concave, smooth, OD = 0.67.

**Measurements.** Holotype (Fig. 107): H = 3.45; D = 1.94; PH = 1.19; PD = 1.21; W = 5.5.

**Distribution** (Fig. 170). central and northeastern part of Viti Levu.

**Remarks.** For a differential diagnosis, refer to *P. glabella* sp. n. From the conchologically similar *P. ascendens*, *P. labeosa* sp. n. differs by possession of a bulb, and the columellar labrum, which is characterised by the presence of a tooth in *P. ascendens*.

### *Palaina parietalis* sp. n.

<http://zoobank.org/E1F87B79-DB75-43B7-AC59-528110A40CC9>

Figs 110–112

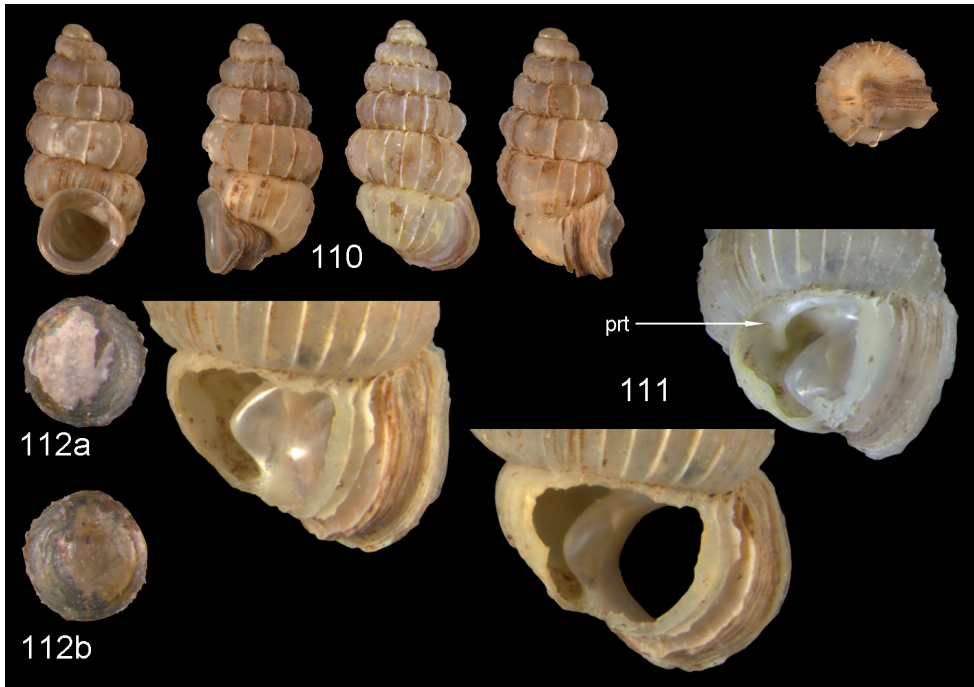
**Type material.** Holotype MNHN IM-2000-27461, paratypes MNHN/207 IM-2000-27462, NMBE 516865/20. — Viti Levu, Saweni karst, 50–60 m, dry forest, -17.9032 177.7983, leg. Bouchet, 22.08.1998.

**Material.** ZMZ 526683/4, Fiji, Viti Levu, Island of Nagara, ex Godeffroy 1882 [as *latecostata* Mousson].

**Etymology.** Latin adjective derived from the noun *paries* = wall.

**Diagnosis.** Shell sinistral, small, white, bulb reduced, teleoconch whorls with widely spaced ribs, columella twisted forming a triangular lamella, palatalis and an elongate parietalis present.

**Description.** Shell sinistral, small, elongate oval, white to faintly yellow; protoconch acute, granulated; last whorl not constricted, slightly ascending; bulb reduced, internally demarcated by a faint bulb lamella; umbilicus closed, periomphalum narrow; sculpture of teleoconch whorls with widely spaced ribs, ribbing pattern above the aperture somewhat denser; aperture suboblique, simple, adhered to the last whorl; by oblique view into the aperture columellaris almost invisible; internally, columella twisted, forming a broad triangular lamella, opposite with a perpendicular palatalis, parietum with an elongate parietalis.



**Figures 110–112.** *Palaina parietalis* sp. n. **110** Holotype MNHN 4 IM-2000-27461, Viti Levu, Saweni karst, 50–60 m, H = 3.3 mm **111** paratype, last whorl opened to show internal lamellae (enlarged, not to scale) **112** operculum **112a** inner surface **112b** outer surface. Figure 110  $\times 10$ , Figure 112  $\times 40$  magnification.

Operculum corneous, outer surface with several indistinct concentric lamellae and a single, short raised lamella; internal surface concave, smooth, OD = 0.55.

**Measurements.** Holotype (Fig. 110): H = 3.3; D = 1.63; PH = 1.16; PD = 1.18; W = 7.

**Distribution** (Fig. 170). beside the 19th century record, only known from the type locality.

**Remarks.** *P. parietalis* sp. n. is close to *P. subquadrata* sp. n. and *P. latecostata*, but has a strong parietalis and a palatalis, lacking in the latter two species, which can easily be seen by oblique view into the shell.

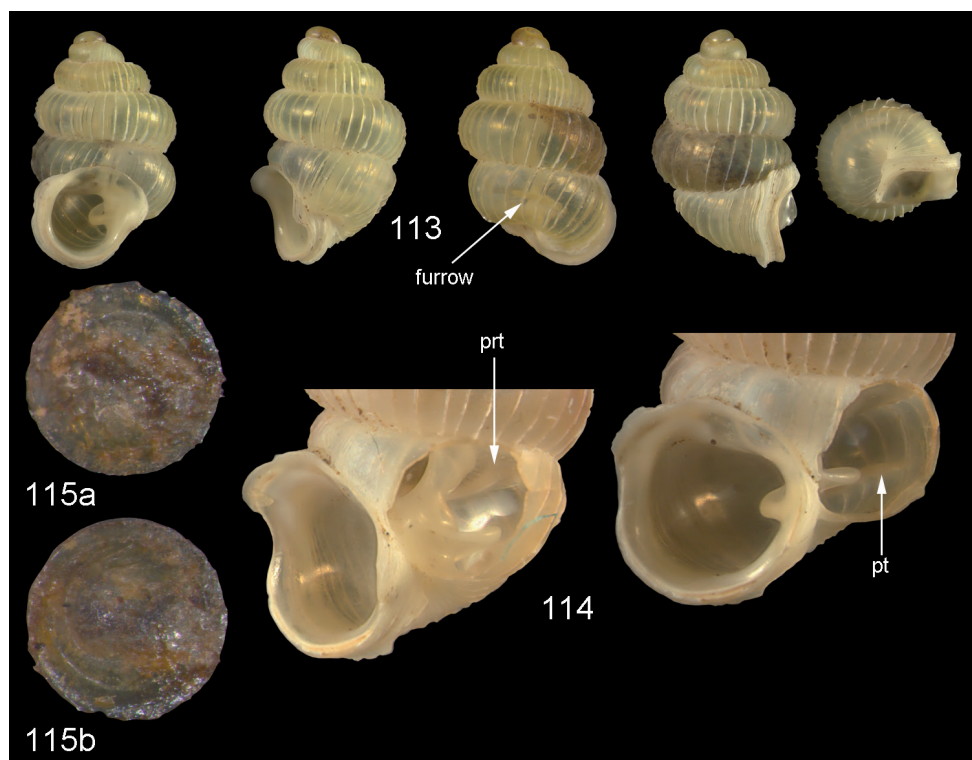
### *Palaina sulcata* sp. n.

<http://zoobank.org/6880C433-4964-4CF7-951F-513785C510D6>

Figs 113–115

**Type material.** Holotype MNHN IM-2000-27463, paratypes MNHN/31 IM-2000-27464, NMBE 516866/5. — Viti Levu, Wailotua karst, 50–80 m, rainforest, -17.7582 178.4166, leg. Bouchet, 25–27.08.1998.

**Material.** Viti Levu, Waivisa karst, 50–80 m, rainforest, -17.6879 178.4033, leg. Bouchet, 27.08.1998, MNHN/21, NMBE 516901/3; Viti Levu, Wailotua karst,



**Figures 113–115.** *Palaina sulcata* sp. n. **113** Holotype MNHN IM-2000-27463, Viti Levu, Wailotua karst, 50–80 m, H = 3.13 mm **114** paratype, last whorl opened to show internal lamellae (enlarged, not to scale. **115** operculum **115a** inner surface **115b** outer surface. Figure 113  $\times 10$ , Figure 115  $\times 40$  magnification.

near summit Uluitova, 370–390 m, rainforest, -17.7582 178.4166, leg. Bouchet, 28.08.1998, MNHN/1.

**Etymology.** Latin adjective *sulcatus*, -a, -um = with a furrow.

**Diagnosis.** Shell sinistral, small broadly oval, yellow to greenish, bulb reduced, aperture with a large horizontal columellaris, a strong palatalis corresponding to a deep furrow on the dorsal side of the last whorl, elongated parietalis present.

**Description.** Shell sinistral, small to medium sized, broadly oval, faintly yellow to greenish; protoconch acute, granulated; last whorl not constricted, ascending; bulb reduced; umbilicus closed, periomphalum narrow; sculpture of teleoconch whorls with widely spaced ribs, area above the aperture almost smooth; aperture subquadrate, with a double lip, and two ear-like processes on the upper edges of the peristome; adhered to the last whorl; aperture with a large horizontal columellaris in a central position; internally, columellaris forming a large horizontal lamella of approximately one whorl, slightly bent upwards towards its end; opposite a strong palatalis corresponding to a deep furrow on the dorsal side of the last whorl; an elongated parietalis and a faint bulb lamella present.

Operculum corneous, outer surface with indistinct concentric lamellae and a single, short raised lamella; internal surface concave, smooth, OD = 0.66.



**Measurements.** Holotype (Fig. 113): H = 3.13; D = 1.92; PH = 1.31; PD = 1.38; W = 5.

**Distribution** (Fig. 170). Eastern Viti Levu.

**Remarks.** *P. sulcata* sp. n. is unmistakable for its columellaris, which is unique among all Fiji diplommatinids, because it is formed like a classical columellaris, i.e. a horizontal lamella running into the interior of the shell twisting around the columella. The columella itself is not transformed. Another unique feature is the strong palatalis with the corresponding furrow in the last whorl.

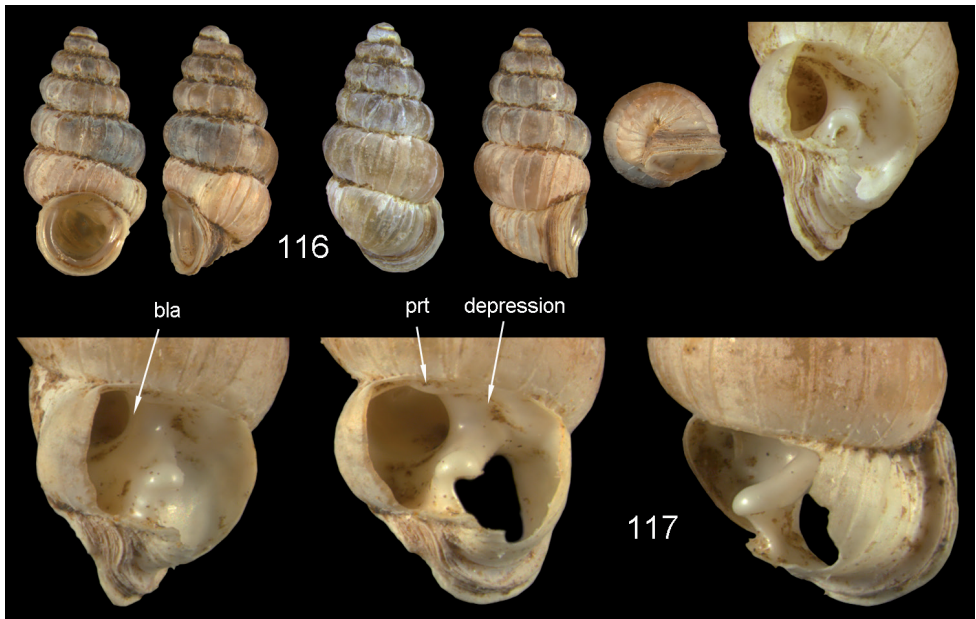
*P. sulcata* sp. n. is provisionally placed in *Palaina*, because there is no bulb formation in *Diancta*, but a constriction of the last whorl, and the columella is usually transformed to form a columellar plate, not present here in *P. sulcata*.

***Palaina truncata* sp. n.**

<http://zoobank.org/650F5A65-A767-4ABF-81A4-19453A75463E>

Figs 116–117

**Type material.** Holotype MNHN IM-2000-27465, paratypes MNHN/4 IM-2000-27466. — Viti Levu, surroundings of Nandele village, 50 m, secondary agroforest with *Albizia* and coffee shrubs, -17.7083 177.5249, leg. Bouchet, Warén & Dayrat, 17.03.1999.



**Figures 116–117.** *Palaina truncata* sp. n. **116** Holotype MNHN IM-2000-27465, Viti Levu, surroundings of Nandele village, H = 3.29 mm **117** paratype, last whorl opened to show internal lamellae (enlarged, not to scale). Figure 116  $\times 10$  magnification.

**Etymology.** Latin adjective, past participle of verb *truncare* = to truncate.

**Diagnosis.** Shell sinistral, small, bulb well developed with strong bulb lamella, columella obliquely twisted, truncate, basal tooth-like callus, one parietalis

**Description.** Shell sinistral, small, oval, whitish to greyish; protoconch acute granulated; last whorl not constricted, slightly ascending; bulb well developed; umbilicus closed, periomphalum narrow; sculpture of teleoconch whorls with widely spaced ribs; aperture circular, simple, adhered to the last whorl; oblique view into the aperture revealing a strong columellaris; internally, columella obliquely twisted, truncate in the lower third with a basal tooth-like callus, parietum with a small parietalis in front of the bulb and a parietal furrow or depression next to the columella; a strong bulb lamella present.

Operculum unknown.

**Measurements.** Holotype (Fig. 116): H = 3.29; D = 1.63; PH = 1.12; PD = 1.23; W = 6.5.

**Distribution** (Fig. 170). Only known from the type locality.

**Remarks.** *P. truncata* sp. n. is close to *P. tuberosissima* sp. n., but this species has a large parietalis, a lamella in the bulb, and a deep palatalis. It is also similar to *P. subregularis*, but differs from it in having the twisted columella, a parietalis and a bulb.

***Palaina tuberosissima* sp. n.**

<http://zoobank.org/4110D702-10BD-43BB-9BF1-9EF242E20C10>

Figs 118–120

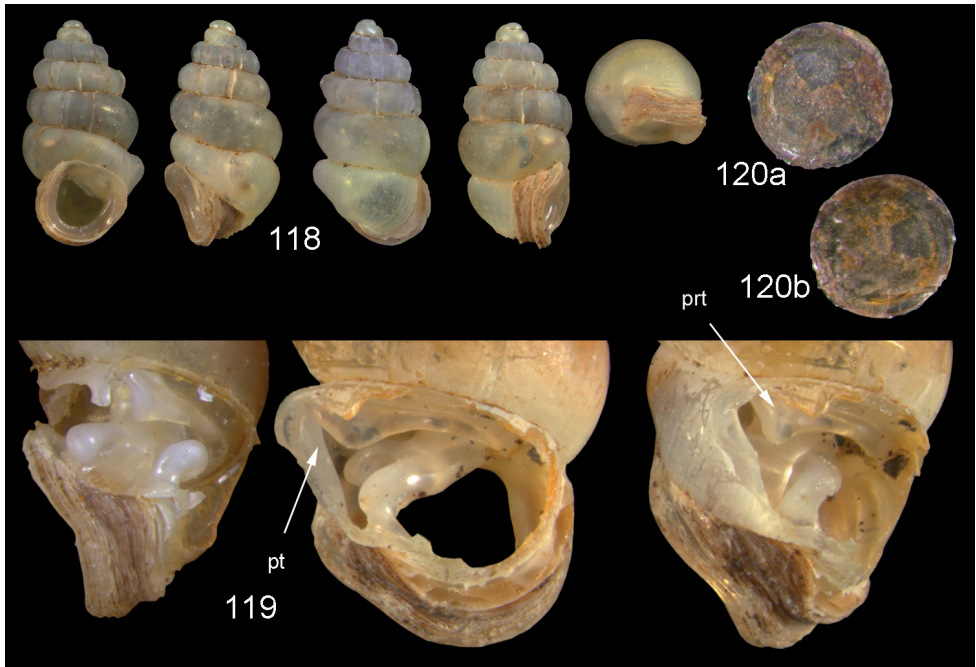
**Type material.** Holotype MNHN IM-2000-27467, paratypes MNHN/183 IM-2000-27468, NMBE 516867/20. — Viti Levu, limestone outcrop SE of Nambukulevu, 230 m, rainforest, -18.1366 177.8149, leg. Bouchet, Warén & Dayrat, 20.02.1999.

**Material.** Viti Levu, Saweni karst, 50–60 m, dry forest, -17.9032 177.7983, leg. Bouchet, 22.08.1998, MNHN/1; Viti Levu, Tuvu karst, 50 m, dry forest, -17.9332 177.7067, leg. Bouchet, 23.08.1998, MNHN/2.

**Etymology.** Adjective, derived from Latin *tuber* = swelling, and suffix *-issimus*, *-a*, *-um* = very.

**Diagnosis.** Shell sinistral, small, faint yellowish, bulb well developed, whorls with widely spaced ribs, peristome with labial callus, columella obliquely twisted with a second columellaris beyond the bulb, a very long spatulate parietalis and a strong palatalis inside the bulb.

**Description.** Shell sinistral, small, broadly oval, faint yellowish; protoconch acute, granulated; last whorl not constricted, slightly ascending; bulb well developed; umbilicus closed, periomphalum narrow; sculpture of teleoconch whorls with widely spaced ribs, area above the aperture almost smooth; aperture circular, simple, adhered to the last whorl; peristome reinforced by a strong labial callus, and two ear-like processes on the upper edges of the peristome; by oblique view into the aperture columellaris visible; internally, columella obliquely twisted and reinforced, truncate in the lower half



**Figures 118–120.** *Palaina tuberosissima* sp. n. **118** Holotype MNHN IM-2000-27467, Viti Levu, limestone outcrop SE of Nambukulevu, 230 m, H = 2.97 mm **119** paratype, last whorl opened to show internal lamellae (enlarged, not to scale) **120** operculum **120a** inner surface **120b** outer surface. Figure 118  $\times 10$ , Figure 120  $\times 40$  magnification.

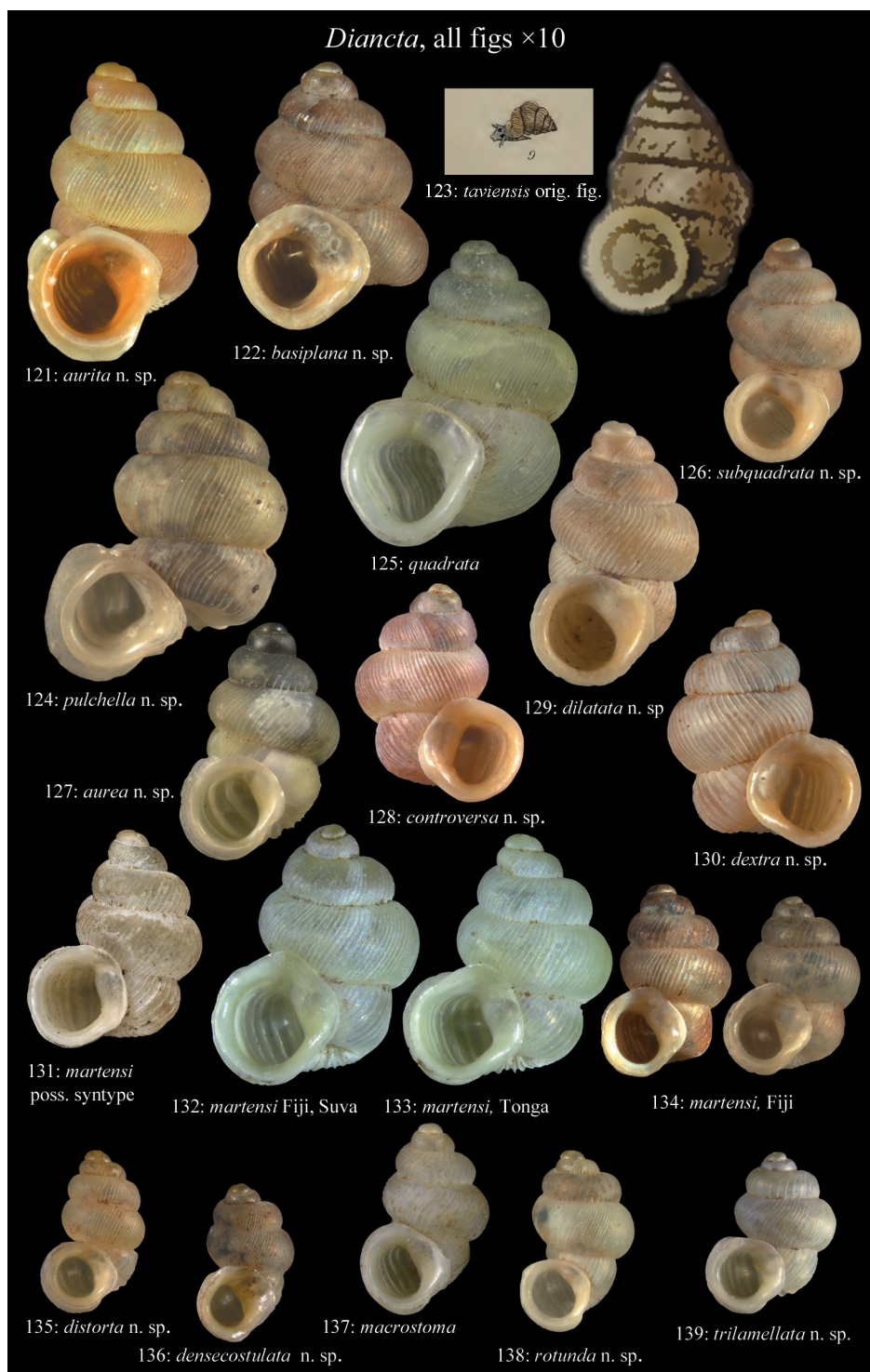
forming a basal knob-like tooth, and a second columellaris beyond the bulb; parietum with a very long spatulate parietalis in front of the bulb; a strong palatalis inside the bulb present.

Operculum corneous, outer surface with several concentric lamellae and a single, short raised lamella; internal surface concave, smooth, OD = 0.67.

**Measurements.** holotype (Fig. 118): H = 2.97; D = 1.61; PH = 1.12; PD = 1.21; W = 6.

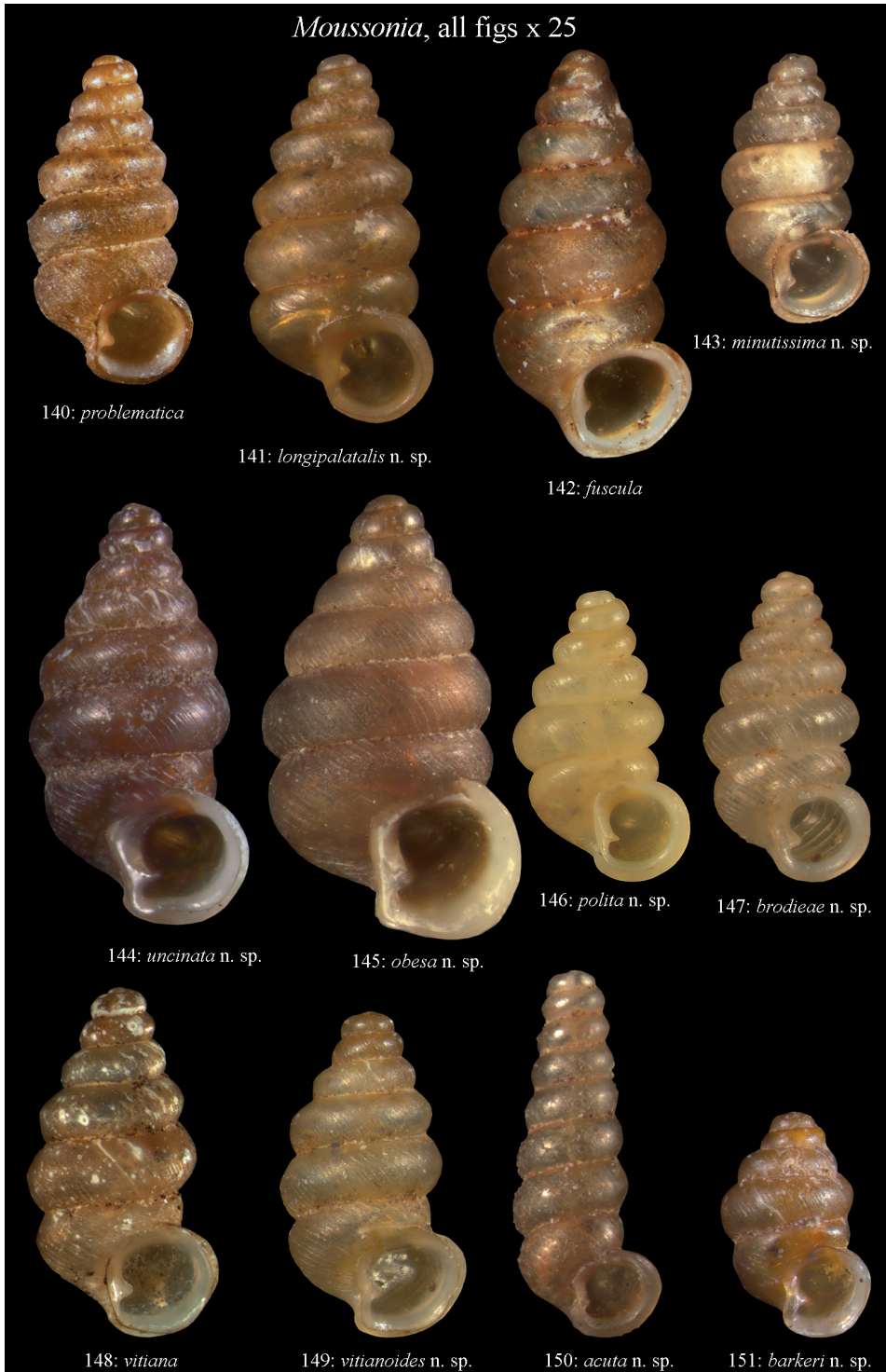
**Distribution** (Fig. 170). Central Viti Levu.

**Remarks.** *P. tuberosissima* sp. n. is close to *P. tuberosa*, which differs by having a dense ribbing pattern on the area above the aperture. Possession of a second columellaris makes this species unique, as there is no other diplommatinid species on Fiji with this character.



**Figures 121–139.** Synoptic view of the *Diancta* species of Fiji.



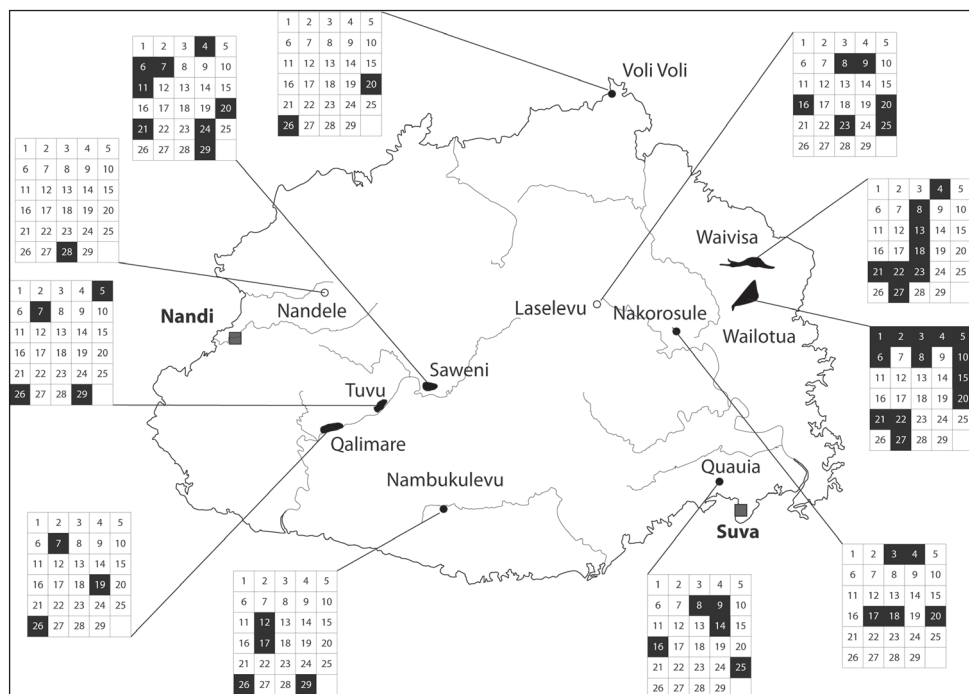


**Figures 140–151.** Synoptic view of the *Moussonia* species of Fiji.





**Figures 152–169.** Synoptic view of the *Palaina* species of Fiji.



**Figure 170.** Species diversity of Diplommatinidae on Viti Levu. **1** *Diancta aurea* sp. n. **2** *Diancta aurita* sp. n. **3** *Diancta basiplanata* sp. n. **4** *Diancta controversa* sp. n. **5** *Diancta densecostulata* sp. n. **6** *Diancta dextra* sp. n. **7** *Diancta dilatata* sp. n. **8** *Diancta distorta* sp. n. **9** *Diancta martensi* (H. Adams, 1866), comb. n. **10** *Diancta pulchella* sp. n. **11** *Diancta rotunda* sp. n. **12** *Diancta subquadrata* sp. n. **13** *Diancta trilamelata* sp. n. **14** *Moussonia barkeri* sp. n. **15** *Moussonia obesa* sp. n. **16** *Moussonia uncinata* sp. n. **17** *Moussonia vitiana* (Mousson, 1870) **18** *Moussonia vitianoides* sp. n. **19** *Palaina flammulata* sp. n. **20** *Palaina glabella* sp. n. **21** *Palaina godeffroyana* (Mousson, 1870) **22** *Palaina kitteli* sp. n. **23** *Palaina labeosa* sp. n. **24** *Palaina parietalis* sp. n. **25** *Palaina pomatiaeformis* (Mousson, 1870) **26** *Palaina subregularis* (Mousson, 1870) **27** *Palaina sulcata* sp. n. **28** *Palaina truncata* sp. n. **29** *Palaina tuberosissima* sp. n.

## Doubtful species

### *Diplommatina paradoxa* Crosse, 1867

1867 *Diplommatina paradoxa* Crosse, Journal de Conchyliologie, 15: 449 [in Oceania?].  
 1902 *Palaina* (*Palaina*) *paradoxa*, – Kobelt, Cyclophoridae: 400 [as a synonym of *martensi*].

**Type material.** No type specimens in MNHN, probably lost.

**Original description.** “T. sinistrorsa, subrimata, irregulariter ovato-conica, pellucida, tenuissime et oblique striatula, pallide luteocornea; spira oblongo-conica, apice obtusulo; sutura impressa; anfr. 5 1/2 convexi, subglobosi, embryonales 1 1/2 laeves, antepenultimus et penultimus inflati, ultimus angustior, devius, usque ad antepenul-

timum ascendens, et penultimi partem obtegens, valide costulato-striatus; apertura fere verticalis, rotundata, intus nitidula; perist. continuum, plica parietali (in adultis speciminibus) munitum, subduplicato-expansum, reflexum citrino-luteum.— Long. 3, diam. maj. 1 1/2 mill. Apert. diam. 1 mill.”.

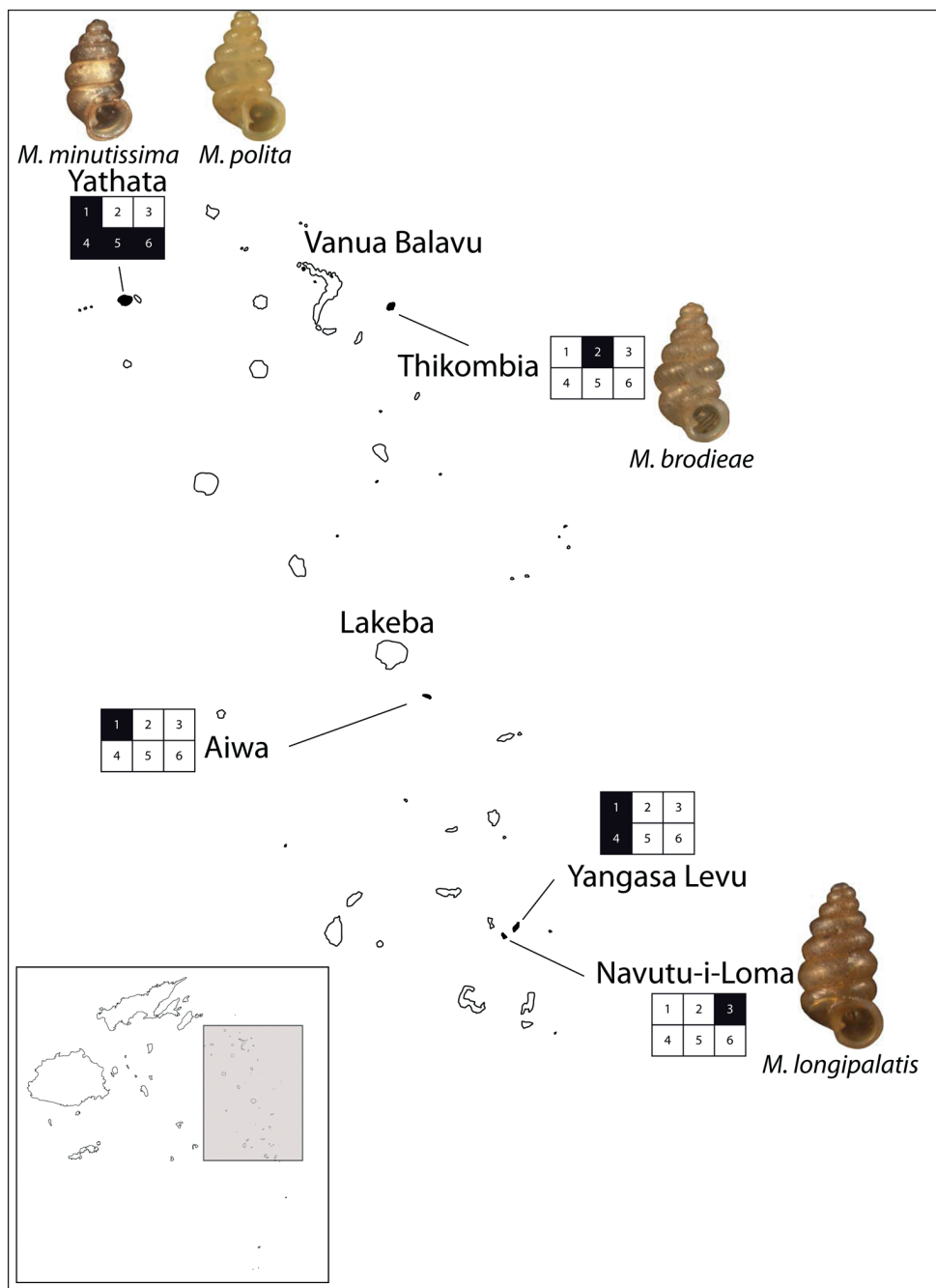
**Remarks.** It is not clear whether *Diplommatina paradoxa* originates from Fiji or somewhere else. Due to the absence of type material and the imprecise original description, the correct identification is impossible.

## Discussion

### Biodiversity

Twelve species of Diplommatinidae were historically known from Fiji, and an additional one (*Palaina alberti* sp. n.) is described here based on historical material. Of these thirteen species, six are present in the material collected in 1998–99 that forms the basis of the present paper, and seven have not been re-collected: one (*Diancta taviensis*) from Taveuni and one (*D. macrostoma*) from Ovalau, two islands that have not been surveyed for land snails since the 19th century; and five species are from Viti Levu (*D. quadrata*, *Palaina ascendens*, *P. latecostata*, *P. alberti*, *P. tuberosa*). It is difficult to speculate on whether the cause for not re-collecting them is environmental change — and thus perhaps extinction — or micro-endemism within Viti Levu. The localities for these species are either vague (“Viti Levu”) or use 19th century place names (“Tatatan” or “Tatatau”, “Vaini-Loba”) that cannot be recognized in modern usage. In the 1860–1870s when Graeffe collected in Fiji, access to the interior of Viti Levu was difficult and it is probable that much of his collecting was done near the coast. During the 1998–99 field work, emphasis was placed on the limestone outcrops, and coastal localities were generally avoided precisely because the habitats there are more degraded than in the interior and especially on limestone. The lack of documentation of these five species in 1998–99 does not imply, in our opinion, that they are extinct, or even threatened. Such a statement would require a much more thorough survey.

The 1998–99 field work documented 35 diplommatinid species — six already known and 29 new. Six species (all in *Moussonia*) were recorded from the Lau Islands, and 29 from Viti Levu, with no overlap between the two guilds. Very limited collecting was done on Vanua Levu, and a single diplommatinid (also occurring on Viti Levu) was found. There are two main karst areas in Viti Levu: a group in the north-east drained by the Wainimbuka river (Wailotua, Wainivesi and Nakorosule karsts), and a group in the center drained by the Sigatoka river (Qalimare, Saweni, Tuvu and Toga karsts). The Wailotua karst is the largest limestone area in Viti Levu. It extends for approximately 4 km along the Wailotua creek, a tributary of the Wainimbuka river, and reaches 425 m on Uluitova Peak. The Nakorosule limestone crops out on the eastern side of the Wainimala river and extends for nearly 2 km. Smaller limestone outcrops are situated in the southwest between Sigatoka and Natadola (Voli Voli), near Suva



**Figure 171.** Species diversity of Diplommatinidae on the Lau Islands. *Moussonia fuscula* (Mousson, 1870) **2** *Moussonia brodieae* sp. n. **3** *Moussonia longipalatalis* sp. n. **4** *Moussonia acuta* sp. n. **5** *Moussonia minutissima* sp. n. **6** *Moussonia polita* sp. n. **7** *Moussonia vitiana* (Mousson, 1870).

(Qauia), and near Nabukulevu. There is apparently very little limestone in western and northern Viti Levu, and no sample was taken in that part of the island (Fig. 170).

In the Lau Islands, five islands were visited, with numbers of species on each ranging from one (Evuevu, Thikombia, Navutu-i-Loma) or two (Aiwa, Yagasa Levu) to four (Yacata). Four species are known from single islands (*M. brodieae* on Thikombia, *M. longipalatalis* on Navutu-i-Loma, and *M. minutissima* and *M. polita* both on Yacata), one was found on two islands (*M. acuta* on Yacata and Yagasa Levu), and one (*M. fuscula*) on three, with literature records from a further three. Given the patchiness of our sampling in the Lau Islands (the group consists of some 60 islands), there is no basis to suggest that the species recorded from only one island are single-island endemics. However, it is certain that all — except *Moussonia vitiana* (which also occurs on Viti Levu) — are Lau Islands endemics, and probable that many are indeed restricted to discrete island groups within the Lau Islands (Fig. 171).

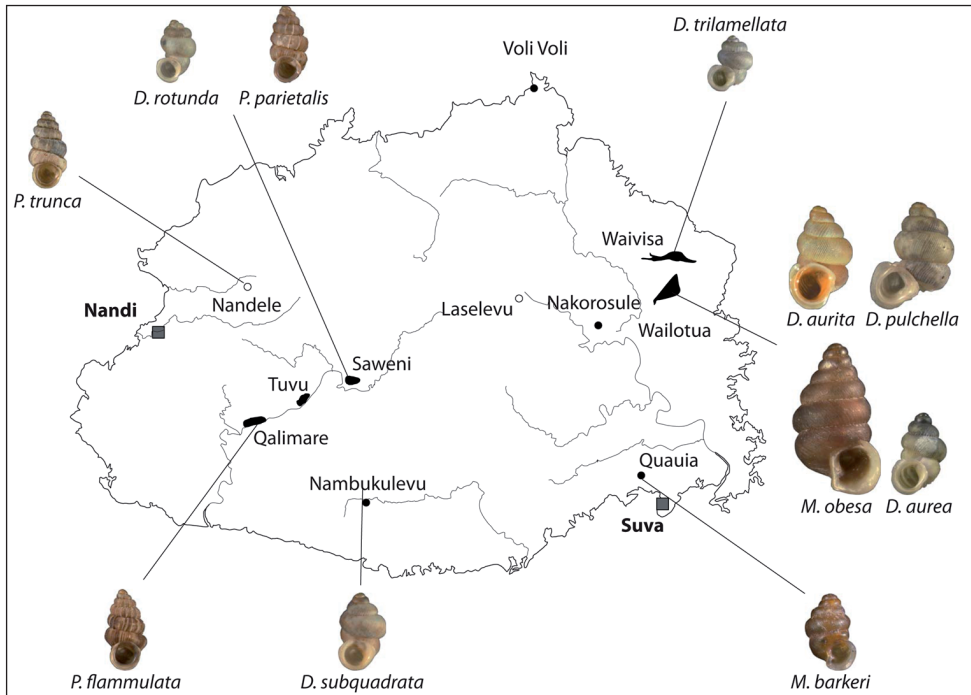
In Viti Levu, 12 localities were surveyed, each with 1 to 13, with an average of 5, species of Diplommatinidae. Ten species were found at only one site: *Diancta aurea*, *D. aurita*, *D. pulchella* and *Moussonia obesa* (Wailotua), *D. rotunda* and *Palaina parietalis* (Saweni), *D. trilamellata* (Waivisa), *D. subquadrata* (Nambukulevu), *M. barkeri* (Qauia), *P. flammulata* (Qalimare) and *P. truncata* (Nandele). Most species were found in 2–3 localities only, with a maximum of six.

The number of historically known species not re-collected in 1998–99 (7 species), the number of single-site occurrences (14 species), and the numerous islands — including limestone islands — that have not been surveyed at all, all indicate that the 42 species of Diplommatinidae currently known from Fiji represent perhaps only half of the Fiji diplommatinid fauna (Fig. 172). Such numbers approach the famous diplommatinid diversity of Palau (39 described and more than 60 undescribed species — Rundell 2008, 2010; Yamazaki et al. 2013), and surpasses by far the diversity of other South Pacific archipelagos of comparable land area: New Caledonia, 11 species (Tillier 1981), Vanuatu, 2 species (Solem 1959), Samoa, 1 species (Cowie 1998). Lord Howe and Norfolk, both considerably smaller, have 7 and 2 species respectively (Stanisic et al. 2010). While some of these figures probably reflect biogeographic differences, others may, however, merely reflect the lack of focused diplommatinid collecting effort.

### Sexual dimorphism

Like all other caenogastropod land snails, diplommatinids have separate sexes, and it is important not to mistake sexually dimorphic individuals as separate species. Sexual dimorphism has been reported in Cochlostomatidae, the sister group of Diplommatinidae from Europe (Raven 1990; Gofas 2001; Reichenbach et al. 2012). It mainly concerns shell size and shell shape, while other shell traits like ribbing pattern and colour variation do not show significant variation between males and females. On average, females have larger shells than males, which may be correlated with reproductive organs differing in volume between males and females — those of the latter being





**Figure 172.** Single site endemics on Viti Levu.

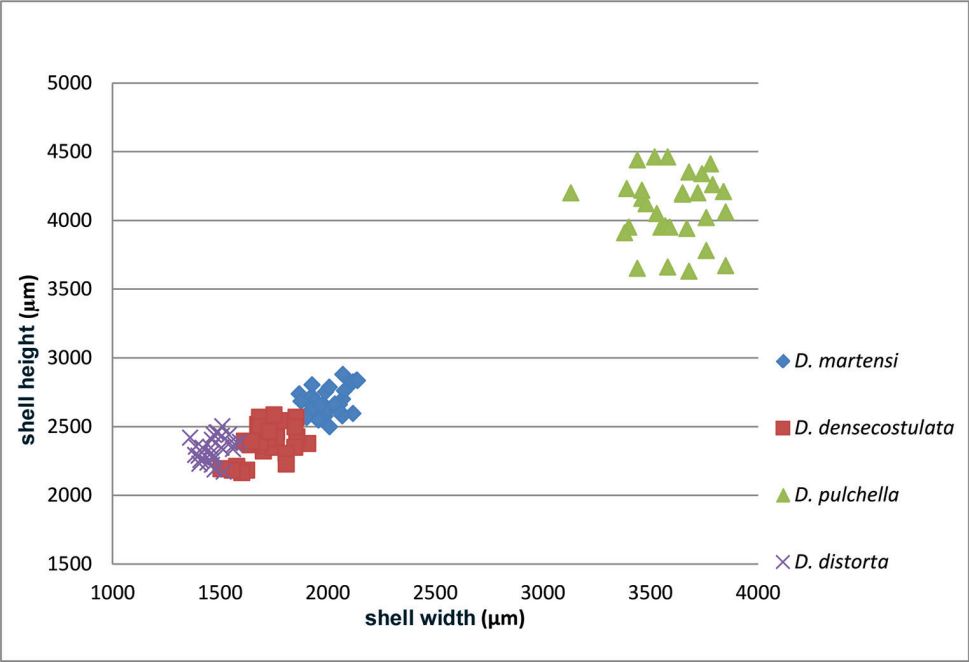
considerably larger, especially when eggs are present in the uterus. These differences are obvious enough that, based on shells alone, a trained person can sex cochlostomatid individuals with an accuracy of 90% (Reichenbach et al. 2012).

This problem has not been sufficiently addressed in Diplommatinidae. Solem (1959: 192) claimed to have observed sexual dimorphism in *Palaina* from Santo (Vanuatu), but this observation was based on two “sculptural types of shells”, and not on preserved animals that could be sexed. Based on the present material from Fiji, sculpture alone is an insufficient guide to species identification, and even more so for recognition of sexes. Solem’s hypothesis was repeated by Fontaine et al. (2011: 173, figs 198C, 198D), but again the specimens were not sexed, and thus there is no evidence that Solem’s speculation was correct. In the present study, as only dried specimens were available, the animals could not be sexed. However, we could not observe any size differences among shells of a given population, although it should be stressed that diplommatinids are so small that differences in the range of 100–500  $\mu\text{m}$  are not immediately discernible. For this reason, we measured shell height and shell diameter of four sympatric species from the Wailotua karst, *D. martensi*, *D. densecostulata*, *D. pulchella* and *D. distorta*. Thirty specimens of each species were randomly selected and shell measurements were taken using an optical measuring tool. In all species, there is some variation, with the standard deviation on average being approximately 10%. All species exhibited a single cloud of points with no clear dimorphism in size or shape (Fig. 173, Table 2). There is little morphological

**Table 2.** Dimensions of four species of *Diancta* from the Wailotua karst, all values in  $\mu\text{m}$ .

	<i>D. martensi</i>		<i>D. densecostulata</i>		<i>D. pulchella</i>		<i>D. distorta</i>	
	Height	Width	Height	Width	Height	Width	Height	Width
	2878.73	2070.27	2375.61	1907.47	4200	3720	2292.28	1384.91
	2673.1	1916.47	2568.11	1853.18	4160	3460	2228.58	1404.29
	2839.35	2135.73	2384.36	1683.52	4460	3520	2274.83	1478.21
	2498.11	2008.65	2323.11	1701.51	3630	3680	2344.69	1419.58
	2721.23	1925.92	2358.11	1708.54	4200	3650	2419.43	1361.56
	2751.85	1990.59	2449.98	1748.77	3950	3550	2379.73	1544.83
	2686.23	1941.27	2515.61	1675.26	4440	3440	2440.75	1541.7
	2563.73	1862.56	2423.73	1857.16	3670	3850	2458.21	1488.89
	2664.35	1978.23	2498.11	1848.76	4210	3840	2370.89	1568.19
	2699.35	2070.06	2349.36	1749.17	3650	3440	2344.69	1506.65
	2594.36	2117.23	2393.11	1613.34	4190	3650	2314.49	1414.01
	2761.69	2078.74	2463.11	1762.46	3780	3760	2286.89	1401.27
	2824.49	2117.43	2419.36	1761.53	4350	3680	2257.37	1409.78
	2624.98	1964.34	2568.11	1684.01	4060	3850	2301.03	1456.66
	2738.73	1868.09	2349.36	1846.54	4340	3740	2404.04	1462.58
	2602.42	2060.59	2410.61	1723.56	3660	3580	2186.04	1474.33
	2629.6	1929.27	2541.86	1776.05	4120	3480	2171.03	1516.64
	2576.86	1989.79	2209.36	1577.62	3940	3670	2432.02	1508.25
	2804.35	1928.04	2498.11	1684.35	3960	3570	2290.4	1470.76
	2566.7	1903.09	2305.61	1806.84	3950	3400	2222.44	1462.78
	2624.65	2002.04	2366.86	1640.6	4230	3390	2501.88	1511.18
	2786.85	2008.09	2183.11	1623.1	4020	3760	2353.42	1388.46
	2684.42	1876.84	2165.61	1601.22	4200	3130	2345.22	1457.88
	2576.86	2068.65	2585.61	1750.05	4050	3530	2236.85	1441.45
	2659.98	2054.55	2226.86	1806.91	3910	3380	2274.83	1462.17
	2620.61	2047.39	2183.11	1556.7	4260	3790	2388.35	1592.72
	2834.98	2138.8	2191.86	1504.97	3950	3590	2456.33	1483.74
	2664.35	2033.9	2384.36	1688.06	4410	3780	2335.96	1559.71
	2655.6	1964.34	2463.11	1728.1	4460	3580	2344.69	1505.81
	2546.23	1956.74	2393.11	1644.94	4220	3460	2440.75	1471.42
Mean	2678.49	2000.25	2384.94	1717.14	4087.66	3597.33	2336.6	1471.68
St. deviation	98.20	80.55	121.92	97.52	246.43	169.43	85.47	57.92
Min	2498.11	1862.56	2165.61	1504.97	3630	3130	2171.03	1361.56
Max	2878.73	2138.8	2585.61	1907.47	4460	3850	2501.88	1592.72

overlap between the species, although if the other nine species known from Wailotua were included, this picture may become more complex. Nonetheless, major differences in shell morphology — like presence and absence of a palatal or parietal lamella — confirm that different species, and not different sexes of the same species, are involved. Likewise, Yamazaki et al. (2013) found that differences in shell characters of Palau diplommatinids reflected differences among species and/or subspecies and not sexual dimorphism.



**Figure 173.** Diagram showing the shell height/width ratio of four species of *Diancta*.

**Key to the genera and species of Diplommatinidae from Fiji**

This key is based on adult specimens with fully developed apertural characteristics. To facilitate recognition, an overview plate with a frontal view of the species is given for each of the three genera. However, to ensure a reliable identification, shells of a few specimens should be opened to check the internal lamellar system.

**Key to genera**

- 1 Shells dextral with a columellaris visible in the aperture ...*Moussonia*, Key II
- 1' Shells different ..... **2**
- 2 Shells with a constricted last whorl, aperture shifted to the left or right from columellar axis ..... *Diancta*, Key I
- 2' Shells with normally sized last whorl, aperture rather central on shell axis.....  
..... *Palaina*, Key III

**Key I: species of *Diancta* (excluding *D. taviensis*), Figs 121–139**

- 1 shell dextral..... **2**
- 1' shell sinistral ..... **3**
- 2 penultimate whorl densely ribbed, palatalis present..... *Diancta controversa*

2'	penultimate whorl coarsely ribbed, palatalis missing .....	<i>Diancta dextra</i>
3	columella broadened to form a columellar plate .....	5
3'	columella different .....	4
4	columella simple .....	<i>Diancta rotunda</i>
4'	columella a twisted tooth .....	<i>Diancta basiplana</i>
5	aperture subtriangular, last whorl with shallow furrow ....	<i>Diancta quadrata</i>
5'	aperture different, last whorl always rounded .....	6
6	a palatal lamella present .....	7
6'	a palatal lamella absent.....	11
7	aperture subquadrate, peristome adhered to penultimate whorl .....	8
8	columellar plate simple, parietalis absent.....	<i>Diancta martensi</i>
8'	columellar plate bipartite, parietalis present .....	<i>Diancta densecostulata</i>
7'	aperture rounded, peristome not attached to penultimate whorl .....	9
9	columellar plate broad, parietalis present.....	<i>Diancta trilamellata</i>
9'	columella narrow, parietalis absent.....	10
10	shell small with a strong constriction .....	<i>Diancta distorta</i>
10'	shell large, constriction inconspicuous .....	<i>Diancta dilatata</i>
11	shell < 3 mm shell length .....	<i>Diancta macrostoma</i>
11'	shell > 3 mm shell length .....	12
12	aperture subquadrate, shifted to the left of shell's axis, large periomphalum ....	
	.....	<i>Diancta pulchella</i>
12'	aperture rounded, almost in central position, narrow periomphalum .....	13
13	peristome doubled with an ear-like process above aperture...	<i>Diancta aurita</i>
13'	peristome simple.....	14
14	neck of last whorl with a few heavy ribs .....	<i>Diancta aurea</i>
14'	neck of last whorl with fine ribs .....	<i>Diancta subquadrata</i>

## Key II: species of *Moussonia*, Figs 140–151

1	Palatalis missing, shell very narrow.....	<i>Moussonia acuta</i>
1'	Palatalis present, shell elongate-oval .....	2
2	A single palatalis situated above aperture.....	4
2'	A vertical palatalis present, situated behind aperture .....	3
3	Two palatal lamellae present (horizontal and vertical), shell small, yellowish ....	
	.....	<i>Moussonia vitianoides</i>
3'	One vertical palatalis present, shell large, red-brown ....	<i>Moussonia uncinata</i>
4	Palatalis an elongate lamella .....	5
4'	Palatalis short, tooth-like.....	8
5	Shell almost smooth, with faint axial threads (if at all) .....	6
5'	Shell with clearly visible axial threads.....	7
6	Last whorl conspicuously narrower than penultimate whorl, shell yellowish ....	
	.....	<i>Moussonia polita</i>
6'	Shell with regularly increasing whorls, shell brown....	<i>Moussonia longipalatalis</i>

7	Shell elongate, cylindrical .....	<i>Moussonia vitiana</i>
7'	Shell broad, stout, very small .....	<i>Moussonia barkeri</i>
8	Shell coarsely ribbed .....	<i>Moussonia brodieae</i>
8'	Shell with axial threads only .....	9
9	Shell < 2 mm height .....	<i>Moussonia minutissima</i>
9'	Shell > 2 mm height .....	10
10	Shell slender, aperture circular .....	<i>Moussonia fuscula</i>
10'	Shell broad, aperture quadrate .....	<i>Moussonia obesa</i>

### Key III: species of *Palaina*, Figs 152–169

1	shell right coiling .....	<i>Palaina alberti</i>
1'	shell left coiling .....	2
2	peristome with a columellar denticle .....	<i>Palaina ascendens</i>
2'	peristome without columellar denticle .....	3
3	species with a twisted columella .....	4
3'	species with a differing type of columella .....	6
4	parietalis missing .....	<i>Palaina latecostata</i>
4'	parietalis present .....	5
5	parietalis short .....	<i>Palaina truncata</i>
5'	parietalis very long .....	<i>Palaina tuberosissima</i>
6	columellaris a horizontal lamella visible in the aperture .....	<i>Palaina sulcata</i>
6'	columellaris not visible at all .....	7
7	columellaris a broad lamella .....	<i>Palaina kitteli</i>
7'	columellaris different .....	8
8	columellaris a bi-lobed tooth .....	<i>Palaina tuberosa</i>
8'	columellaris different .....	9
9	columella oblique with basal knob-like denticle, or reinforced .....	10
9'	columella straight .....	13
10	parietalis present .....	<i>Palaina parietalis</i>
10'	parietalis missing .....	11
11	large species > 4.2 mm shell length .....	<i>Palaina pomatiaeformis</i>
11'	medium sized species < 4.2 mm shell length .....	12
12	small bulb visible, columella narrow .....	<i>Palaina flammulata</i>
12'	bulb inconspicuous, columella broad .....	<i>Palaina subregularis</i>
13	area right above aperture almost smooth .....	<i>Palaina glabella</i>
13'	area right above aperture ribbed .....	14
14	area right above aperture densely ribbed, peristome reinforced by a lip .....	<i>Palaina labeosa</i>
14'	area right above aperture coarsely ribbed, peristome simple .....	<i>Palaina godeffroyana</i>



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# Peruvian oribatid mites (Acari, Oribatida) from the German Biological Expedition, with description of a new species of the genus *Pergalumna*

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## Abstract

The present study is based on oribatid mite material (Acari, Oribatida) collected during the German Expedition in 2011 in Peru. An annotated checklist of identified oribatid mites, including 16 species from 14 genera and 8 families, is provided. Thirteen species and two genera (*Notohermannia*, *Zetomimus*) are recorded for the first time in Peru; the genus *Notohermannia* and species *Notohermannia obtusa* are recorded for the first time in the Neotropical region. A new species of the genus *Pergalumna* (Galumnidae), *P. paraboliviana* sp. n., is described. The new species is most similar to *Pergalumna boliviana* Ermilov, 2013 from Bolivia, however, it differs from the latter by the body size, morphology of porose areas *A1* and the presence of interlamellar setae.

## Keywords

Oribatid mites, fauna, checklist, new record, new species, *Pergalumna*, Peru



## Introduction

Oribatid mites (Acari: Oribatida) of Peru are poorly known (see Hammer 1961; Balogh 1962a, b, 1986; Beck 1962a, b; Balogh and Balogh 1985; Woas 1986; Starý 1992; Wunderle 1992; Niedbala 1982, 2004; Franklin et al. 2006; Schatz 2006).

Our investigation is based on Peruvian material collected during a one-month German Expedition organized by Bavarian State Collection of Zoology in September (second half) and October (first half) 2011. The primary goal of the paper is to present the checklist of the identified species with new records for Peru as well as for the Neotropical region.

In the course of taxonomic identification, we found one new species of the genus *Pergalumna* (Galumnidae). The secondary goal of this paper is to describe and illustrate this species. *Pergalumna* is a large genus that was proposed by Grandjean (1936) with *Oribata nervosa* Berlese, 1914 as type species. Currently, it comprises more than 130 species having a cosmopolitan distribution collectively (Subías 2004, updated 2014). The generic characters of the genus are summarized by Ermilov et al. (2013a), and an identification key to known species from the Neotropical region was presented by Ermilov et al. (2014a).

## Materials and methods

Samples were collected from six localities in Peru, Panguana, basin of the Río Yuyapichis (9°36'49.32"S, 74°56'8.16"W) by D.J. Gwiazdowicz:

- Locality 6, rotting wood, 26.09.2011;
- Locality 12, forest litter, 29.09.2011;
- Locality 16, forest litter, 29.09.2011;
- Locality 28, rotting wood, 3.10.2011;
- Locality 29, forest litter, 5.10.2011;
- Locality 44, forest litter, 8.10.2011.

Specimens were mounted in lactic acid on temporary cavity slides for measurement and illustration. The body length was measured in lateral view, from the tip of the rostrum to the posterior edge of the ventral plate. The notogastral width refers to the maximum width in dorsal aspect. Lengths of body setae were measured in lateral aspect. All body measurements are presented in micrometers. Formulas for leg setation are given in parentheses according to the sequence trochanter–femur–genu–tibia–tarsus (femulus included). Formulas for leg solenidia are given in square brackets according to the sequence genu–tibia–tarsus. Microscope figures were made with a drawing tube using a Carl Zeiss transmission light microscope “Axioskop-2 Plus”. General terminology used in this paper follows that of Grandjean (summarized by Norton and Behan-Pelletier 2009).

## Checklist<sup>1</sup>

This annotated checklist includes the specific localities where oribatid mites were collected, and notes new records and overall known distribution<sup>2</sup>.

### Hypochthoniidae

- *Eohypochthonius becki* Balogh & Mahunka, 1979. Locality: 29 (7 spec.). Distribution: Neotropical region. First record for Peru.

### Nanhermanniidae

- *Cythermannia guadeloupensis* Mahunka, 1985. Locality: 29 (1 spec.). Distribution: Neotropical region. First record for Peru.
- *Notohermannia obtusa* Balogh, 1985. Locality: 29 (10 spec.). Distribution: Australia. First record of genus for Peru and the Neotropical region.

### Oppiidae

- *Brachioppia cuscensis* Hammer, 1961. Locality: 29 (1 spec.). Distribution: Neotropical region, India and Japan.
- *Gittella variabilis* Ermilov, Sandmann, Marian & Maraun, 2013. Locality: 44 (2 spec.). Distribution: Ecuador. First record for Peru.
- *Ramusella (Insculptoppia) merimna* (Balogh & Mahunka, 1977). Locality: 29 (1 spec.). Distribution: Neotropical region. First record for Peru.

### Rhynchoribatidae

- *Rhynchoribates spathulatus* Balogh & Mahunka, 1969. Locality: 28 (1 spec.). Distribution: Neotropical region. First record for Peru.

### Ceratozetidae

- *Zetomimus naias* Behan-Pelletier, 1998. Locality: 16 (3 spec.). Distribution: Neotropical region. First record of genus for Peru.

### Haplozetidae

- *Protoribates paracapucinus* (Mahunka, 1988). Localities: 12 (5 spec.), 16 (19 spec.). Distribution: Ethiopian, Neotropical, Oriental and Palearctic regions. First record for Peru.
- *Trachyoribates (Rostrozetes) ovulum* Berlese, 1908 sensu Beck (1965) as *Rostrozetes foveolatus* Sellnick, 1925. Localities: 16 (3 spec.), 29 (24 spec.). Distribution: Cosmopolitan.

### Scheloribatidae

- *Scheloribates (Scheloribates) praeincisus acuticlava* (Pérez-Íñigo & Baggio, 1986). Locality: 28 (1 spec.). Distribution: Neotropical region. First record for Peru.

### Galumnidae

- *Carinogalumna clericata* (Berlese, 1914). Locality: 28 (1 spec.). Distribution: Neotropical region. First record for Peru.
- *Galumna (Galumna) cf. flabellifera* Hammer, 1958. Localities: 6 (1 spec.), 16 (44 spec.), 29 (229 spec.), 44 (4 spec.). Distribution: pantropics and subtropics. First record for Peru.

<sup>1</sup> Ptyctimous mites are not included in the checklist.

<sup>2</sup> See Subías (2004, updated 2014).

- *Pergalumna bifissurata* Hammer, 1972. Localities: 28 (2 spec.), 29 (1 spec.). Distribution: Polynesia and Neotropical region. First record for Peru.
- *Pergalumna decoratissima* Pérez-Íñigo & Baggio, 1986. Locality: 44 (4 spec.). Distribution: Neotropical region. First record for Peru.
- *Pergalumna paraboliviana* sp. n. Localities: 28 (3 spec.), 44 (2 spec.). Distribution: Peru.

In the course of the taxonomic studies of materials, we identified 16 species belonging to 14 genera and 8 families. Of these, 13 species and two genera, *Notohermannia* Balogh, 1985 and *Zetomimus* Hull, 1916, are recorded for the first time in Peru; genus *Notohermannia* and species *Notohermannia obtusa* are recorded for the first time in the Neotropical region.

## Taxonomy

### *Pergalumna paraboliviana* sp. n.

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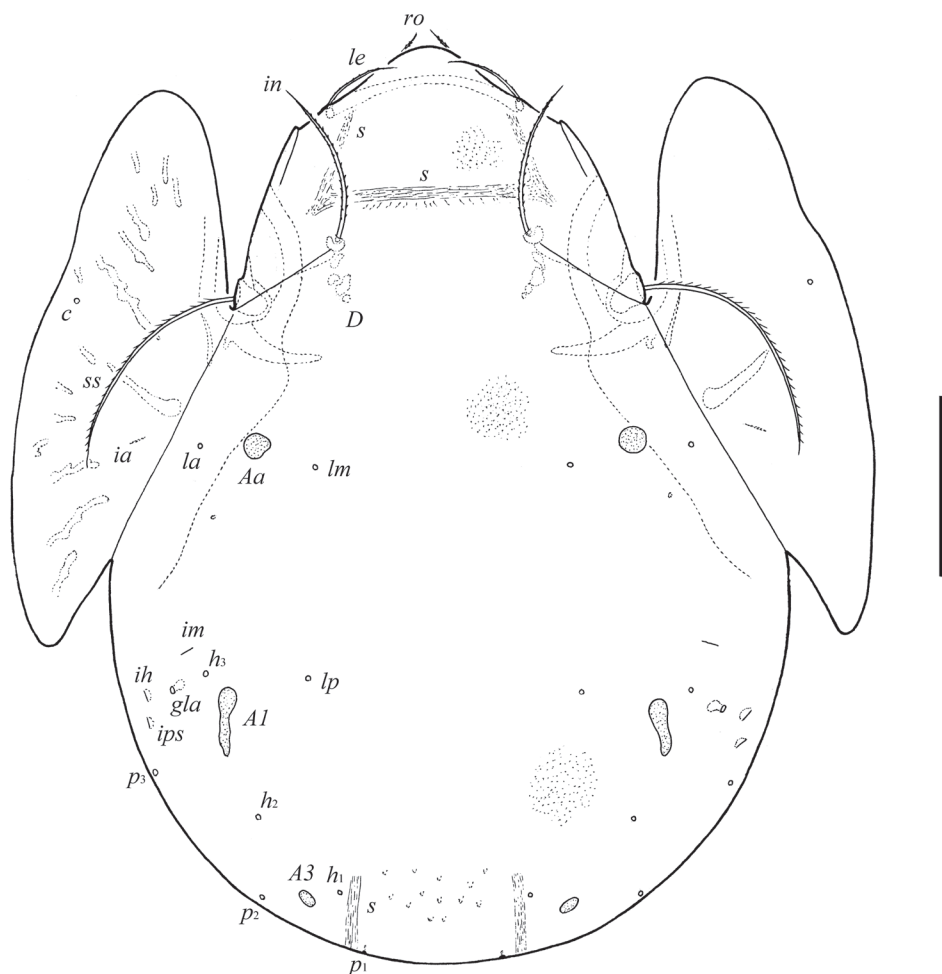
Figs 1–5

**Diagnosis.** Body size: 531–697 × 365–448. Body surface punctate and with striate bands. Rostrum pointed. Rostral, lamellar and interlamellar setae well developed, barbed. Bothridial setae setiform, ciliate unilaterally. Lamellar and sublamellar lines parallel, curving backwards. Anterior notogastral margin not present. Notogaster with three pairs of porose areas: *Aa* and *A3* oval, *A1* slightly triangular, longitudinally elongated. Median pore absent. Adanal setae *ad*<sub>3</sub> inserted laterally or antero-laterally to lyrifissures *iad*. Postanal porose area oval.

**Description.** *Measurements.* Body length: 614 (holotype, male), 531–614 (three paratypes: all males) to 697 (paratype: one female); notogaster width: 365 (holotype), 398 (three paratypes: all males) to 448 (paratype: one female).

*Integument.* Body color light brown to brown. Body surface punctate. Ventral part of pteromorphs with slightly developed reticulate pattern in one paratype. Prodorsum with one transverse and two longitudinal striate bands (*s*): transverse band located anterior to insertions of interlamellar setae; longitudinal bands parallel, each located from the transverse band medially to insertions of lamellar setae. Posterior part of notogaster with two parallel, longitudinal striate bands located medially to notogastral alveoli *h*<sub>1</sub>. Between these longitudinal bands, two arcuate bands present, which fused medially by the transverse band. Ventral body side with one pair of diagonal striate bands nearly of pedotecta I (Pd I), one transverse striate band located anteriorly to genital plates, two lateral, transversal striate bands located between genital and anal plates, and one arcuate striate band located posteriorly to anal plates, extending marginally into the anadanal region. All striate bands well visible only in light colored or dissected specimens.

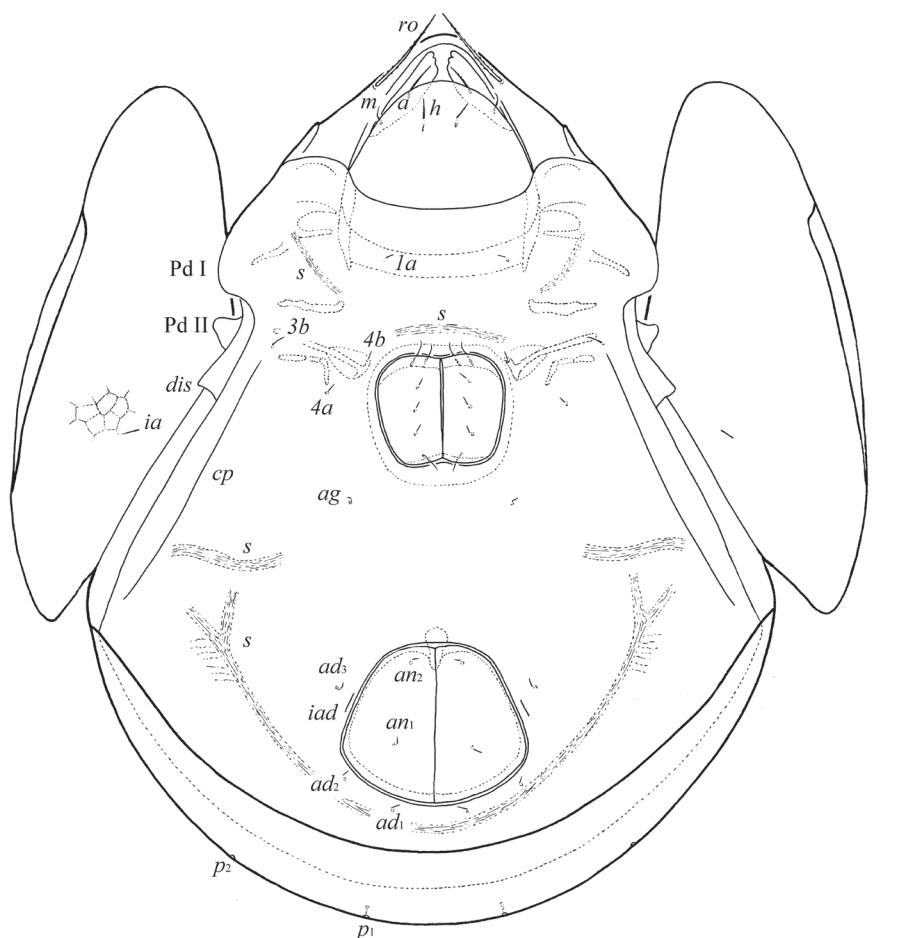
*Prodorsum.* Rostrum pointed (see in dorso-lateral and frontal views). Rostral (*ro*, 57–61 in males to 82 in female), lamellar (*le*, 49–57 in males to 69 in female) and in-



**Figure 1.** *Pergalumna paraboliviana* sp. n.: dorsal view. Scale bar 100  $\mu$ m.

terlamellar (*in*, 110–118 in males to 127 in female) setae simple, barbed; lamellar setae thinnest, interlamellar setae thickest. Bothridial setae (*ss*, 159–172 in males to 205 in female) setiform, densely ciliate unilaterally. Exobothridial setae absent. Lamellar and sublammellar lines distinct, parallel, curving backwards. Insertions of lamellar setae distanced from lamellar lines. Porose areas *Ad* absent.

*Notogaster.* Anterior notogastral margin not developed. Dorsophragmata of medium size, longitudinally elongated. Notogastral setae represented by 10 pairs of alveoli. Three pairs of porose areas with distinct margins: *Aa* (20–24  $\times$  14–16) and *A3* (12–16  $\times$  8–12) oval, *A1* (36–45  $\times$  8–20) slightly triangular, longitudinally elongated. Porose areas *Aa* located between notogastral alveoli *la* and *lm*. Median pore absent. All lyrifissures distinct; *im* located latero-anteriorly to *A1*. Opisthonotal gland openings (*gla*) located laterally to *A1*.

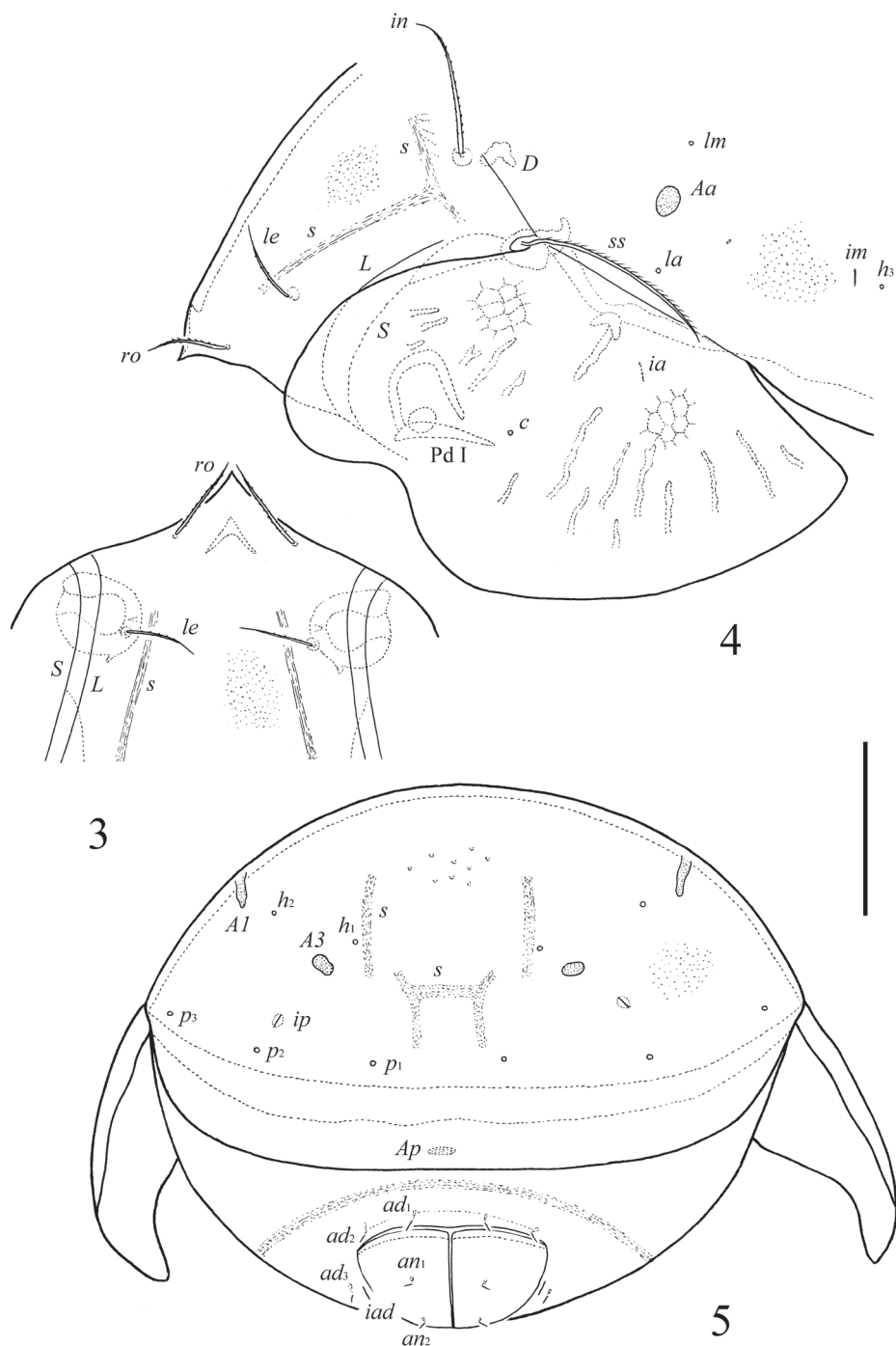


**Figure 2.** *Pergalumna paraboliviana* sp. n.: ventral view (legs not illustrated). Scale bar 100  $\mu$ m.

*Gnathosoma*. Morphology of subcapitulum, palps and chelicerae typical for *Pergalumna* (see Engelbrecht 1972; Ermilov et al. 2011, 2014b, c). Subcapitulum longer than wide (127–131  $\times$  114–118). Subcapitular setae simple, slightly barbed; *a* (32) longer than *m* (16–20) and *h* (20). Two pairs of adoral setae (*or*<sub>1</sub>, *or*<sub>2</sub>, 12) setiform, hook-like distally, barbed. Palps (77–82) with setation 0–2–1–3–9(+ $\omega$ ). Solenidion attached to eupathidium, both located on dorsal tubercle. Chelicerae (143–147 to 196 in female) with two setiform, barbed setae; *cha* (65–69) longer than *chb* (45–49). Trägårdh's organ distinct.

*Epimeral and lateral podosomal regions*. Apodemes 1, 2, sejugal and 3 well visible. Four pairs of setiform, smooth epimeral setae observed; setal formula: 1–0–1–2. Setae *3b* (12) longer than *1a*, *4a* and *4b* (6–8). Pedotecta II (Pd II) scale-like in lateral view, slightly triangular, rounded distally in ventral view. Discidia (*dis*) narrowly triangular. Circumpedal carinae (*cp*) distinct, directed to setae *3b*.





**Figures 3–5.** *Pergalumna paraboliviana* sp. n.: **3** rostrum, dorso-frontal view **4** dorso-lateral view of prodorsum, pteromorph and anterior part of notogaster (gnathosoma and legs not illustrated) **5** posterior view. Scale bar 100  $\mu$ m.

**Table 1.** Leg setation and solenidia of *Pergalumna paraboliviana* sp. n.

Leg	Trochanter	Femur	Genu	Tibia	Tarsus
I	<i>v'</i>	<i>d, (l), bv''</i>	<i>(l), v', σ</i>	<i>(l), (v), ϕ<sub>1</sub>, ϕ<sub>2</sub></i>	<i>(ft), (tc), (it), (p), (u), (a), s, (pv), v', (pl), l'', ε, ω<sub>1</sub>, ω<sub>2</sub></i>
II	<i>v'</i>	<i>d, (l), bv''</i>	<i>(l), v', σ</i>	<i>(l), (v), ϕ</i>	<i>(ft), (tc), (it), (p), (u), (a), s, (pv), ω<sub>1</sub>, ω<sub>2</sub></i>
III	<i>v'</i>	<i>d, ev'</i>	<i>l', σ</i>	<i>l', (v), ϕ</i>	<i>(ft), (tc), (it), (p), (u), (a), s, (pv)</i>
IV	<i>v'</i>	<i>d, ev'</i>	<i>d, l'</i>	<i>l', (v), ϕ</i>	<i>ft'', (tc), (p), (u), (a), s, (pv)</i>

Roman letters refer to normal setae (ε to famulus), Greek letters to solenidia. Single prime (') marks setae on anterior and double prime (") setae on posterior side of the given leg segment. Parentheses refer to a pair of setae.

*Anogenital region.* Six pairs of genital (*g*<sub>1</sub>, *g*<sub>2</sub>, 8–10; *g*<sub>3</sub>–*g*<sub>6</sub>, 6–8), one pair of aggenital (*ag*, 6–8), two pairs of anal (*an*<sub>1</sub>, *an*<sub>2</sub>, 10–12) and three pairs of adanal (*ad*<sub>1</sub>–*ad*<sub>3</sub>, 12–16) setae thin, smooth. Anterior parts of genital plates with two setae. Adanal setae *ad*<sub>3</sub> inserted laterally or antero-laterally to lyrifissures *iad*. Postanal porose area oval (16–20 × 6–10).

*Legs.* Morphology of leg segments, setae and solenidia typical for *Pergalumna* (see Engelbrecht 1972; Ermilov et al. 2010, 2011, 2014c). Formulas of leg setation and solenidia: I (1–4–3–4–20) [1–2–2], II (1–4–3–4–15) [1–1–2], III (1–2–1–3–15) [1–1–0], IV (1–2–2–3–12) [0–1–0]; homology of setae and solenidia indicated in Table 1. Solenidion ϕ on tibiae IV inserted in the middle of dorsal parts.

**Type deposition.** The holotype is deposited in the collection of the Senckenberg Institution Frankfurt, Germany; three paratypes are deposited in the collection of the Tyumen State University Museum of Zoology, Tyumen, Russia; one pratype is deposited in the collection of the Natural History Museum, Lima, Peru.

**Etymology.** The prefix *para* is Latin meaning “near” and refers to similarity between the new species and *Pergalumna boliviana* Ermilov, 2013.

**Remarks.** In having the setiform bothridial setae, pointed rostrum, indeveloped anterior notogastral margin, three pairs of porose areas and striate bands on body, *Pergalumna paraboliviana* sp. n. is most similar to *P. boliviana* Ermilov, 2013 from Bolivia (see Ermilov and Niedbala 2013). However, it differs from the latter by the larger body size (531–697 × 365–448 versus 415–464 × 282–332 in *P. boliviana*), elongated, slightly triangular notogastral porose areas *A1* (versus rounded in *P. boliviana*) and the presence of interlamellar setae (versus represented by alveoli in *P. boliviana*).

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We are very grateful to Prof. Dr. Badamdorj Bayartogtokh (National University of Mongolia, Ulaanbaatar, Mongolia) for the valuable comments, Dr. Juliane Diller and Erich Diller (Bavarian State Collection of Zoology, Germany) for permission to work in the Panguana Research Station in Peru and for providing logistic support. The reported study was supported by the Russian Foundation for Basic Research (project: 15-04-02706 A).

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# A new species of *Scolopocryptops* Newport: a troglobitic scolopocryptopine centipede from a remarkable siliciclastic area of eastern Brazil (Scolopendromorpha, Scolopocryptopidae, Scolopocryptopinae)

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## Abstract

We describe *Scolopocryptops troglocaudatus* **sp. n.**, a new troglobitic scolopocryptopine centipede species. The species was found in a remarkable siliciclastic karst area of Eastern Brazil, in three caves of the Chapada da Diamantina, in the state of Bahia. *S. troglocaudatus* **sp. n.** is close to *S. miersii* Newport, 1845 and *S. ferrugineus macrodon* (Kraepelin, 1903) but differs from them by troglomorphic features, such as depigmentation, long appendages and a thin cuticle. This new species is the second troglobitic scolopocryptopine described and is the first discovered in Brazil.

## Keywords

Chilopoda, Cave, Chapada Diamantina, eastern Brazil, Taxonomy



## Introduction

*Scolopocryptops* are blind scolopendromorphs with 23 pairs of legs, and the prefemora of the ultimate legs with one dorsomedial and one ventral spinous process. There are currently 24 species and eight subspecies known from the Americas, Greater and Lesser Antilles, West Africa and along the Pacific Rim of Asia from Japan to Indonesia and the Fiji Islands (Chagas-Jr 2008, 2010).

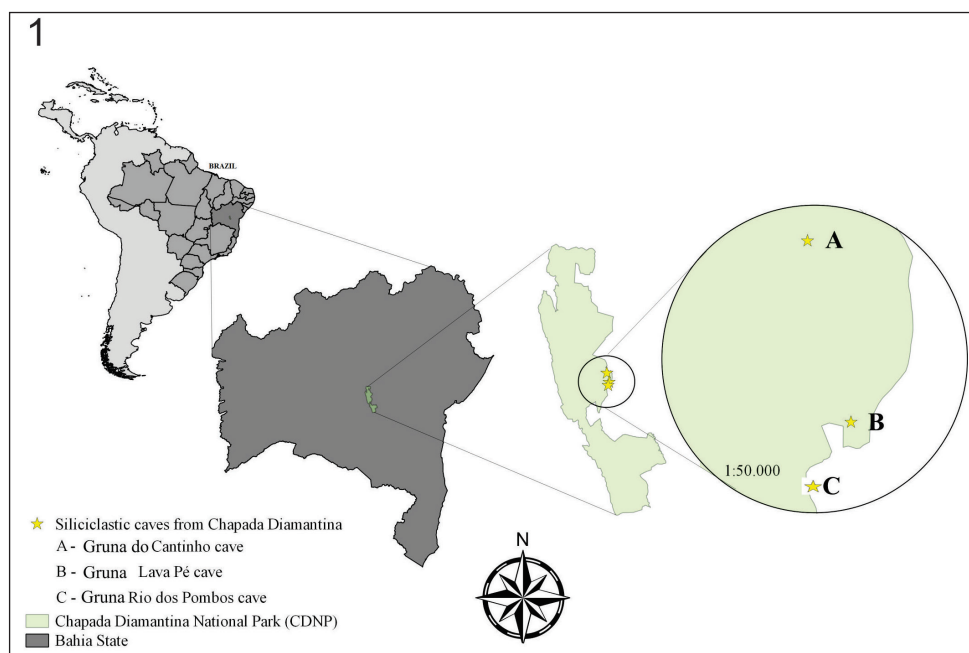
In the Neotropics, the genus includes seven species: *S. miersii* Newport, 1845, *S. melanostoma* Newport, 1845, *S. ferrugineus* (Linnaeus, 1762), *S. denticulatus* Bücherl, 1946, *S. guacharensis* Manfredi, 1957, *S. piauihyensis* Chagas-Jr, 2004 and *S. spiculifer* (Bücherl, 1949); three non-nominal subspecies: *S. ferrugineus inversus* (Chamberlin, 1921), *S. ferrugineus macrodon* (Kraepelin, 1903) and *S. ferrugineus riveti* (Brölemann, 1919); and three doubtful species: *S. aurantiaca* Gervais, 1847, *S. quadrisulcatus* Day, 1891 and *S. viridis* Gervais, 1847.

True troglobitic species in the family Scolopocryptopidae have been described from the subfamilies Kethopiinae and Newportiinae: *Thalkethops grallatrix* Crabill, 1960 was found in the caves of New Mexico in the USA (Crabill 1960, Shelley 2002), *Newportia* (N.) *troglobia* Chagas-Jr & Shelley, 2003 was reported from a cave in Mexico (Chagas-Jr and Shelley 2003), *Newportia* (N.) *stoevi* Schileyko, 2013 from a cave in Puerto Rico (Schileyko 2013), and *Newportia* (N.) *spelaea* Ázara & Ferreira, 2014 and *Newportia* (N.) *potiguar* Ázara & Ferreira, 2014, both of which were reported from caves in northeastern Brazil.

Within the subfamily Scolopocryptopinae, two species of the genus *Scolopocryptops* have been recorded to be present in caves: *S. guacharensis*, from Cueva Del Guacharo, and *S. ferrugineus*, collected in three caves – Cueva Gruxent Graciliano, Cueva del Bunceo and Cueva Alfredo Jahn, all of which are in Venezuela (Manfredi 1957, Chagas-Jr 2003, 2008). *S. ferrugineus* is a widespread species that lives in a hypogean environment, but it could also be occasionally found in caves. Conversely, *S. guacharensis* seems to be a troglobitic species because it is restricted to a single cave and has peculiar features, such as some degree of depigmentation and a different length of the ultimate legs, which could be interpreted as troglomorphisms. Here, we describe a new species of *Scolopocryptops* from Brazil, which is the second troglobite in the subfamily.

## Material and methods

The type and additional material were first collected and examined under a stereomicroscope and then fixed in 70% alcohol. Photographs and length measurements were taken using a Leica Stereomicroscope (M205C). The scales are in metric units (millimeters, mm) and were made from photographs of specimens taken on a computer screen. The descriptive terminology follows that reported by Lewis et al. (2005) and Bonato et al. (2010).



**Figure 1.** Map of the area where *Scolopocryptops troglocaudatus* sp. n. was found, Chapada Diamantina, Central Bahia. Author: D. M. von Schimonsky.

The repository acronyms are as follows: MNRJ – Museu Nacional, Rio de Janeiro, Rio de Janeiro, Brazil; UFMT – Universidade Federal de Mato Grosso; UFSCar – Universidade Federal de São Carlos, São Carlos, Brazil.

## Study area

Chapada Diamantina is located in the central portion of the state of Bahia, eastern Brazil (Fig. 1). The caves where *S. troglocaudatus* sp. n. occurs were formed by siliciclastic (non-carbonatic sedimentary rocks) and quartzitic rocks inserted in a Mesoproterozoic Basin of the Chapada Diamantina Group, disposed in three layers, two of which formed from siliciclastic rocks (Schobbenhaus et al. 1984) (Fig. 2). Caves in this area are formed by the erosion of soft rock components by rainwater penetrating through surface cracks and leaving spaces delimited by the harder components. The caves are located in the Chapada Diamantina National Park (CDNP) and are thus under legal protection. However, most of the caves in the upper sector of Chapada Diamantina were heavily impacted by diamond mining in the past, an activity that extended to the early 1990s and continues to the present day (Bichuette et al. 2008).



**Figure 2.** The entrance of Gruna do Cantinho Cave (type locality of *Scolopocryptops troglocaudatus* sp. n.) with roots and rock blocks. Author: E. C. Igual.

## Taxonomy

**Order Scolopendromorpha** Pocock, 1895

**Family Scolopocryptopidae** Pocock, 1896

**Subfamily Scolopocryptopinae** Pocock, 1896

**Genus *Scolopocryptops*** Newport, 1845

***Scolopocryptops troglocaudatus* sp. n.**

<http://zoobank.org/F8B7359F-7FCD-4EC9-86C3-31F168F61919>

Figs 3–20

*Scolopocryptops* sp. n. in Gallão and Bichuette (2015).

**Type material examined.** Holotype unsexed (MNRJ) collected by Gallão, JE., Igual, EC. and von Schimonsky, DM. on 01.iv.2013 in Gruna do Cantinho Cave, Igatu, Andaraí, Bahia, Brazil.

**Additional material examined.** Two juveniles (UFMT), two juveniles (UFSCar) all collected by Gallão, JE., Igual, EC. and von Schimonsky, DM. on 31.iii.2013 in Gruna Rio dos Pombos Cave, Igatu, Andaraí, Bahia, Brazil.



**Figure 3.** A live specimen showing the greenish coloration, displaying autogrooming in the natural habitat (Gruna do Cantinho Cave). Author: E. C. Igual.

**Etymology.** The name *troglocaudatus* is in allusion to the troglobitic status and the longest ultimate legs in the subfamily Scolopocryptopinae. This is from Latin *troglo*, meaning “cave”, and *caudatus*, meaning “with a tail”.

**Diagnosis.** *Scolopocryptops* with a straight anterior margin of the forcipular coxosternum; tooth-plates formed by two long thickened chitinous layers, not fused with each other, more elevated on the sides than in the middle; without a pair of spiracles in the seventh pedal segment; ventral spinous process of the prefemur of the ultimate pair of legs short (small), and a very short dorsomedial spinous process; femur of the ultimate pair of legs longer than the prefemur and tibia.

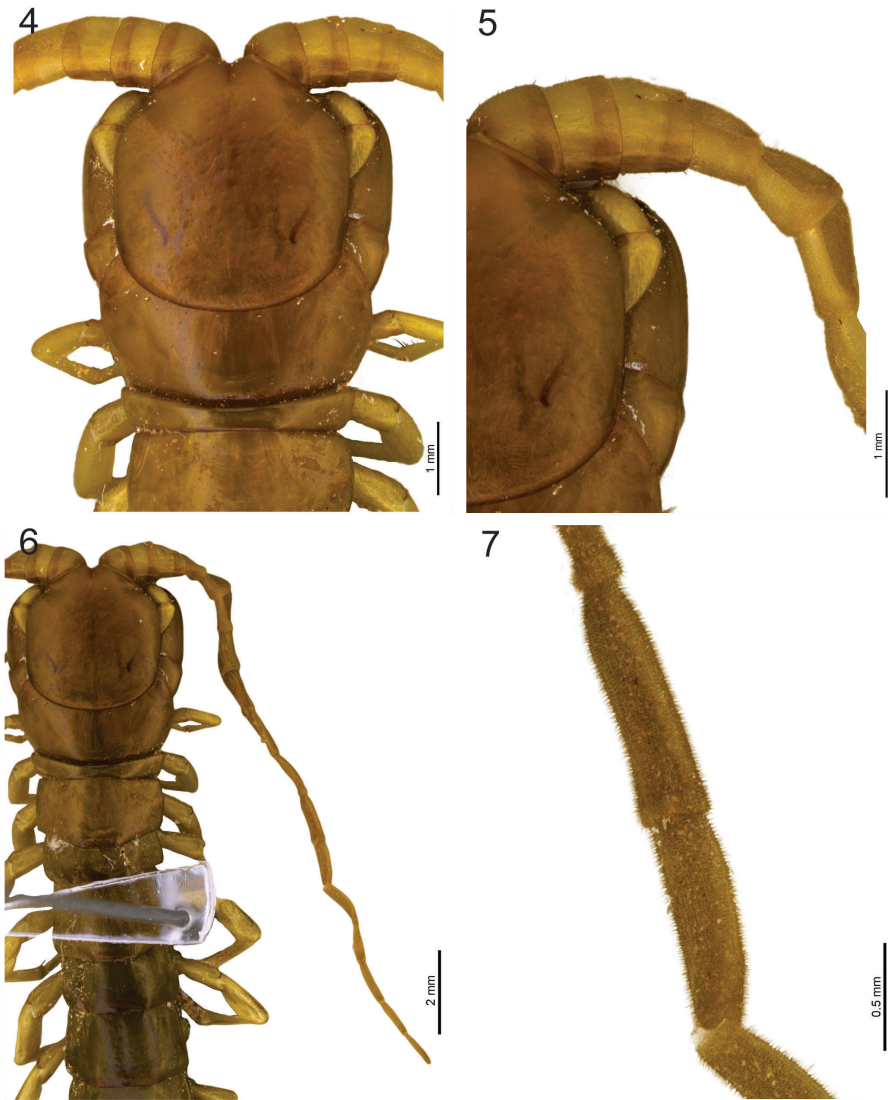
**Description of holotype.** *Length:* length of body (anterior margin of cephalic plate to posterior margin of tergite 23) 45 mm.

*Pigmentation in life:* cephalic plate, first and last pedal segment, and coxosternite orange; body and pedal segments greenish, legs 1 to 21 and antennae light yellow, last two pairs of legs pale (Fig. 3). *Pigmentation in alcohol:* cephalic plate, coxosternite, tergites and sternites light brown and legs orange.

*Cephalic plate:* slightly longer than wider (length: 3.4 mm; width: 3.2 mm), smooth, without marginal ridges, sutures, sulci or depressions, its posterior margin overlying tergite 1 (Fig. 4).

*Antennae:* extending to the posterior border of T10 (Fig. 5); 17 articles; the first two basal articles and dorsal 1/3 of the third glabrous (Fig. 6); from the third to twelfth or seventeenth with short bristles covering all articles; first three basal articles wider than longer (length: 0.6 mm; width: 0.9 mm); fourth to seventeenth articles longer than wider; distal articles three times longer than wider (length: 1.1 mm; width: 0.3 mm) (Fig. 7).

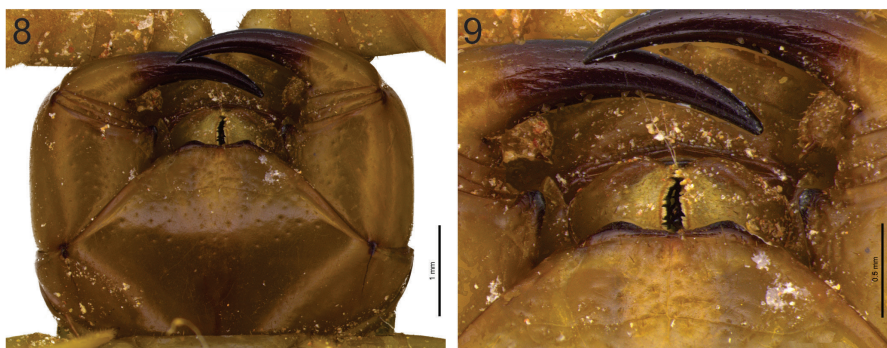




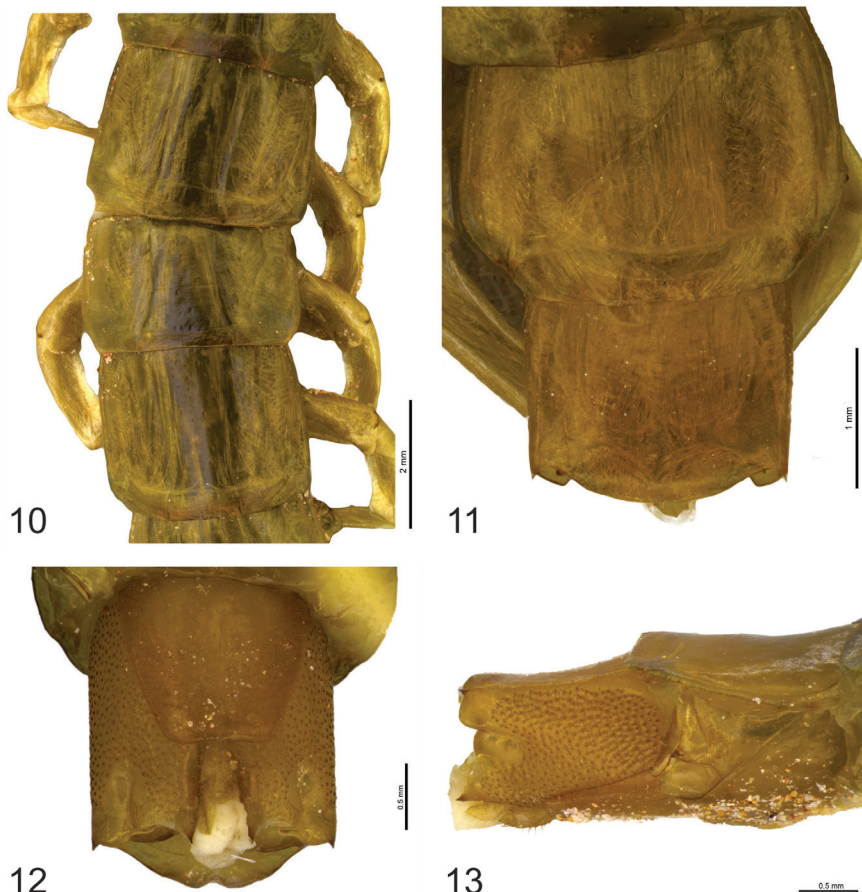
**Figure 4–7.** **4** *Scolopocryptops troglocaudatus* sp. n. Holotype (MNRJ). Cephalic plate and first two tergites. **5** *Scolopocryptops troglocaudatus* sp. n. Holotype (MNRJ). Part of the cephalic plate showing the first two basal articles of the right antenna **6** *Scolopocryptops troglocaudatus* sp. n. Holotype (MNRJ). Cephalic plate and the first eight tergites showing the length of the right antenna **7** *Scolopocryptops troglocaudatus* sp. n. Holotype (MNRJ). Eleventh and twelfth articles showing the length and width. Scale bar for Figure 4, 5 = 1 mm; 6 = 2 mm; 7 = 0.5 mm.

*Forcipular coxosternum*: anterior margin straight, with a longitudinal suture ending in the middle of the transversal suture (Fig. 8); tooth-plates formed by two long thickened chitinous layers, not fused with each other, more elevated on the sides than in the middle. Process of forcipular trochanteroprefemur short, apex truncated (Fig. 9).

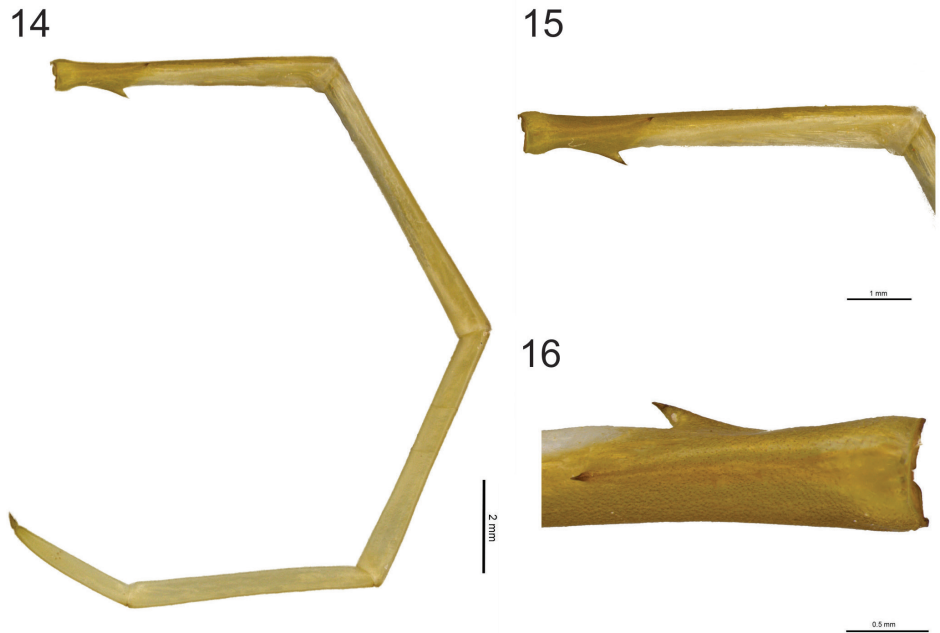




**Figure 8–9.** 8 *Scolopocryptops troglocaudatus* sp. n. Holotype (MNRJ). Forcipular coxosternum 9 *Scolopocryptops troglocaudatus* sp. n. Holotype (MNRJ). Tooth plates. Scale bar for Figure 8 = 1 mm; 9 = 0.5 mm.



**Figure 10–13.** 10 *Scolopocryptops troglocaudatus* sp. n. Holotype (MNRJ). Tergites 12, 13 and 14 11 *Scolopocryptops troglocaudatus* sp. n. Holotype (MNRJ). Tergites 22 and 23 12 *Scolopocryptops troglocaudatus* sp. n. Holotype (MNRJ). Segment 23. Ventral view 13 *Scolopocryptops troglocaudatus* sp. n. Holotype (MNRJ). Segment 23. Lateral view. Scale bar for Figure 10 = 2 mm; 11 = 1 mm; 12, 13 = 0.5 mm.



**Figure 14–16.** **14** *Scolopocryptops troglocaudatus* sp. n. Holotype (MNRJ). Ultimate right leg **15** *Scolopocryptops troglocaudatus* sp. n. Holotype (MNRJ). Prefemur of the ultimate right leg **16** *Scolopocryptops troglocaudatus* sp. n. Holotype (MNRJ). Dorsomedial and ventral spinous processes of the prefemur of the ultimate leg. Scale bar for Figure 14 = 2 mm; 15 = 1 mm; 16 = 0.5 mm.

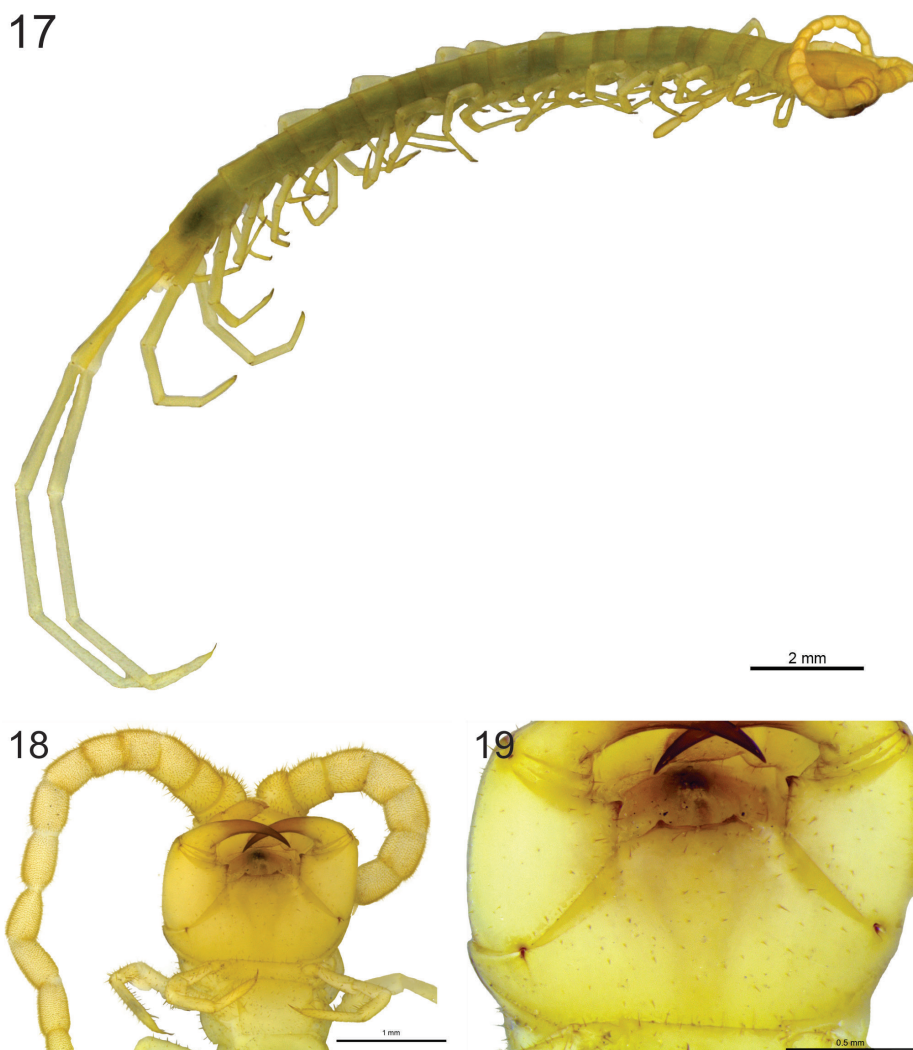
*Tergites*: smooth, with very light fine punctuation. Tergite 1 with an anterior transverse sulcus, but without sutures; T3 to T7 with incomplete short paramedian sutures; T8 to T20 with complete paramedian sutures (Fig. 10). Tergites 6 (or 7) to T22 with margination. Tergite of ultimate leg-bearing segment without margination, but with a membranous line separating tergite and coxopleura (Fig. 11); posterior border with a low longitudinal depression and a convex posterior margin.

*Spiracles*: not present in the seventh pedal segment.

*Sternites*: smooth, wider than longer. Sternite of ultimate leg-bearing segment narrow posteriorly, longer than wide, posterior margin straight (Fig. 12).

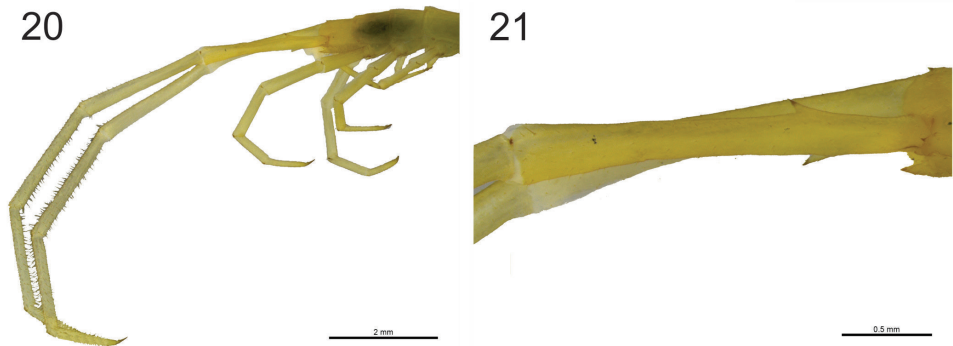
*Coxopleuron*: Coxopleural process short, parallel and pointed. Pore field reaching almost the whole area of the coxopleura, except the dorsal and posterior areas and the medial depression, its posterior corner ending at a strong, sclerotized point (Fig. 13).

*Legs*: Legs 1 to 21 with undivided tarsus, legs 22 and 23 with tarsi 1 and 2. Legs 1 to 19 with two tibial spurs, legs 20 and 21 with one lateral tibial spur, legs 22 and 23 without spurs; legs 1 to 21 with one lateral tarsal spur, legs 22 and 23 without. Pretarsus of legs 1 to 21 with well-developed pairs of accessory spurs, accessory spurs on legs 22 and 23 very short.



**Figure 17–19.** **17** *Scolopocryptops troglocaudatus* sp. n. Juvenile (UFSCar). Habitus **18** *Scolopocryptops troglocaudatus* sp. n. Juvenile (UFSCar). Forcipular coxosternum **19** *Scolopocryptops troglocaudatus* sp. n. Juvenile (UFSCar). Tooth plates. Scale bar for Figure 17 = 2 mm; 18 = 1 mm; 19 = 0.5 mm.

Ultimate pair of legs smooth, longer and slender (length: 26.2 mm) (Fig. 14). Ventral spinous process of the prefemur short (small) and the dorsomedial spinous process very short (Figs 15 and 16). Femur longer (length: 6.1 mm) than the prefemur (length: 6.0 mm) and tibia (5.7 mm); tarsus 1 (length: 5.3 mm), tarsus 2 (length: 2.7 mm) and pretarsus (length: 0.4 mm).



**Figure 20–21.** **20** *Scolopocryptops troglocaudatus* sp. n. Juvenile (UFSCar). Ultimate pair of legs showing the length of the articles and the pilosity of the tibiae and tarsi **21** *Scolopocryptops troglocaudatus* sp. n. Juvenile (UFSCar). Prefemur of the right ultimate leg showing the dorsomedial and ventral spinous processes. Scale bar for Figure 20 = 2 mm; 21 = 0.5 mm.

**Type locality.** Gruna do Cantinho Cave, Igatu, Andaraí, Bahia, Brazil.

**Distribution.** Gruna do Cantinho Cave, Gruna Rio dos Pombos Cave and Gruna Lava Pé Cave, all Caves from Chapada Diamantina, central Bahia, Eastern Brazil (Fig. 1).

**Remarks on juveniles.** The color pattern of the juveniles: antennae, cephalic plate, first and last pedal segments, and coxosternite light orange (Fig. 17); from T2 to T22 light greenish; legs pale. The first two basal articles of the antennae pilose, with long and short setae. The integument of the cephalic plate, coxosternite (Fig. 18), tergites, sternites and legs pilose, with long and fine setae. Prefemora and femora of ultimate legs with few long and short setae. The tooth-plates are formed by two long thickened chitinous layers, not fused with each other, more elevated on the sides than in the middle (Fig. 19). The margins of the sides of the tooth plates are pointed. Process of the forcipular trochanteroprefemur short, and apex pointed. Coxopleural processes median in length, parallel and pointed. Ventral and dorsomedial spinous processes of the prefemur of the ultimate legs longer than holotype (Figs 20 and 21).

**Habitat and habits.** *Scolopocryptops troglocaudatus* sp. n. adults were observed exposed in the substrate formed by humid sand (Fig. 2). The adults are apparently indifferent to light, showing a very calm behavior when lit in the natural habitat. In contrast, the juveniles were collected buried in the humid sand, which represented a more cryptobiotic habit.

## Discussion

So far, at least 18 species of Scolopendromorpha have been described from caves worldwide, and five of these species are found in Brazil. Considering the Scolopocryptopinae, the species described herein represents the second troglobitic (restricted to subterranean environments) species in the world. The first troglobitic scolopocryptopine was

described after its discovery in a cave in Venezuela by Manfredi (1957) as *Otocryptops ferrugineus guacharensis* Manfredi, 1957. Chagas-Jr (2003) revised the taxonomic status of the species and compared it with *S. ferrugineus*. He concluded that *O. ferrugineus guacharensis* was exclusive to the Cueva del Guacharo and showed that some troglomorphic features, such as depigmentation and long legs, were strong evidence that *S. guacharensis* was restricted to subterranean life (Chagas-Jr 2003). *Scolopocryptops troglocaudatus* sp. n. shares some troglomorphic characters with *S. guacharensis* such as depigmentation, the length of the antennae, the length of the ultimate pair of legs, and the pilosity of the tibia and tarsi of ultimate pair of legs.

*Scolopocryptops troglocaudatus* sp. n. resembles *S. miersii* in having a straight anterior margin of the forcipular coxosternum and tooth-plates formed by two long thickened chitinous layers, which are not fused with each other and are more elevated on the sides than in the middle. However, *Scolopocryptops troglocaudatus* sp. n. differs from *S. miersii* in the length of the ultimate pair of legs, the length of the coxopleural process, and the length of the dorsomedial and ventral spinous process of the prefemur of the ultimate pair of legs. In addition, there is no pair of spiracles on the seventh pedal segment of *S. troglocaudatus* sp. n.

A noteworthy characteristic is the length of the ultimate pair of legs in *S. troglocaudatus* sp. n., which is almost the half of the length of the body, whereas their length in *S. miersii* is short, never reaching even half the length of the body. The dorsomedial and ventral spinous process in the prefemur of the ultimate legs in *S. troglocaudatus* sp. n. are short and small, whereas those in *S. miersii* are long and large.

*Scolopocryptops troglocaudatus* also resembles *S. ferrugineus macrodon* in the length of the coxopleural process, which is short in both taxa, but differs from *S. ferrugineus macrodon* in the anterior margin of the forcipular coxosternum, the shape of the tooth-plates, the length of the ultimate pair of legs, and the length of the dorsomedial and ventral spinous processes of the prefemur of the ultimate pair of legs. The anterior margin of *S. ferrugineus macrodon* is almost straight; the tooth-plates are formed by two chitinous lobes, sometimes with a chitinous crest, with its margin being slightly granulated. The length of the ultimate pair of legs and the length of the dorsomedial and ventral spinous processes of the prefemur of the ultimate pair of legs are very similar to *S. miersii* but very different from that described for *Scolopocryptops troglocaudatus* sp. n.

**Endemism.** *Scolopocryptops troglocaudatus* sp. n. is most likely endemic existing only in siliciclastic caves from Igatu, occurring in an area of approximately 10 km<sup>2</sup>. This statement is corroborated by the numerous collections conducted by the Laboratório de Estudos Subterrâneos team in the region since 2006, when no specimens were found in the limestone caves close to these. Other troglobitic and endemic species occur in this region, and the area is clearly an area of high diversity for terrestrial cave invertebrates, with at least 20 unique troglobitic invertebrates distributed in a 25 km<sup>2</sup> area (Gallão and Bichuette 2015).

**Troglomorphic traits and troglobitic status.** Troglomorphic organisms in general are highly homoplastic, widely known for reduced eyes and melanistic pigmentation, a phenomenon also observed to be related to the behavioral traits (Trajano and



Bockmann 1999, Parzefall and Trajano 2010). These characters are not necessarily adaptive, unless pleiotropic effects have been shown (Jeffery 2010). The lack of eyes is shared by all species of Scolopocryptopidae and depigmentation and is shared by many other characters suggesting troglomorphisms must be verified because these are not sufficient to prove the cave-restricted status for a scolopocryptopid species. For Scolopocryptopinae, we suggest that the last two pairs of legs represent a possible troglomorphism because they are very distinct in length compared with other species. The adult *S. troglocaudatus* sp. n. shows greenish body coloration, with pale yellow legs and head. On the contrary, the juvenile individuals show a pale aspect in the entire body, including the appendages. These differences in the pigmentation must be reported in several studies that try to detect troglomorphisms, or equivocal classifications can be proposed. Even with the absence of one typical troglomorphism (reduction of melanic pigmentation), the non-occurrence of the species outside the caves clearly indicates the troglitic status of *S. troglocaudatus* sp. n.

Considering other character-states, we detected at least three troglomorphisms in *S. troglocaudatus* sp. n.: an extremely long ultimate pair of legs (exceeding 2/3 of the body length: 26.2 mm), a long antennae and a reduced sclerotization of the cuticle. The long antennae and the reduced cuticle are most likely related to optimization of the detection of chemical and mechanical stimuli and to the intolerance for desiccation. Caves are extremely humid habitats, and troglitic arthropods show, in general, a reduction in the cuticle (Barr 1968). There is no information about the function of the last pair of legs in the subfamily Scolopocryptopinae, and it is not possible to draw any conclusions about its importance with regard to the isolation in subterranean habitats, the detection of prey and/or even defense of territory.

**Conservation remarks.** Caves are unique habitats that are often inhabited by relict taxa showing high degree of endemism (Trajano and Bichuette 2010). The region of Igatu, Chapada Diamantina shows a high diversity of troglites and some relict taxa, being the type-locality of four troglites: the harvestman *Discocyrtus pedrosoi* Kury, 2008, the catfish *Glaphyropoma spinosum* Bichuette, Pinna & Trajano, 2008, the scorpion *Troglophalurus translucidus* Lourenço, Baptista & Giupponi, 2004 and the mygalomorph spider *Tmesiphantes hypogeus* Bertani, Bichuette & Pedroso, 2013. Furthermore, the region shows endemisms and phylogenetical and geographical relicts as, for example, the collembolan of *Verhoefiella* genus, previously only thought to have Palaearctic distribution (Gallão and Bichuette 2015).

The new species described herein represents the sixth troglite described for the region, and its restricted distribution (three caves in a 10 km<sup>2</sup> area) categorizes it as fragile in terms of conservation criteria.

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# Review of Canadian species of the genus *Mocyta* Mulsant & Rey (Coleoptera, Staphylinidae, Aleocharinae), with the description of a new species and a new synonymy

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## Abstract

Six species of the genus *Mocyta* Mulsant & Rey are reported from Canada: *Mocyta amblystegii* (Brundin), *M. breviscula* (Mäklin), *M. discreta* (Casey), *M. fungi* (Gravenhorst), *M. luteola* (Erichson), and *M. sphagnorum* Klimaszewski & Webster, **sp. n.** New provincial and state records include: *M. breviscula* – Saskatchewan and Oregon; *M. discreta* – Quebec, Ontario and Saskatchewan; *M. luteola* – New Brunswick, Quebec, Ontario, Massachusetts and Minnesota; and *M. fungi* – Saskatchewan. *Mocyta sphagnorum* is described from eastern Canada from specimens captured in Newfoundland, New Brunswick, Quebec and Ontario. *Mocyta negligens* Mulsant and Rey, a native European species suspected of occurring in Canada, is excluded from the Nearctic fauna based on comparison of European types with similarly coloured Canadian specimens, which are now identified as *M. luteola*. The European species, *Mocyta gilvicollis* (Scheerpeltz), is synonymized with another European nominal species, *M. negligens*, based on examination of type material of the two species. Lectotypes are designated for *Eurypronota discreta* Casey, *Atheta gilvicollis* Scheerpeltz, *Homalota luteola* Erichson, *Colpodota negligens* Mulsant and Rey, *Acrotona prudens* Casey and *Dolosota redundans* Casey. The latter species is here synonymized with *M. luteola*. A review of the six Nearctic species is provided, including keys to species and closely related genera, colour habitus images, images of genitalia, biological information and maps of their distributions in Canada.

**Keywords**

Coleoptera, Staphylinidae, Aleocharinae, *Mocyta*, taxonomy, Canada

**Introduction**

There has been considerable confusion about the taxonomic status of the genus *Mocyta* Mulsant & Rey, 1874. Species have historically been assigned to many genera including *Atheta* Thomson, 1858, *Acrotona* Thomson, 1859, *Colpodota* Mulsant & Rey, 1873, *Dolosota* Casey, 1910, *Eurypronota* Casey, 1894, and *Homalota* Mannerheim, 1830. Seevers (1978) included *Mocyta fungi*, and other groups with the pronotal hypomeron strongly deflexed and not visible in lateral view, within the genus *Acrotona*. Casey (1894, 1910) did not formally recognize *Mocyta* as a distinct genus and described several species of *Mocyta* and *Acrotona* in the genera *Eurypronota* Casey and *Dolosota* Casey. Lohse and Smetana (1985) examined types of *Homalota breviscula* Mäklin from Sitka, Alaska and assigned the species to *Mocyta* as a subgenus of *Atheta*. This species was later recorded as *Mocyta breviscula* from eastern Canada by Klimaszewski et al. (2005, 2007a, 2008), Webster et al. (2009), and Majka and Klimaszewski (2010). Lohse et al. (1990) recognized *Mocyta* as a distinct genus and reported *M. amblystegii* (Brundin) for the first time from northwestern North America, confirming it as a holarctic species. An adventive Palaearctic species, *M. fungi* (Gravenhorst), is now broadly distributed in Canada and the USA (Muona 1984, Gusarov 2003, McLean et al. 2009, Klimaszewski et al. 2011, 2013).

We believe that species of *Mocyta* constitute a monophyletic evolutionary lineage defined by the shape of the spermatheca, antennal and pronotal structure, and pubescence and punctation patterns. The genus is externally similar to *Acrotona*, *Strigota* and *Atheta*, sharing with the two former genera a strongly deflexed hypomeron on the pronotum, which is not visible in lateral view. Molecular studies by Elven et al. (2012) clearly treat *Mocyta* as a taxon of generic rank within the clade of Athetini. The purpose of this paper is to review all Canadian species of *Mocyta* and to provide modern tools and illustrations for their proper identification. *Mocyta* species are often abundant in forest litter samples and may be used as indicators of forest health.

**Material and methods**

Approximately 1000 adults of the genus *Mocyta* from Canada were studied, and most specimens were dissected to examine the genitalic structures that were dehydrated in absolute alcohol, mounted in Canada balsam on celluloid microslides, and pinned with the specimens from which they originated. Images of the entire body and the genital structures were taken using an image processing system (Nikon SMZ 1500 stereoscopic microscope; Nikon Digit-like Camera DXM 1200F, and Adobe Photoshop software).

Morphological terms mainly follow those used by Seevers (1978), Ashe (2000), and Klimaszewski et al. (2011). The ventral side of the median lobe of the aedeagus is



considered to be the side of the bulbus containing the foramen mediale, the entrance of the ductus ejaculatorius, and the adjacent ventral side of the tubus of the median lobe with internal sac and its structures (this part is referred to as the parameral side in some recent publications); the opposite side is referred to as the dorsal part. In the species descriptions, microsculpture refers to the surface of the upper forebody (head, pronotum and elytra).

The structure of antennae, body proportions including size, shape and convexity of pronotum, density of punctures on the forebody, and the shape of the spermatheca, particularly that of the capsule with apical invagination, provide the best diagnostic characteristics for species of *Mocyta*. The shape of the median lobe of the aedeagus is generally similar in all species of *Mocyta* occurring in Canada, except for some structures of the internal sac, but several features differ among species, including: the shape of sternite VIII and the form of its basal suture (antecostal suture); the distance between the antecostal suture and the base of the disc; and the shape of the apical part of the disc. In addition, there is great diversity in the form of the spermathecal stem and particularly its posterior part with variable coils and twists within the same species.

### Depository/institutional abbreviations

<b>AAFC</b>	Agriculture and Agri-Food Canada, Atlantic Cool Climate Crop Research Centre, St. John's, Newfoundland and Labrador, Canada.
<b>BGC</b>	Benoit Godin Collection, Whitehorse, Yukon Territory, Canada.
<b>CNC</b>	Canadian National Collection of Insects, Arachnids and Nematodes, Agriculture and Agri-Food Canada, Ottawa, Ontario, Canada.
<b>CCL</b>	Centre de Conservation et d'Etude des Collections Musée des Confluences, Lyon, France.
<b>LFC</b>	Natural Resources Canada, Canadian Forest Service, Laurentian Forestry Centre, R. Martineau Insectarium, Quebec City, Quebec, Canada.
<b>NHNV</b>	Natural History Museum, Vienna, Austria.
<b>RWC</b>	Reginald Webster Collection, Charters Settlement, New Brunswick, Canada.
<b>USNM</b>	United States National Museum, Smithsonian Institution, Washington, D.C., USA.
<b>ZMB</b>	Zoological Museum of Humboldt University, Berlin, Germany.
<b>ZML</b>	Museum of Zoology, Lund University, Lund, Sweden.
<b>ZMH</b>	Zoological Museum Helsinki, Helsinki, Finland.

### Checklist of Canadian *Mocyta* species

New jurisdictional records are indicated in bold type.

#### **I. *Mocyta amblystegii* species group**

- 1) *Mocyta amblystegii* (Brundin, 1952), Holarctic. Canada: YT, NT, NU; USA: AK.

- 2) *Mocyta breviscula* (Mäklin, 1852), Nearctic. Canada: YT, BC, AB, **SK**, ON, QC, NB, NS, LB, NF; USA: **OR**, AK.
- 3) *Mocyta fungi* (Gravenhorst, 1806), Palaearctic, adventive in North America, cosmopolitan in many regions of the world. Canada: YT, NU, BC, AB, **SK**, ON, QC, NB, NS, PE, LB, NF; USA: AK.

## II. *Mocyta luteola* species group

- 4) *Mocyta luteola* (Erichson, 1839), Nearctic, new Canadian record. Canada: **NB**, **QC**, **ON**; USA: IN, MA, MN, NY, WI.

## III. *Mocyta discreta* species group

- 5) *Mocyta discreta* (Casey, 1894), Nearctic, new Canadian record. Canada: **QC**, **ON**; USA: IA, MN.
- 6) *Mocyta sphagnorum* Klimaszewski & Webster, **sp. n.** Canada: **NF**, **NB**, **QC**, **ON**.

## Distribution

Each species is cited with its currently known distribution in Canada and USA. Data for distribution map (Canada only) were extracted from specimens in collections. Geographic coordinates were standardized using the NAD83 datum, and maps projected onto a Lambert Conic Conformal using ESRI ArcMap version 10 for Windows. The following abbreviations are used in the text for Canadian provinces and territories:

AB – Alberta, BC – British Columbia, LB – Labrador, MB – Manitoba, NB – New Brunswick, NF – Newfoundland (island), NS – Nova Scotia, NT – Northwest Territories, NU – Nunavut, ON – Ontario, PE – Prince Edward Island, QC – Quebec, SK – Saskatchewan, YT – Yukon Territory.

USA state abbreviations follow those of the USA Postal Service.

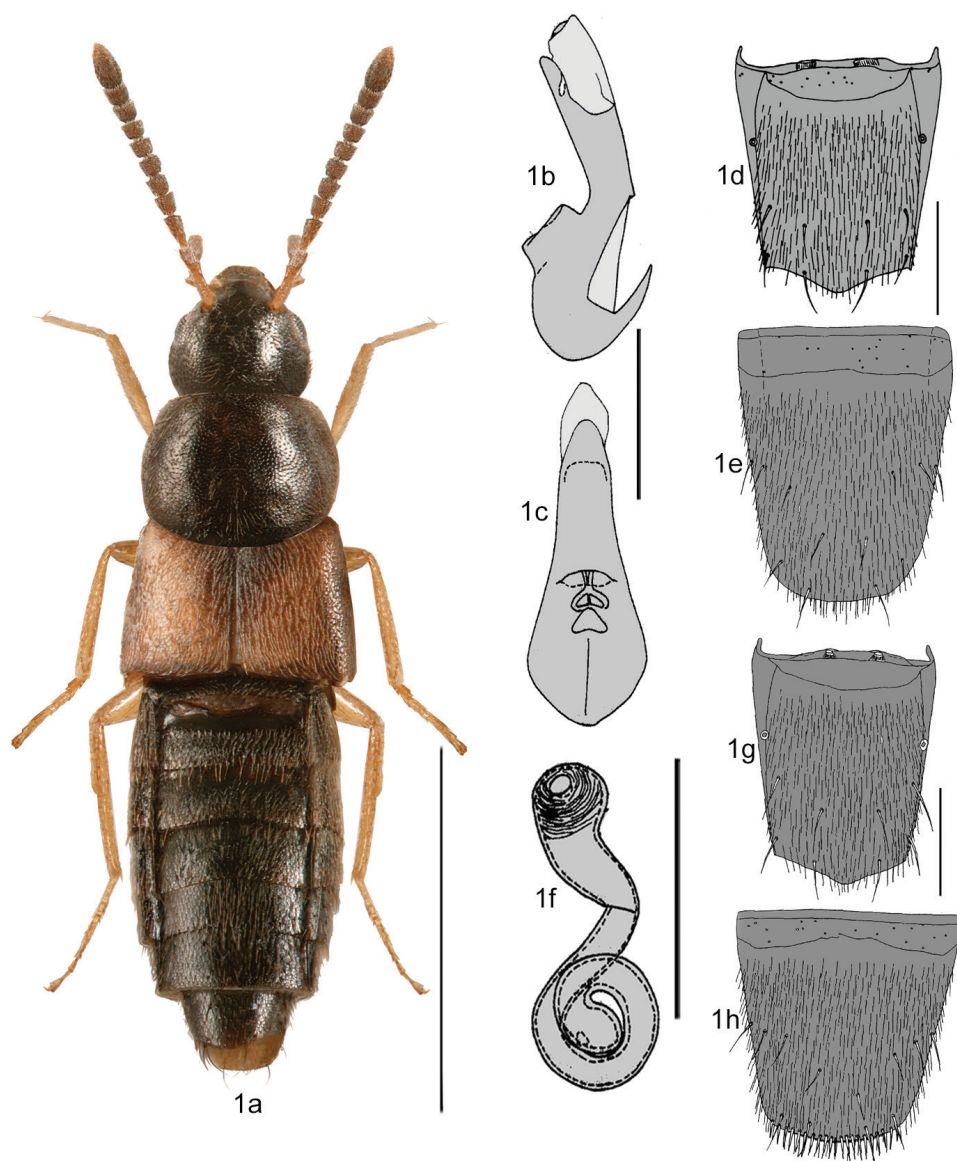
## Taxonomic review

### Tribe Athetini Casey, 1910

### Key distinguishing *Mocyta*, *Acrotona* and *Strigota*

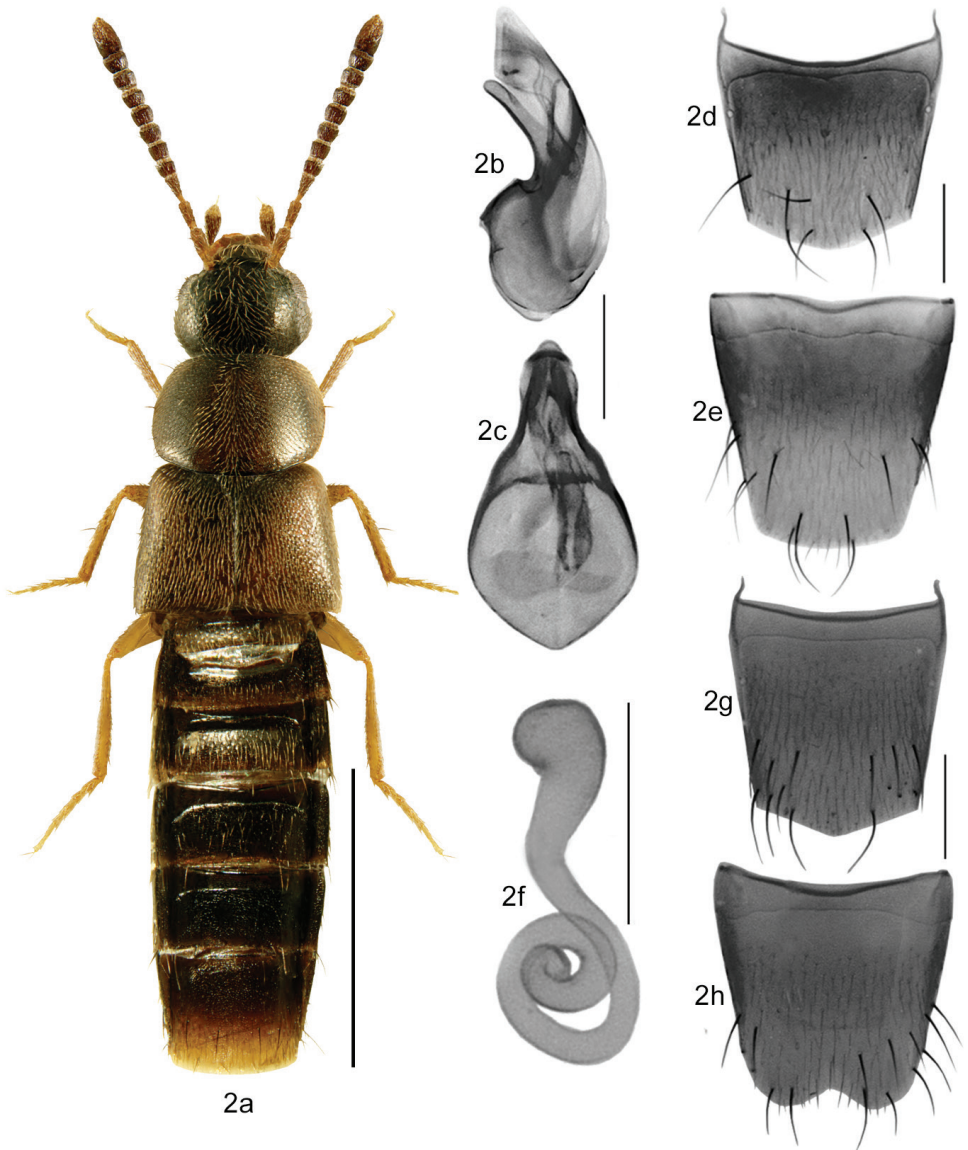
[Canadian genera with pronotal hypomeron not visible in lateral view]

- 1 Antennae thick, articles V–X more or less transverse (Fig. 1a); body narrowly elongate, densely punctate, particularly on abdomen, dorsal surface with fine white pilose pubescence (Fig. 1a); pronotum approximately as broad as maximum width of elytra (Fig. 1a); tergite VIII in both sexes with the basal line (antecostal suture) joining the base of tergite (Figs 1d, g), and not the sides of the disc as in other aleocharines; apical margin of female sternite VIII with row of strong microsetae on its dorsal side (Fig. 1h)..... ***Strigota* Casey**



**Figures 1a–h.** *Strigota ambigua* (Erichson): **1a** habitus in dorsal view **1b** median lobe of aedeagus in lateral view **1c** median lobe of aedeagus in ventral view **1d** male tergite VIII **1e** male sternite VIII **1f** spermatheca **1g** female tergite VIII **1h** female sternite VIII. Figures 1b–h after Gusarov 2003, slightly modified. Scale bar for habitus = 1 mm, and the remaining scale bars = 0.2 mm.

- Antennae in most specimens thin, articles V–X subquadrate or slightly transverse (Figs 2a–8a); body broadly to narrowly elongate, moderately densely punctate, pubescence different (Figs 2a–8a); pronotum often broader than maximum width of elytra; tergite VIII in both sexes with the basal line join-



**Figures 2a–h.** *Acrotona subpygmaea* (Bernhauer): **2a** habitus in dorsal view **2b** median lobe of aedeagus in lateral view **2c** median lobe of aedeagus in dorsal view **2d** male tergite VIII **2e** male sternite VIII **2f** spermatheca **2g** female tergite VIII **2h** female sternite VIII. Scale bar for habitus = 1 mm, and the remaining scale bars = 0.2 mm.

ing sides of the disc (Figs 2d, g, 3e, i); apical margin of female sternite VIII with less strongly developed apical microsetae (Figs 3j, 4h).....**2**  
2 Antennae very thin and pale, in most specimens contrasting in colour with head, articles V–X subquadrate, transverse to slightly elongate (Figs

3a–8a, e); pronotum broad and shield-shaped, often broader than maximum width of elytra, pubescence moderately dense and directed straight posteriad or obliquely posterolaterad from midline of disc (Figs 3a–8a, e); abdomen gradually narrowed apically and broadly rounded posteriorly; spermatheca with capsule hemispherical or elongate and sac-shaped with usually small apical invagination and short neck, stem thin and regularly or irregularly coiled posteriorly (Figs 3g, h, 4f, 5d–h, 6e–g, 7e, 8f).....

- ..... ***Mocyta* Mulsant & Rey**  
 – Antennae normally developed and not appearing very thin, usually not strongly contrasting in colour with head (Fig. 2a); pronotum subquadrate to transverse, approximately as wide as elytra, pubescence usually very dense and directed lateroposteriad from midline of disc (Fig. 2a); abdomen tapering apically and often slightly pointed; spermatheca differently shaped, capsule more or less spherical and extended to elongate neck, stem broader than that in *Mocyta*, regularly coiled posteriorly and often with swelled apex (Fig. 2f) ..... ***Acrotona* Thomson**

### ***Mocyta* Mulsant & Rey, 1874**

For synonymy, see Gusarov 2003, Lohse et al. 1990, Smetana 2004

**Diagnosis.** *Mocyta* may be distinguished from the other genera of Canadian Aleocharinae except for *Acrotona* Thomson and *Strigota* Casey, by having the pronotal hypomeron not visible in lateral view. From *Acrotona* and *Strigota*, as well as other aleocharine genera, it may be distinguished by the following combination of characters: antennae very thin and pale, in most specimens contrasting with body colour (Figs 3a–7a); pronotum glossy, moderately convex, broad and shield-shaped, widest at or near middle, with pubescence directed posteriad in midline or entire central section of disc (Fig. 6a) and posterolaterad at sides, pronotum is at least as broad as the base of the elytra but in most specimens broader (Figs 3a–7a); median lobe of aedeagus of a simple form, tubus *ca.* half length of median lobe, narrowly tapering and rounded apically in dorsal view (Figs 3d, 4c, 5c) and straight and narrow apically in lateral view (Figs 3b, c, 4b, 5b, 6b), internal sac structures inconspicuous, usually elongate and not strongly pronounced (Figs 3b–d, 4b, c, 6b); male tergite VIII truncate apically and without teeth and other secondary sexual characters (Figs 3e, 4d, 5i, 6c), sternite VIII with longer macrosetae than those of females (Figs 3f, 4e, 6d); spermatheca with capsule hemispherical, or elongate and sac-shaped with usually small apical invagination and short neck, stem thin and regularly or irregularly coiled posteriorly (Figs 3g, h, 4f, 5d–h, 6e–g).

The shape of the spermatheca in *Acrotona* is different, with a capsule more or less spherical and extended to a broad and long neck, often pitcher-shaped, and a stem that is broader than that in *Mocyta*, regularly coiled posteriorly and often with a swelled apex (Fig. 2f). *Strigota* may be easily distinguished from *Mocyta* and *Acrotona* by the



basal line of the abdominal tergum VIII laterally joining the base of the tergum in both sexes (Figs 1d, g), while in other athetines the basal line is separated from the tergite base (Figs 3e, i). For illustrations, see also Gusarov (2003).

### Key to Canadian species of the genus *Mocytta*

- 1 Body bicoloured, head and at least posterior part of abdomen brown to almost black, and remainder of the body reddish to yellowish-brown, pronotum in most specimens paler than the rest of the body, in some specimens elytra mottled with small and irregular in shape darker spots (Figs 6a, 7a); genital structures as illustrated (Figs 6b, c–g, 7b–e).....2
- Body uniformly brown to black except for paler appendages in most specimens.....3
- 2 Pronotum approximately as broad as elytra (Fig. 6a); antennal articles V–X subquadrate (Fig. 6a); median lobe of aedeagus with tubus arcuate and apex pointing ventrally in lateral view (Fig. 6b); spermatheca with capsule sac-shaped and sinuate stem irregularly coiled posteriorly (Figs 6e–g); eastern Canada ..... *Mocytta luteola* (Erichson)
- Pronotum much broader than elytra (Fig. 7a); antennal articles V–X in most specimens slightly elongate; median lobe of aedeagus with tubus straight and apex in horizontal position in lateral view; spermatheca with capsule club-shaped and straight stem coiled posteriorly (Figs 7b, e); eastern Canada ..... *Mocytta discreta* (Casey)
- 3 Elytra distinctly longer than pronotum (Figs 3a, 5a).....4
- Elytra as long as or slightly shorter than pronotum (Figs 4a, 8a, e).....5
- 4 Pronotum approximately rectangular in shape, gradually narrowed in apical third of its length (Fig. 5a); spermathecal capsule pear-shaped, rounded apically and gradually narrowed posteriorly, apical invagination small and shallow, stem thin and irregularly twisted posteriorly (Figs 5d–h); only females are present in North America; adventive species broadly distributed across North America and transcontinental in Canada *Mocytta fungi* (Gravenhorst)
- Pronotum approximately trapezoidal in shape, strongly narrowed apically from basal third of its length (Fig. 3a); spermathecal capsule narrowly elongate and sac-shaped, apical invagination small and shallow; stem sinuate and irregularly twisted or coiled posteriorly (Figs 3g, h); median lobe of aedeagus with tubus straight in lateral view (Figs 3b, c); holarctic species known from northwestern Canada and Alaska ..... *Mocytta amblystegii* (Brundin)
- 5 Pronotum as broad as elytra (Fig. 4a); spermatheca with capsule pitcher-shaped and flat apically with elongate apical invagination, stem broadly coiled posteriorly (Fig. 4f); median lobe of aedeagus with tubus straight in lateral view (Fig. 4b); transcontinental in Canada and reported from Alaska, Oregon, California and Nevada ..... *Mocytta breviscula* (Mäklin)

- Pronotum in many specimens broader than elytra (Fig. 8e); spermatheca with capsule pear-shaped with short apical invagination, stem broadly irregularly coiled posteriorly (Fig. 8f); median lobe of aedeagus with tubus straight and apex in horizontal position in lateral view (Fig. 8b); known from sphagnum in black spruce and cedar forests and swamps; distributed in eastern Canada  
 ..... *Mocyta sphagnorum* Klimaszewski & Webster, sp. n.

### I. *Mocyta amblystegii* species group

**Diagnosis.** Body entirely dark brown to black except for light-coloured appendages; pronotum moderately transverse, approximately as broad as elytra or slightly broader, sides arcuate, pubescence directed posteriad only in midline and obliquely posteriad elsewhere (Figs 3a, 4a, 5a); elytra in most specimens longer than pronotum (Figs 3a, 5a) except for *M. breviscula* (Fig. 4a); spermatheca and median lobe of aedeagus as illustrated (Figs 3b–d, g, h, 4b, c, f, 5b–h).

#### 1. *Mocyta amblystegii* (Brundin)

Figs 3a–j

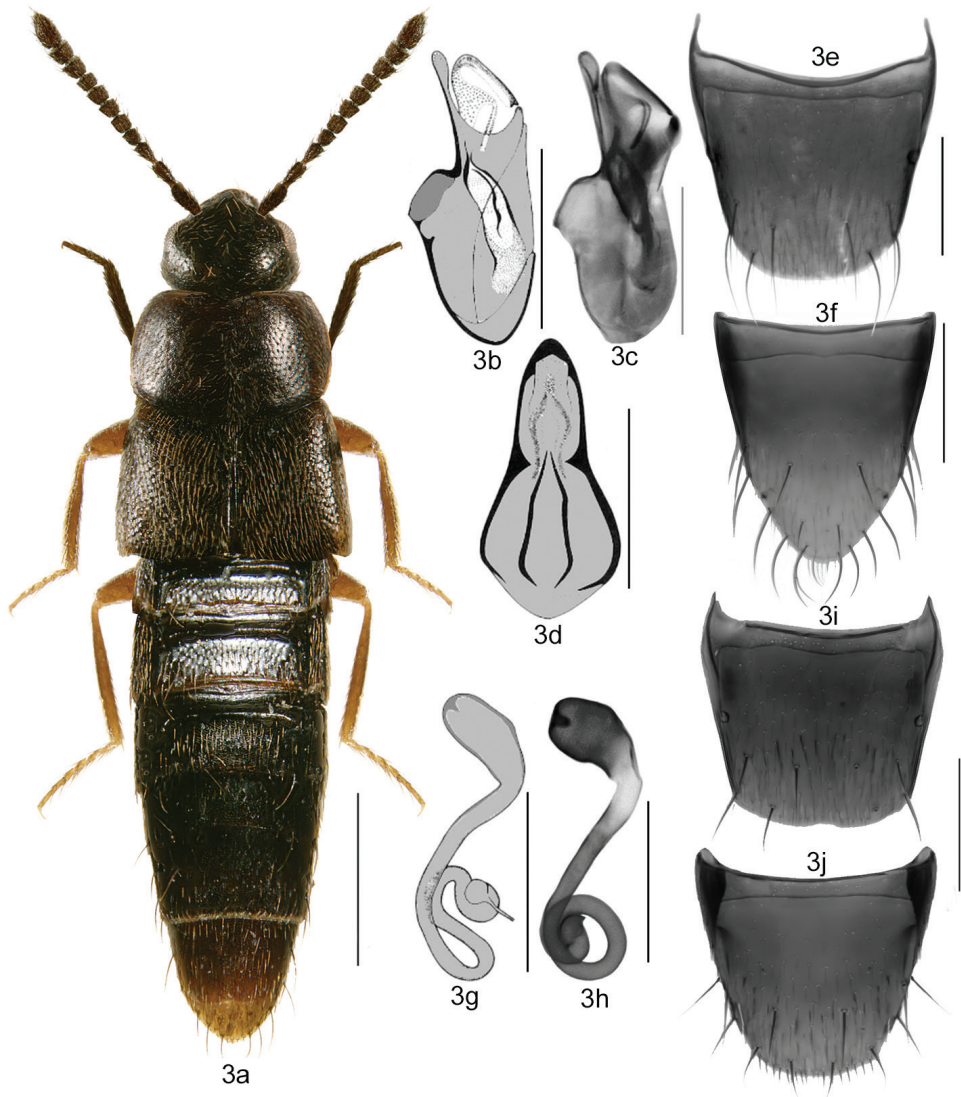
*Atheta amblystegii* Brundin 1952: 135; Lohse et al. 1990, Smetana 2004.

**Diagnosis.** Body narrowly oval (Fig. 3a), length 2.5–3.0 mm; uniformly brown to black, appendages light brown (Fig. 3a); antennal articles I–IV elongate and V–X subquadrate or slightly transverse (Fig. 3a); pronotum broad, strongly transverse, rounded laterally and arcuate basally; elytra transverse and at least as long as pronotum; broadly arcuate laterally. MALE: median lobe of aedeagus as illustrated (Figs 3b–d); tergite VIII truncate apically (Fig. 3e); sternite VIII produced apically, with numerous macrosetae and with a broad space between base of disc and antecostal suture, the suture nearly straight or slightly sinuate (Fig. 3f). FEMALE: spermatheca with capsule sac-shaped, as illustrated (Figs 3g, h); tergite and sternite VIII truncate apically (Figs 3i, j).

Adults are externally similar to those of *M. fungi* and may be identified with certainty by the pear-shaped capsule of spermatheca. The presence of males in Canadian populations of *M. amblystegii* and lack of males in Canadian populations of *M. fungi* may also aid in identification of this species.

**Distribution.** *Mocyta amblystegii* is, according to Lohse (Lohse et al. 1990), a holarctic species recorded in North America from Alaska, Northwest Territories, Yukon and northern Manitoba (Lohse et al. 1990). In Europe, it is recorded from Finland, Norway, and Sweden (Smetana 2004).

**Natural history.** Adults were found under leaf litter and in moss (Lohse et al. 1990).

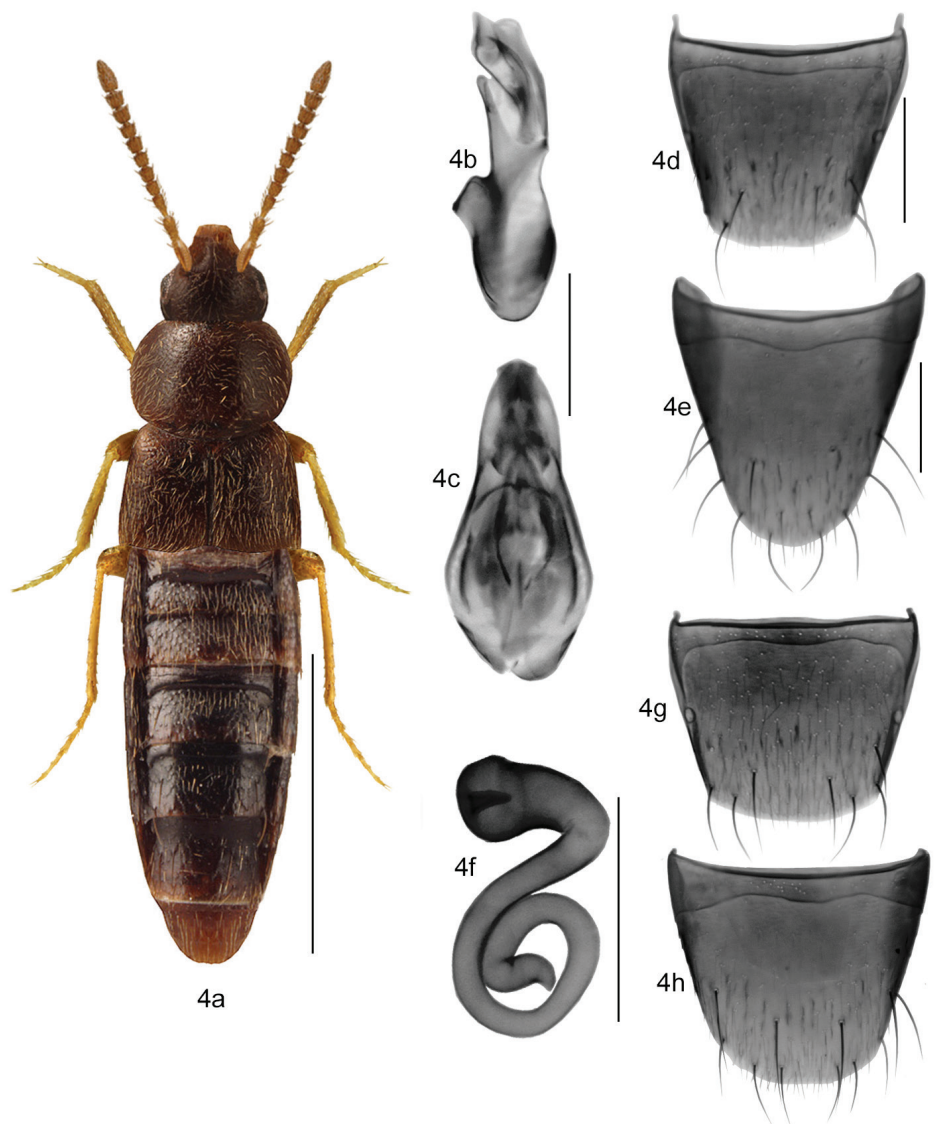


**Figures 3a–j.** *Mocyta amblystegii* (Casey): **3a** habitus in dorsal view **3b, c** median lobe of aedeagus in lateral view **3d** median lobe of aedeagus in dorsal view **3e** male tergite VIII **3f** male sternite VIII **3g–h** spermatheca **3i** female tergite VIII **3j** female sternite VIII. Scale bar for habitus = 1 mm, and the remaining scale bars = 0.2 mm.

## 2. *Mocyta breviuscula* (Mäklin)

Figs 4a–h

*Homalota breviuscula* Mäklin in Mannerheim, 1852: 309; Lohse and Smetana 1985: 285, 292 (as *Atheta* subgenus *Mocyta*, redescription based on type); Klimaszewski et al. 2011: 107, 218, 246; Gusarov 2003: 100–102. **LECTOTYPE** (male): UNITED STATES, Alaska, Sitka (Sitka); Lectotype, Lohse designation 1983



**Figures 4a–h.** *Mocyta breviscula* (Brundin): **4a** habitus in dorsal view **4b** median lobe of aedeagus in lateral view **4c** median lobe of aedeagus in dorsal view **4d** male tergite VIII **4e** male sternite VIII **4f** spermatheca in lateral view **4g** female tergite VIII **4h** female sternite VIII. Scale bar for habitus = 1 mm, and the remaining scale bars = 0.2 mm.

(ZMH). An extensive list of synonymies for *M. breviscula* is provided by Gusarov 2003: 101.

*Acrotona prudens* Casey 1910: 149; synonymized by Lohse and Smetana 1985: 293. Type localities: British Columbia, Queen Charlotte Islands and Metlakatla (Casey 1910: 149). **LECTOTYPE** (female): 2 CI [Queen Charlotte Islands], Type USNM 38985 (USNM), present designation.

**Diagnosis.** Body narrowly oval (Fig. 4a), length 2.4–3.0 mm; body uniformly dark brown to almost black and often with reddish tinge, appendages yellowish to reddish-brown; antennal articles I–IV elongate and V–X subquadrate; pronotum transverse, arcuate laterally and arcuate basally; elytra transverse and nearly as long as pronotum; abdomen broadly arcuate laterally. MALE: Median lobe of aedeagus as illustrated (Figs 4b, c); tergite VIII truncate apically (Fig. 4d); sternite VIII slightly produced apically with broad space between base of the disc and antecostal suture, the suture more or less sinuate (Fig. 4e). FEMALE: spermatheca with capsule pitcher-shaped and flat apically with elongate apical invagination, stem broadly coiled posteriorly (Fig. 4f); tergite and sternite VIII truncate apically (Figs 4g, h).

The combination of uniform body colour, elytra no longer than pronotum, distinct shape of spermatheca with deep capsular invagination, and shape of male sternite VIII with broad space between base of disc and antecostal suture, can distinguish *M. breviscula* from the remaining Nearctic congeners.

**Distribution.** *Mocyta breviscula* is a native Canadian species distributed transcontinentally in northern Canada, and it was also reported from Alaska, California and Nevada (Lohse and Smetana 1985, Lohse et al. 1990, Gusarov 2003, Webster et al. 2009, Klimaszewski et al. 2005, 2007b, 2008, 2011, Majka and Klimaszewski 2008, Brunke et al. 2012). We include new records of this species from Saskatchewan and Oregon (see below for new distribution localities).

**Natural history.** In Newfoundland, adults were frequently caught in pitfall traps in various forest types (birch, spruce-lichen, spruce-poplar, fir), in vegetation on coastal sand dunes, on shrubby limestone barrens and in disturbed fields amongst grass and weeds (Klimaszewski et al. 2011). The activity period is June to September. Adults were captured in pitfall traps from June to August in yellow birch/balsam fir forest in southern Quebec and in sphagnum and litter in an eastern white cedar swamp in New Brunswick (Klimaszewski et al. 2005, 2007b, Webster et al. 2009).

**New jurisdictional records.** CANADA: Saskatchewan, Saskatoon, 28.IX.1976, E.J. Kiteley (CNC) 1 male.

UNITED STATES: Oregon, Grant Co., Strawberry Range, Strawberry Lake, 1920 m, 1.VI.1989, A. Smetana, NA21 (CNC) 3 males, 1 female.

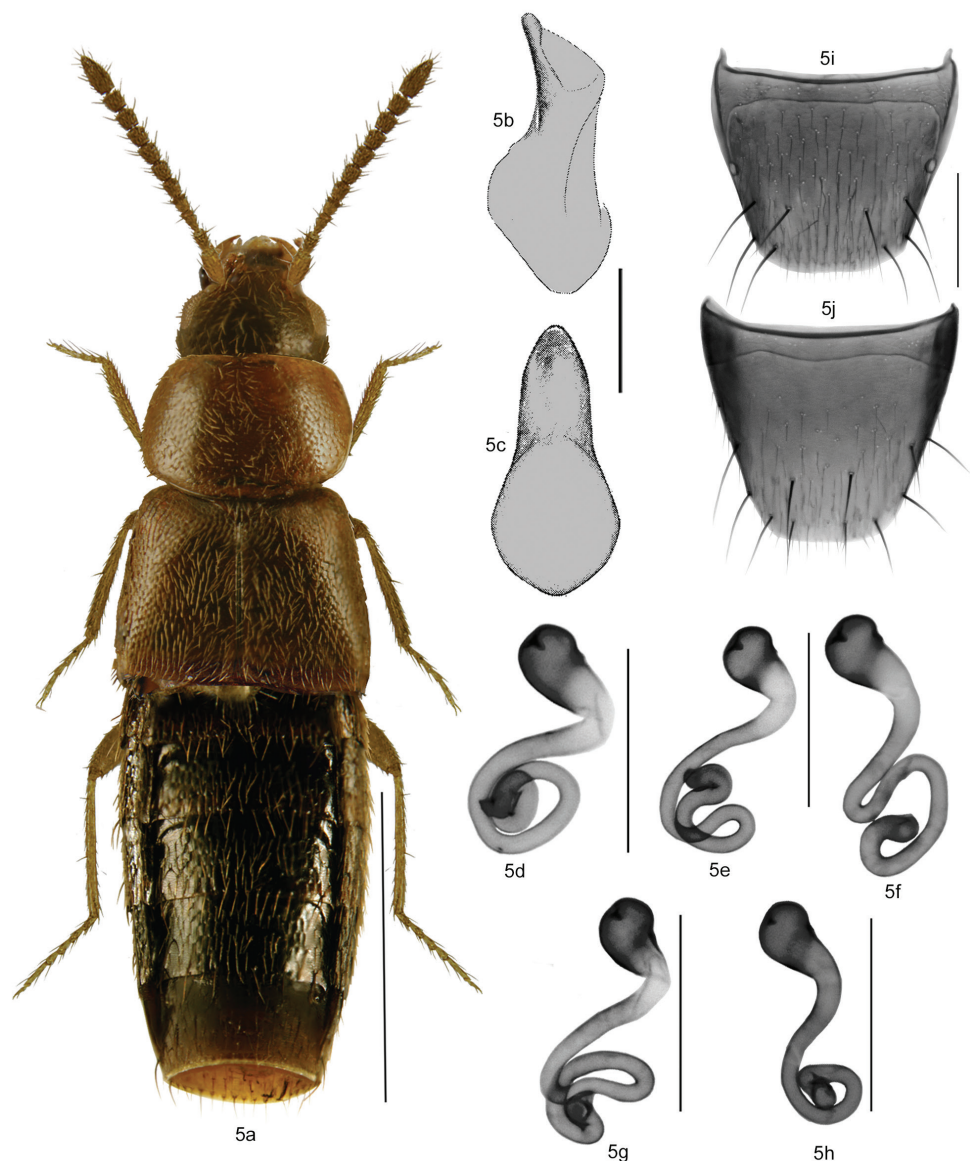
### 3. *Mocyta fungi* (Gravenhorst)

Figs 5a–j

*Aleochara fungi* Gravenhorst 1806: 157; Muona 1984, Gusarov 2003, Smetana 2004, McLean et al. 2009, Klimaszewski et al. 2011. For extensive synonymy, see Gusarov 2003 and Smetana 2004. **LECTOTYPE** (female): *Aleochara fungi* Gravenhorst; Lectotype, V. Mahler des. 1986; Europa, nr. 5499; typus; *fungi* Gr. (ZMB) [examined by Klimaszewski].

**Diagnosis.** Body broadly oval (Fig. 5a), length 2.4–3.0 mm; body uniformly dark brown to black, in some specimens body black and posterior or central part of elytra





**Figures 5a–j.** *Mocyta fungi* (Gravenhorst): **5a** habitus in dorsal view **5b** median lobe of aedeagus in lateral view **5c** median lobe of aedeagus in ventral view **5d–h** spermatheca **5i** female tergite VIII **5j** female sternite VIII. Scale bar for habitus = 1 mm, and the remaining scale bars = 0.2 mm.

with reddish tinge, appendages light brown; antennal articles I–IV elongate and V–X subquadrate or slightly transverse; pronotum broad, transverse, rounded laterally and arcuate basally; elytra transverse and *ca.* as long as pronotum or longer; abdomen broadly arcuate laterally (Fig. 5a). MALE: median lobe of aedeagus as illustrated (Figs 5b, c) [absent in North America]. FEMALE: spermatheca with capsule pear-shaped, as illustrated (Figs 5d–h); tergite VIII truncate apically (Fig. 5i); sternite VII broadly

rounded apically with fringe of microsetae, distance between antecostal suture and base of disc narrow, antecostal suture sinuate (Fig. 5j).

This species is externally very similar to *M. amblystegii* and may be identified with certainty only by the shape of the spermatheca. The presence of males in Canadian populations of *M. amblystegii* and lack of males in Canadian populations of *M. fungi* may also aid in the identification of these species.

**Distribution.** Palaearctic, adventive in North America, cosmopolitan in many regions of the world (Smetana 2004). Canada: YT, NU, BC, AB, **SK**, ON, QC, NB, NS, PE, LB, NF, and USA: AK, ME, MA, MN, NY, OR, RI (Moore and Legner 1975, Muona 1984, Gusarov 2003, Klimaszewski et al. 2005, 2007a, 2008, 2011, 2012, Majka and Klimaszewski 2008, 2010, Brunke et al. 2012). We include new records of this species from Saskatchewan in Canada.

**Natural history.** *Mocyta fungi* is represented in North America by parthenogenetic females only. In Newfoundland, adults were collected in pitfall traps in cut and burned balsam fir, birch, spruce-poplar and riparian forests, in agricultural fields and amongst vegetation on coastal sand dunes (Klimaszewski et al. 2011). The adult activity period in Newfoundland is June to September. Adults were captured by pitfall traps from May to September in forest litter in mixed wood, red spruce in New Brunswick and yellow birch forest in southern Quebec (Klimaszewski et al. 2005, Majka and Klimaszewski 2010).

**New jurisdictional records.** CANADA: **Saskatchewan:** Cypress Hills, wet willow stand, 49,5978°, -109,9231°, 1134 m, 2.IX.2012, 2 males; wet pond, riparian, 49,6704°, -109,5005°, 1189 m (LFC) 1 female.

## II. *Mocyta luteola* species group

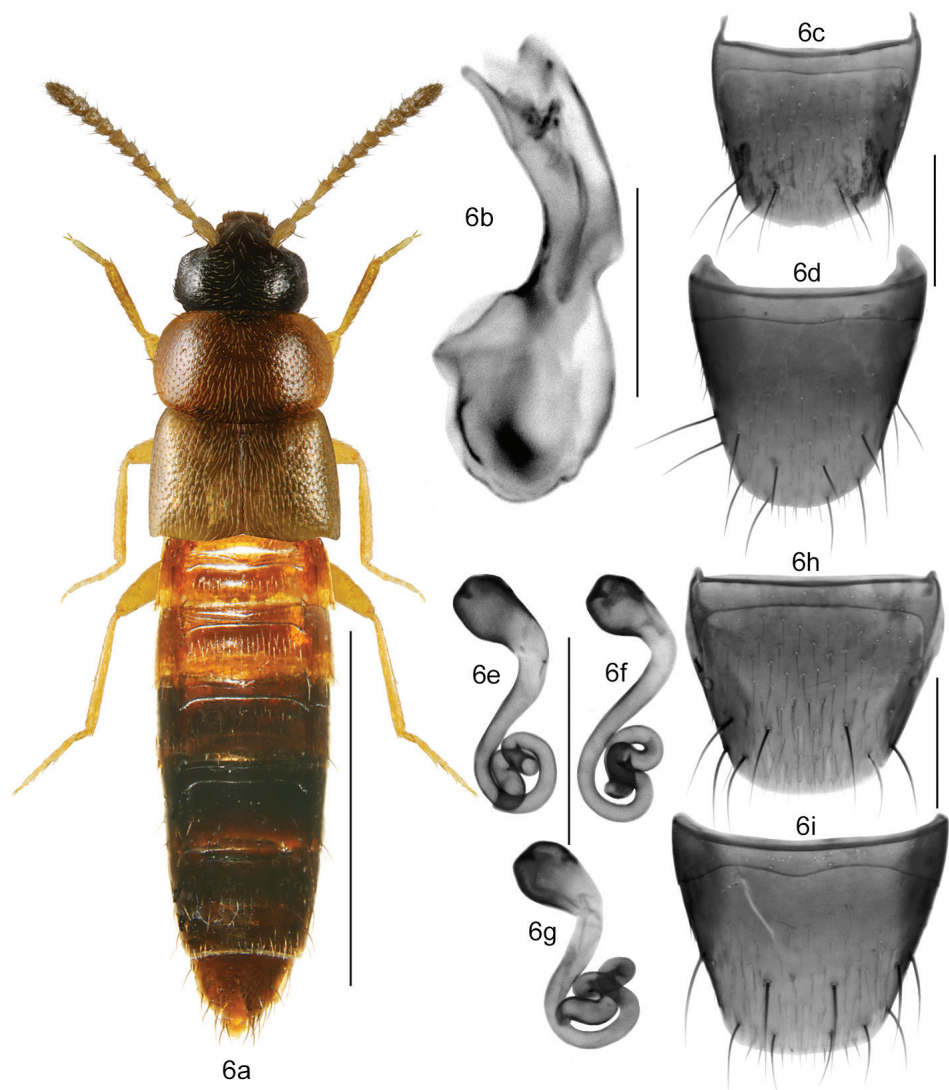
**Diagnosis.** Pronotum strongly transverse, 1.5 times broader than long, sides arcuate, pubescence directed posteriad in midline and central part of the disc (Fig. 6a); elytra approximately as wide as pronotum (Fig. 6a); spermatheca and median lobe of aedeagus as illustrated (Figs 6b, e–g).

### 4. *Mocyta luteola* (Erichson)

Figs 6a–i, Map 1

*Homalota luteola* Erichson 1839: 114 [habitat in America septentrionalis, Dom. Zimmerman]; Bland 1865: 397; Blatchley 1910: 353; Moore and Legner 1975: 365.

**LECTOTYPE** (male): USA: Am.[America] spt.[septentrionalis], Zimm. [Zimmerman]; #5432; Zool. Mus. Berlin.; typus; Lectotype male *Homalota luteola* Erichson, V.I. Gusarov des. 2003 [designation not published]; our lectotype designation label (ZMB) present designation. **PARALECTOTYPES:** labelled as lectotype (ZMB) 1 male, 1 female, present designation.



**Figures 6a–i.** *Mocyta luteola* (Erichson): **6a** habitus in dorsal view **6b** median lobe of aedeagus in lateral view **6c** male tergite VIII **6d** male sternite VIII **6e–g** spermatheca **6h** female tergite VIII **6i** female sternite VIII. Scale bar for habitus = 1 mm, and the remaining scale bars = 0.2 mm.

*Dolosota redundans* Casey 1910: 137; Moore and Legner 1975: 372. **syn. n. LECTOTYPE** (female): United States of America: NY [New York]; *redundans* Casey; Type USNM 39197; Casey bequest 1925; *Dolosota redundans* Casey - Lectotypus des. Gusarov 2000. *Acrotona luteola* (Er.) V.I. Gusarov det. 2000. We have added J. Klimaszewski's lectotype, present designation label because Gusarov's designation was never published (USNM). **PARALECTOTYPES:** United States of America: NY [New York]; *redundans* Casey; Type USNM 39197 (USNM) 2 females, present designation.

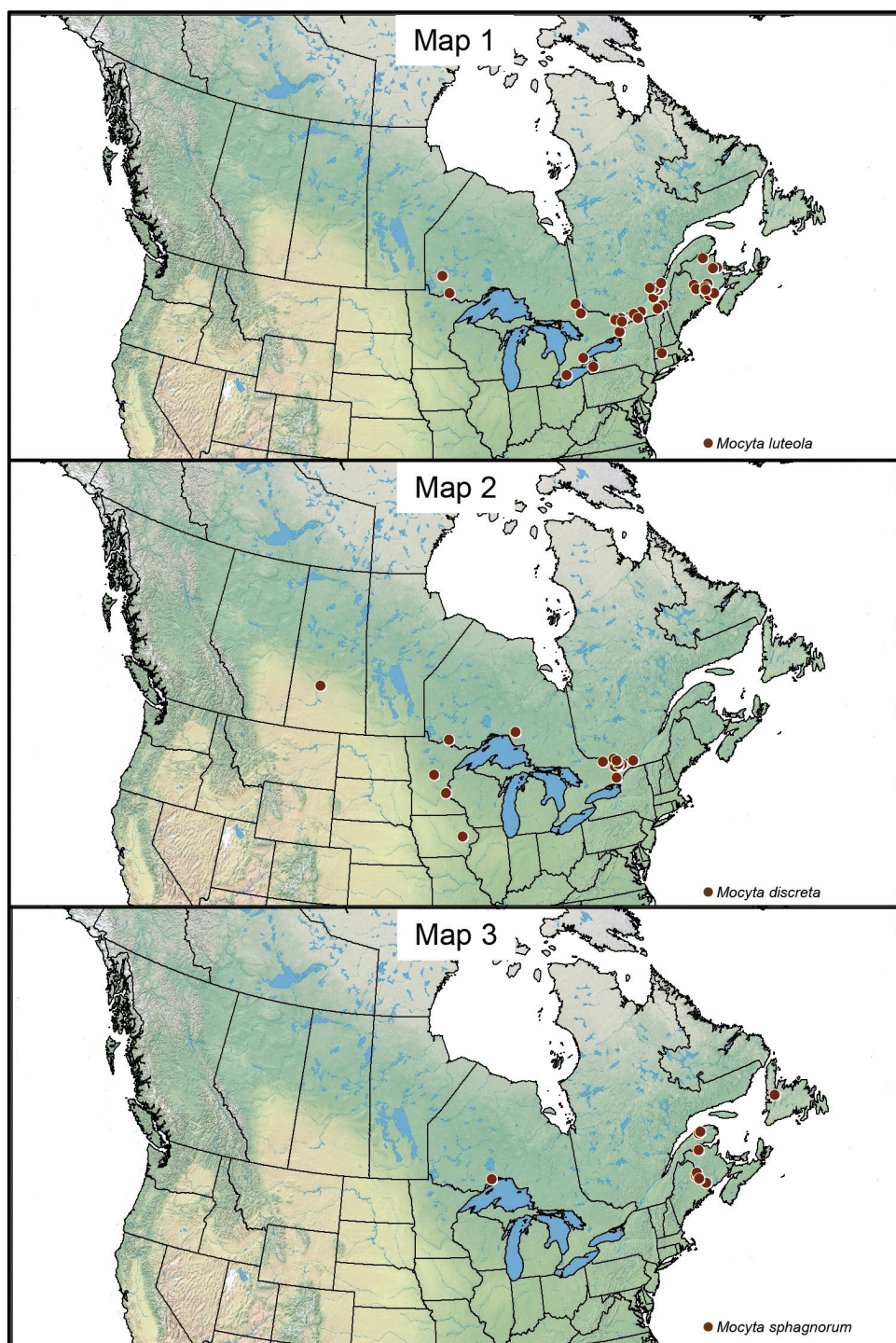
**Diagnosis.** Body narrowly elongate (Fig. 6a), length 1.8–2.6 mm; head and posterior part of abdomen from brown to almost black, pronotum and basal half of abdomen light yellowish-brown to reddish brown, elytra yellowish to reddish-brown with some irregular small dark brown spots; legs and palps yellowish-brown and antennae either uniformly yellowish or basal articles I–IV yellowish and apical ones light brown; antennal articles I–IV elongate and V–X subquadrate to slightly transverse; pronotum short, transverse, strongly rounded laterally, and arcuate basally (Fig. 6a); elytra *ca.* as long as pronotum (Fig. 6a); abdomen broadly arcuate laterally. MALE: median lobe of aedeagus as illustrated (Fig. 6b); tergite VIII truncate apically, distance between base of disc and antecostal suture moderate in width, suture slightly sinuate medially (Fig. 6c); sternite VIII rounded apically (Fig. 6d). FEMALE: spermatheca with capsule small, pear-shaped and with shallow invagination, stem thin and twisted posteriorly, twists are irregular in shape or forming more or less regular coils (Figs 6e–g); tergite VIII truncate apically (Fig. 6h); sternite VIII broadly rounded apically with apical fringe of short microsetae, distance between base of disc and antecostal suture narrow, suture strongly sinuate medially (Fig. 6i).

**Distribution.** This native Nearctic species is reported in Canada for the first time from New Brunswick, Quebec, and Ontario (Map 1). In the USA, new records are provided for Massachusetts and Minnesota, and an additional record is provided for New York. The species was previously reported from Indiana, Michigan, New York and Wisconsin (Erichson 1839, Casey 1910, Bland 1865, Blatchley 1910, Moore and Legner 1975).

**Natural history.** Most adults from Quebec were collected in yellow birch and balsam fir dominated forest using pitfall traps (Klimaszewski et al. 2007b). In New Brunswick, adults were found: under decaying seaweed on sea beach; under driftwood on a riverbank; in grass, moss and leaf litter near water in alder and cedar swamps and *Carex* marshes; in *Spagnum* moss and leaf litter in a young regenerating mixedwood forest; and in other decaying material in forests. In Ontario, adults were captured in litter around raspberry bushes near a bog, in a *Typha* marsh, and in a nest of *Microtus pennsylvanicus*. Adults were active from March to October in Canada. In Minnesota, adults were captured on a lakeshore and in a *Microtus* nest, and in Indiana were taken by sifting dump vegetable debris from March to November (Blatchley 1910).

**Locality data.** CANADA: **New Brunswick:** Carleton Co., Bell Forest, 46.2152°N, 67.7192°W, 11.V.2005, river margin, under drift material, M.-A. Giguère & R. Webster (RWC) 1 sex undetermined; Charlotte Co., ca. 9 km NW of New River, 45.2096°N, 66.6483°W, 13.VI.2005, alder swamp near large brook, in grass and leaf litter, R.P. Webster (RWC) 1 male. Kent Co., Kouchibouguac Nat. Pk., 21.IX.1977, D.B. Lyons (CNC) 1 female; same data except A. Smetana (CNC) 1 female, and S.J. Miller (CNC) 1 female. Northumberland Co., Goodfellow Brook P.N.A., 46.8943°N, 65.3796°W, 23.V.2007, old-growth eastern white cedar swamp, in litter & grasses & moss on hummocks near water, R.P. Webster (RWC) 1 female; Restigouche Co., Jacquet River Gorge P.N.A., 47.8200°N, 66.0015°W, 13.V.2010, *Carex* marsh, under alders in leaf litter & moss near brook, R.P. Webster (RWC) 1 female; Saint John





**Maps 1–3.** 1 Distribution of *Mocyta cupiens* (Casey) in Canada 2 Distribution of *Mocyta discreta* in Canada 3 Distribution of *Mocyta sphagnum* in Canada.



Co., Taylor's Island, 45.2238°N, 66.1265°W, 26.VII.2004, sea beach, under decaying seaweed, R.P. Webster (RWC) 1 sex undetermined; Sunbury Co., 46.0173°N, 66.3741°W, 18.VI.2007, Road 16 regenerating forest, 8.5 year-old regenerating mixed forest, in sphagnum & leaf litter, R.P. Webster (RWC) 1 female; York Co., Canterbury, trail to Browns Mtn. Fen, 45.8978°N, 67.6273°W, 2.V.2005, Mature cedar forest near stream, sifting leaf litter, M. Giguère (RWC) 1 female; Rt. 645 at Beaver Brook, 45.6860°N, 66.8668°W, 3.V.2008, *Carex* marsh in litter at base of dead red maple, R.P. Webster (RWC) 1 female; Charters Settlement, 45.8395°N, 66.7391°W, 14.VI.2008, mixed forest, in decaying (moldy) corncobs & cornhusks, R.P. Webster (RWC) 1 female; 8.5 km W of Tracy, off Rt. 645, 45.6821°N, 66.7894°W, 6.V.2008, wet alder swamp, in leaf litter & grass on hummocks, R.P. Webster (RWC) 1 female.

**Quebec:** Blandford, 13.V.1971, E.J. Kiteley (CNC) 1 female; Hudson Heights, 24–30.VII.1956, Lindberg (CNC) 1 female; Montreal, 22.IX.1968, E.J. Kiteley (CNC) 1 male; Montreal, 30.IX.1968, E.J. Kiteley (CNC) 8 females; Montreal, 16.V.1969, E.J. Kiteley (CNC) 2 females; Montreal, 5.X.1979, E.J. Kiteley (CNC) 1 female; Montreal, 4.V.1980, E.J. Kiteley (CNC) 1 female; Ormstown, 22.VIII.1980, E.J. Kiteley (CNC) 1 female; Rigaud end Ch. de la Croix, 5.V.1988, A. & Z. Smetana (CNC) 2 females; Saint-Etienne, Lévis, 6.VI.1981, C. Chantal (CNC) 1 female; Ste-Catherine, Port., 5.VIII.1961, J.C. Aubé (CNC) 4 females; Scotstown, 29.V.2006, C. Levesque (LFC) 4 females, 1 sex?; Mcy Co., St-Joachim, 11.VI.1963, C. Chantal (CNC) 1 female; Sherbrooke, 20.IX.1972, Dondale and Redner (CNC) 1 female; Portneuf, ZEC Batiscan-Nelson, SSAM project, Sapinière à bouleau jaune, Lac des Étangs, 4 gaps, Pitfall trap 21, 46°58'08"N, 72°02'57"W, 30.VI–07.VII.2008, 1 specimen; Pitfall trap 23, 46°58'08"N, 72°02'57"W, 1 specimen; Lac Poissonneux, clear cut, Pitfall trap 66, 47°02'48"N, 72°07'29"W, 297 m, 12.VIII–19.VIII.2008, 1 specimen; 2 gaps, Pitfall trap 69, 47°02'N, 72°07'W, 15.VII–22.VII.2008, 1 specimen; Clear cut, Pitfall trap 95, 47°02'N, 72°07'W, 1 specimen; 2 gaps, Pitfall trap 98, 47°02'N, 72°07'W, 22.VII–29.VII.2008, 1 specimen; 29.VII–05.VIII.2008, 1 specimen; 25.VI–02.VII.2008, 2 specimens; Pitfall trap 99, 27.V–03.VI.2008, 1 specimen; Pitfall trap 100, 12.VIII–19.VIII.2008, 1 specimen; Pitfall trap 101, 02.VII–08.VII.2008, 1 specimen; Pitfall trap 102, 12.VIII–19.VIII.2008, 1 specimen; 22.VII–29.VII.2008, 1 specimen; 8 gaps, Pitfall trap 103, 47°02'N, 72°07'W, 22.VII–29.VII.2008, 1 specimen; Pitfall trap 105, 25.VI–02.VII.2008, 1 specimen; Pitfall trap 107, 25.VI–02.VII.2008, 1 specimen; 4 gaps, Pitfall trap 109, 47°02'N, 72°07'W, 25.VI–02.VII.2008, 2 specimens; 08.VII–15.VII.2008, 1 specimen; Pitfall trap 110, 1 specimen; 10.VI–17.VI.2008, 2 specimens; Pitfall trap 111, 17.VI–25.VI.2008, 1 specimen; 25.VI–02.VII.2008, 1 specimen; Pitfall trap 113, 08.VII–15.VII.2008, 1 specimen; 10.VI–17.VI.2008, 1 specimen.

**Ontario:** Ancaster, 28.III.1963, J.E.H. Martin (CNC) 4 females; Carleton Co., Fitzroy Prov. Pk., 2–3.V.1979, A. & Z. Smetana (CNC) 1 female; Mer Bleue, 3.III.1973, Redner and Starr (CNC) 27 females; Ottawa, Mer Bleue bog, 16.IV.1972, litter around raspberry, L. LeSage (CNC) 4 females, 1 sex?; Mer Bleue, 17.X.1980, en fauchant herbages dans un champ, L. LeSage (CNC) 7 females; Ottawa, 22.VIII.1912, Beaulieu (CNC) 1 female; Ottawa, Shirleys Bay, 2.V.1970, A. & Z. Smetana (CNC) 1 female; Ottawa,

Mer Bleue bog, 23.IV.1982, ridge litter, L. LeSage (CNC) 5 females; Carlsbad Springs, Mer Bleue, 23.V.1980, A. Smetana (CNC) 9 females; Kinburn, 8.VI.1962, ex *Microtus* nest, J.E.H. Martin (CNC) 9 females; Ottawa, Black Rapids, 19.VIII.1959, J.R. Vockeroth (CNC) 3 females; Osgoode, 20.X.1967, ex nest of *Microtus pennsylvanicus*, J.M. Campbell and A. Smetana (CNC) 7 females; 6 mi. W. Richmond, 28.III.1973, J.E.H. Martin (CNC) 1 female; Rondo Provincial Park, Marsh Trail, 2.VI.1985, tread *Typha* in marsh, A. Davies and J.M. Campbell (CNC) 1 female; South March, 19.X.1967, A. Smetana (CNC) 1 female; 19 mi. S. Temagami, 1-13.VIII.1973, J. Redner and C. Starr (CNC) 1 female; North Bay, 11.VII.1972, E.J. Kiteley (CNC) 1 female.

UNITED STATES OF AMERICA: **Massachusetts**: Northampton, 5.XI.1978, E.J. Kiteley (CNC) 2 females; **Minnesota**, Minneapolis, 25.VI.1958, E.J. Kiteley (CNC) 1 female; New York: Chautauqua Co., Lake Shore, Sheridan, II.1968, ex nest of *Microtus pennsylvanicus*, A.H. Benton (CNC) 1 female.

**Comments.** In new material of *Mocytta* from Quebec and New Brunswick, we discovered an unrecorded bicoloured species from Canada that was similar in body size, coloration and shape of spermatheca to the native *Mocytta luteola* (Erichson) and the European *Mocytta negligens* (Mulsant & Rey) and *Mocytta gilvicollis* (Scheerpeltz). After examining the types and additional specimens of the two European species and *Mocytta luteola* and comparing them with Canadian individuals of our new species, we have concluded that our populations represent *Mocytta luteola* and that they are not conspecific with the two European species, as they differ in external morphological features such as body proportions, microsculpture, and shape and pubescence of pronotum. After examining the types of both nominal species (*M. negligens*, *M. gilvicollis*), and additional specimens from Europe, we found no significant morphological differences between the two species. Therefore these two European species are considered as conspecific, and *M. gilvicollis* is considered as a new synonym of *M. negligens* with details listed below (Figs 9a–g, 10–14).

*Colpodota negligens* Mulsant and Rey 1873: 156 (Figs 10–14); Benick and Lohse 1974 (as *Mocytta*); Smetana 2004 (as *Acrotona*).

**LECTOTYPE** (male): the specimen does not have any original label but it is from the historical Rey collection (CCL) and it is pinned next to the original name label by Rey. It bears V. Gusarov's lectotype designation label (2000), and his identification label as *Atheta fungi* (Gravenhorst), 2000. Because this designation was never published, we formally designate this specimen as a lectotype and put our determination label as *Mocytta negligens* (Mulsant and Rey), J. Klimaszewski 2014.

**PARALECTOTYPES**: there are 4 syntypes (1 male, 3 females) in Rey's collection that are here designated as paralectotypes. One of the syntypes (female) bears a black dot label, which indicates that the specimen was taken in Provence, in southeast France. The specimens bear Paralectotype designation labels by V. Gusarov (2000) but because these designations were not published, we formally designate them as paralectotypes. All are determined as *Mocytta negligens* (Mulsant and Rey), det. J. Klimaszewski 2014.

*Atheta gilvicollis* Scheerpeltz 1949: 355 (Figs 9a–g). **syn. n.**

**LECTOTYPE** (male): Typus; *Atheta* (*Acrotona*) *gilvicollis*; O. Scheerpeltz [red label]; female sign; Üttligen; IX.1943; ex coll. Scheerpeltz [blue card] (MNHV) examined, present designation.

**PARALECTOTYPES**: Erlach; X.1951; male sign; *gilvicollis* ex coll. Scheerpeltz [blue card]; Vienna Museum (NHMV) 1 male, examined; Frauenfeld; VII.1955; *gilvicollis* Scheerpeltz, ex coll. Scheerpeltz (NHMV) sex undetermined, examined, present designation.

### III. *Mocyta discreta* species group

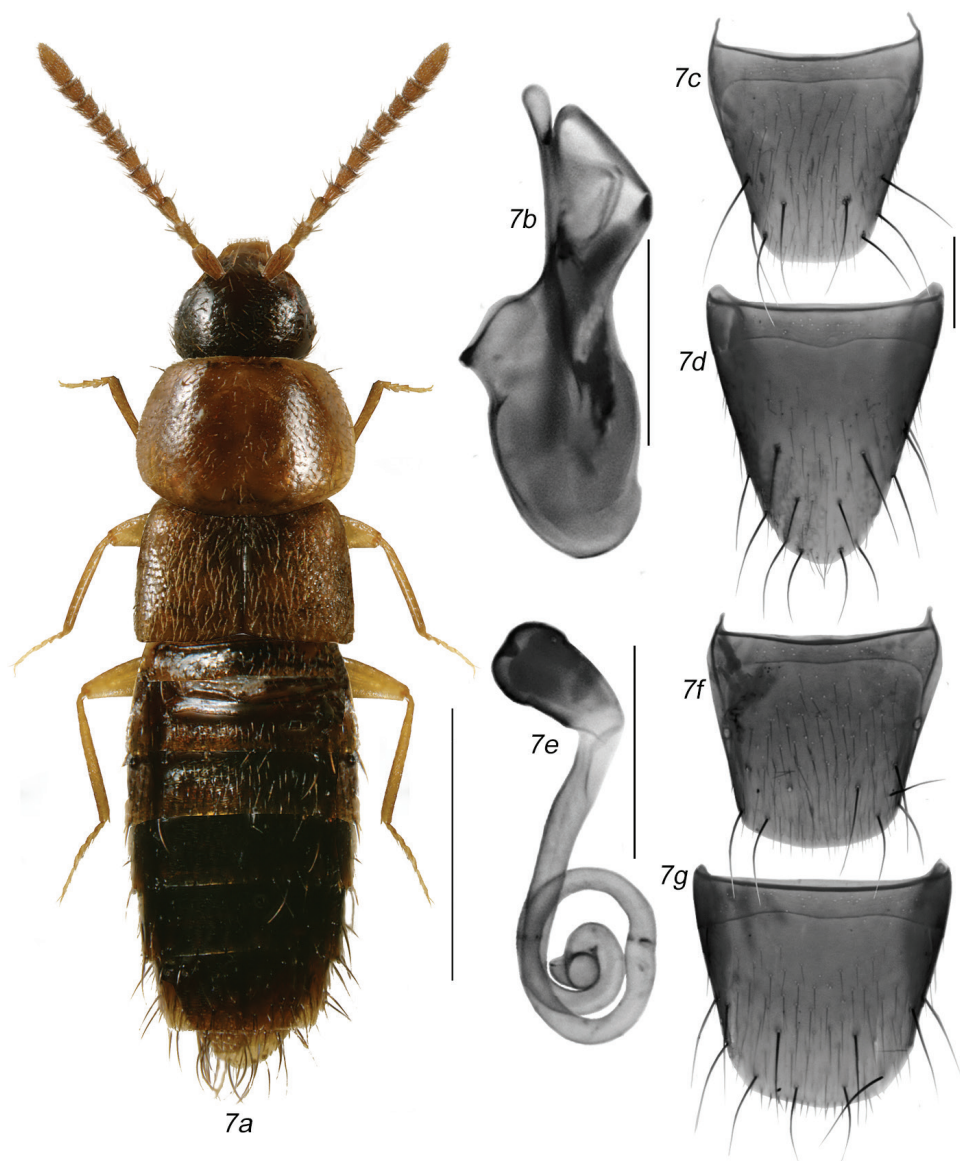
**Diagnosis.** Pronotum large, transversely orbicular with rounded lateral and hind angles, usually much broader than elytra, pubescence directed posteriad only in midline and obliquely posteriad elsewhere (Figs 7a, 8a, e); elytra short, as long as or shorter than pronotum (Fig. 7a); median lobe of aedeagus and spermatheca as illustrated (Figs 7b, e, 8b, f).

#### 5. *Mocyta discreta* (Casey)

Figs 7a–g, Map 2

*Eurypronota discreta* Casey 1894 [1893]: 335; Moore and Legner 1975: 359 (as *Acrotona*). **LECTOTYPE** (male): USA: Ia [Iowa], Cedar Rapids, Dr. E. Brendel [in orig. description]; *Eurypronota discreta* Casey; Casey bequest 1925; Lectotype label designated by V.I. Gusarov, 1999, but because he never published his designation, we here formally designate this specimen as a lectotype with J. Klimaszewski's designation label 2014 (USNM). **PARALECTOTYPES**: USA: Ia [Iowa], paratype 2 (USNM) 1 female; Ia, paratype 3 (USNM) 1 female; Ia, paratype 4 (USNM) 1 female; Ia, paratype 5 (USNM) 1 male; Ia, paratype 6 (USNM) 1 female; Ia, paratype 7 (USNM) 1 female; and Ia, paratype 8 (USNM) 1 female. All these specimens bear V.I. Gusarov paralectotype labels, but because he never published his designations we here formally designate these specimens as paralectotypes with J. Klimaszewski's designation label 2014 (USNM).

**Diagnosis.** Body broadly oval (Fig. 7a), length 2.4–2.8 mm; head and entire abdomen or its basal part only from brown to almost black, pronotum and basal half of abdomen in most specimens light brown, testaceous or reddish-brown, elytra yellowish to reddish-brown with some irregular small dark brown spots and darker than pronotum, legs and palps yellowish to reddish-brown and antennae either uniformly yellowish to light brown; antennal articles I–IV elongate and V–X variable in length from subquadrate to slightly elongate (Fig. 7a); pronotum transverse, usually very large but variable in width, from slightly broader than elytra to 1/7 wider [pronotum usually broader in females than



**Figures 7a–g.** *Mocyta discreta* (Casey): **7a** habitus in dorsal view **7b** median lobe of aedeagus in lateral view **7c** male tergite VIII **7d** male sternite VIII **7e** spermatheca **7f** female tergite VIII **7g** female sternite VIII. Scale bar for habitus = 1 mm, and the remaining scale bars = 0.2 mm.

in males], strongly rounded laterally, and arcuate basally; elytra transverse and shorter than pronotum; abdomen broadly arcuate laterally and with very strong macrosetae apically. MALE: median lobe of aedeagus as illustrated (Fig. 7b); tergite VIII truncate apically (Fig. 7c); sternite VIII slightly produced and rounded apically and with numerous strong macrosetae in apical part of disc, space between base of disc and antecostal suture

broad, antecostal suture sinuate medially (Fig. 7d). FEMALE: spermatheca pear-shaped with small and shallow apical invagination, stem thin and straight anteriorly and coiled posteriorly (Fig. 7e); tergite and sternite VIII truncate apically (Fig. 7f, g).

This species is readily recognisable from other *Mocyta* species by its bicoloured body, large pronotum, very strong macrosetae on the apical part of the abdomen, and antennal articles V–X subquadrate to elongate.

**Distribution.** This nearctic species is newly reported from Canada and the provinces of Ontario, Quebec and Saskatchewan (Map 2), and from Minnesota. Casey (1894) described this species from Cedar Rapids, Iowa, USA, and no other records of this species were published from North America until now.

**Natural history.** In Ontario, adults were collected in forest litter, deciduous leaf mold, and maple forest from March through October. In Quebec, adults were found in maple-oak forest litter and other deciduous tree litter, from May through August. In Saskatchewan, adults were collected from deciduous forest litter in October.

**New jurisdictional records.** CANADA: **Ontario:** 7 km W Petawawa, 16.IV.1988, A. Smetana (CNC) 1 male; Chaffey's Locks, 24.X.1971, forest litter, S. Peck (CNC) 4 females, 1 male, 2 sex undetermined; Kinburn, 8.IV.1962, *Acer* sp., J.E.H. Martin (CNC) 3 sex undetermined; 89 mi. N. Pickle Lake, 21.VI.1973, Campbell and Parry (CNC) 1 male; South March, 19.X.1967, A. Smetana (CNC) 1 female; Merivale, 19.VI.1953, deciduous leaf mold (CNC) 1 female; Mer Bleue, 3.VIII.1973, Redner and Starr (CNC) 1 sex undetermined. **Quebec:** Chelsea, 8.VI.1953, E.C. Becker (CNC) 1 sex undetermined; Chelsea, 22.VIII. 1957, J.R. Vockeroth (CNC) 1 sex undetermined; Danford Lake, 30.VI.1953, Berlese deciduous duff, E.C. Becker (CNC) 1 sex undetermined; Rigaud, 15.V.1979, A. Smetana and E.C. Becker (CNC) 1 male, 3 sex undetermined; Rigaud, end Ch. de la Croix, 5.V.1988, A. and Z. Smetana (CNC) 1 female, 1 sex undetermined; 5 km W. Farrellton, Lake Bernard, 8.VII.1973, maple-oak litter, A. Davies (CNC) 2 sex ? undetermined. **Saskatchewan:** Saskatoon, Saskatchewan River, 52.127°N, 106.662°W, 477 m, 6.X.2008, litter sifting, deciduous, B. Godin (BGC) 3 males, 3 females.

UNITED STATES OF AMERICA: **Minnesota:** Ramsey Co., Lake Vadnais, 10.V.1960, soil sample (CNC) 1 male; Brainerd, 10.VI.1965, E.J. Kiteley (CNC) 1 male [new state record].

## 6. *Mocyta sphagnorum* Klimaszewski & Webster, sp. n.

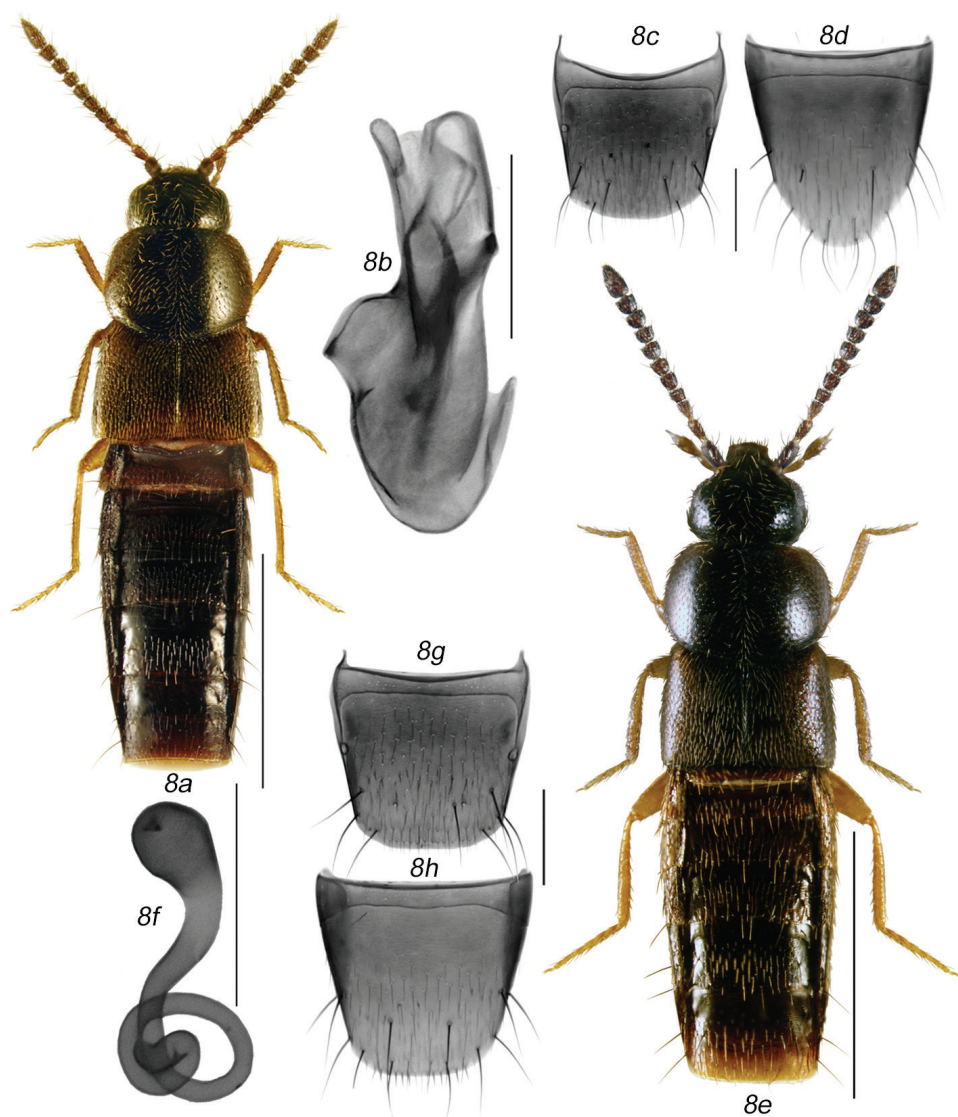
<http://zoobank.org/59167206-821A-42C8-AA6F-13A37A0C2ED6>

Figs 8a–h, Map 3

**Holotype** (female). CANADA, New Brunswick, Restigouche Co., Berry Brook Protected Area, 47.81399°N, 66.75778°W, 26.V.2007, old-growth eastern white cedar swamp, in moss near brook, R.P. Webster (LFC).

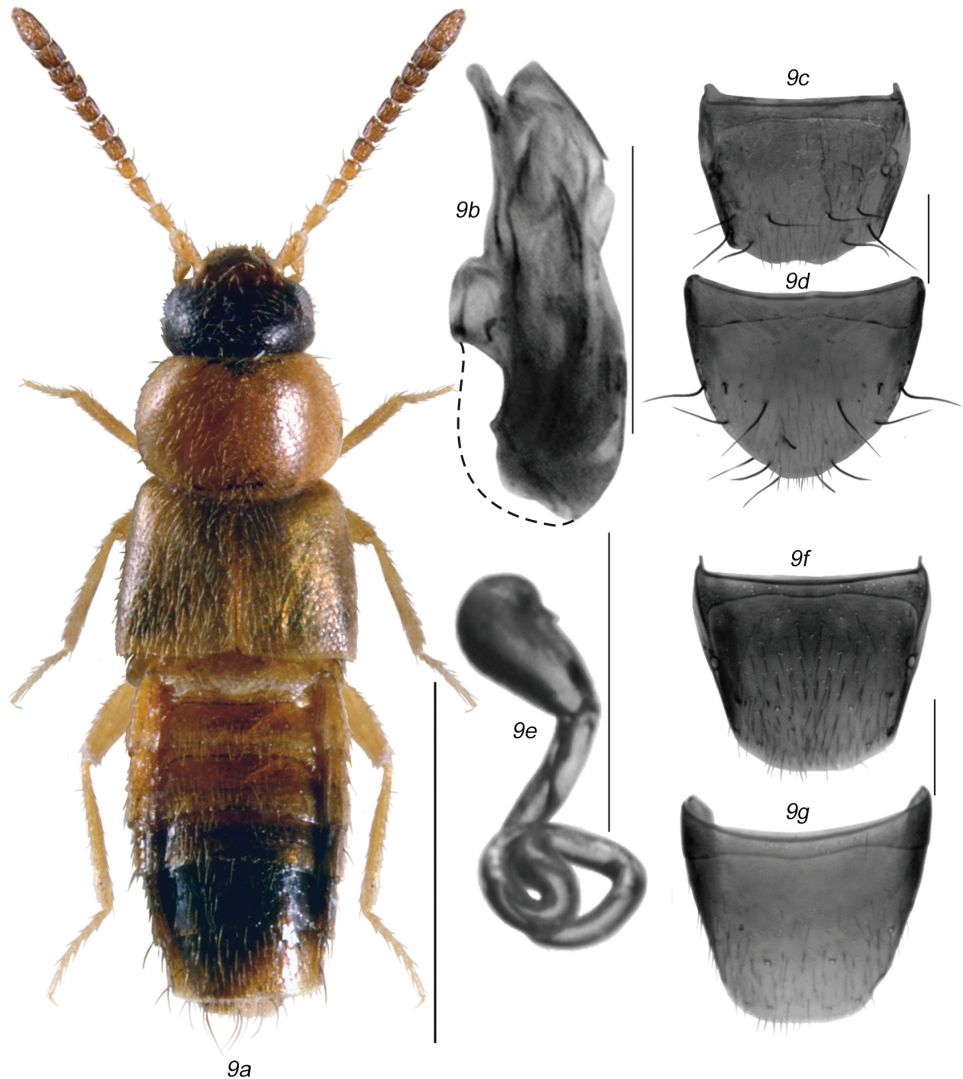
**Paratypes.** CANADA: **Newfoundland:** R.A. Squires Prov. Pk., 23.VII.1970, D.E. Bright (CNC) 1 male. **New Brunswick,** Charlotte Co., Hwy 3 at Deadwater





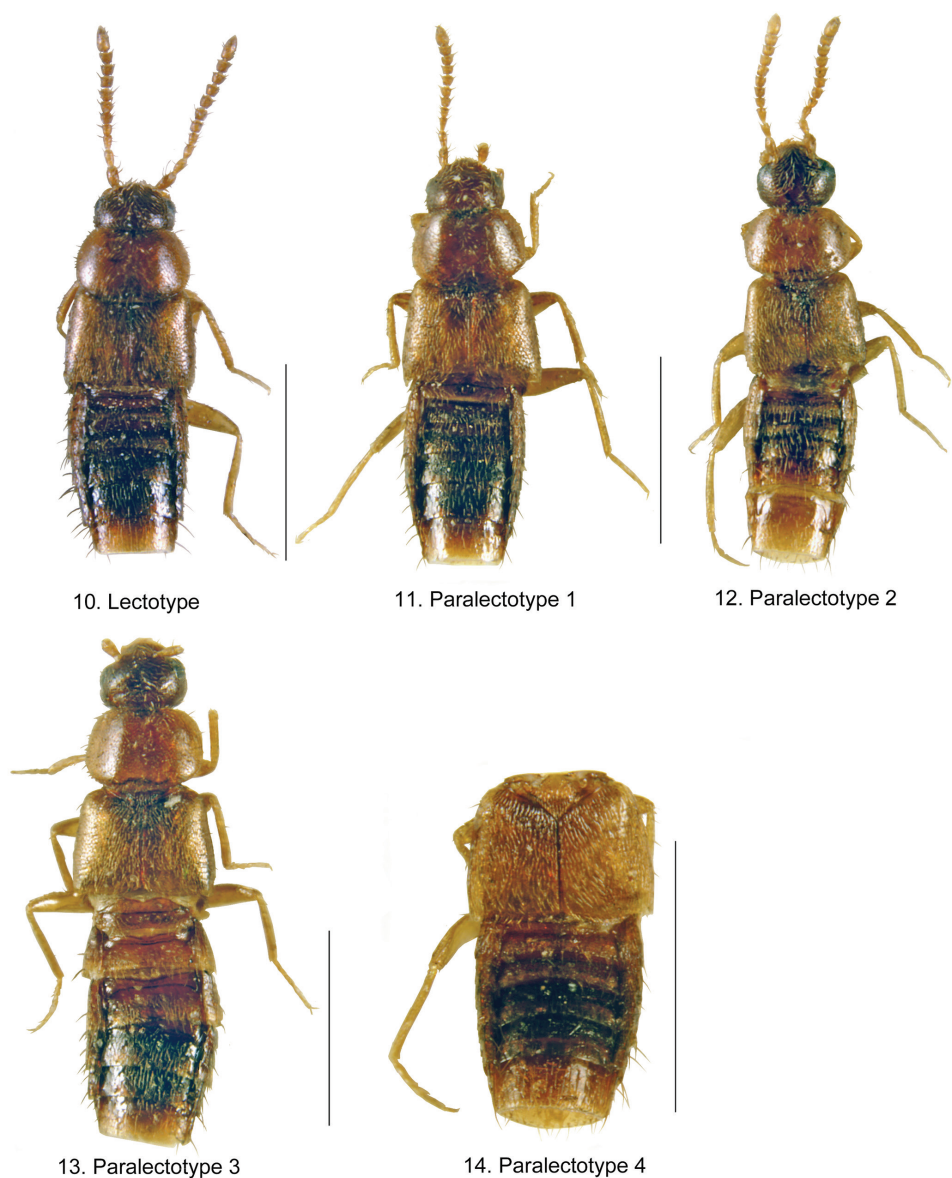
**Figures 8a–h.** *Mocyta sphagnorum* sp. n.: **8a** male habitus in dorsal view **8b** median lobe of aedeagus in lateral view **8c** male tergite VIII **8d** male sternite VIII **8e** female habitus in dorsal view **8f** spermatheca **8g** female tergite VIII **8h** female sternite VIII. Scale bar for habitus = 1 mm, and the remaining scale bars = 0.2 mm.

Brook, 45.4745°N, 67.1225°W, 23.IV.2006, Black spruce forest in *Sphagnum*, R.P. Webster (LFC) 1 male, 1 female; Hwy 3 at Deadwater Brook, 45.4745°N, 67.1225°W, 23.IV.2006, Black spruce forest, in sphagnum, R.P. Webster, (RWC) 3 males, 1 female; Carleton Co., Wakefield, Meduxnekeag Valley Nature Preserve, 46.1935°N, 67.8825°W, 19.IV.2005, mixed forest in moist moss, R. Webster (RWC) 1 female; Belleville, Meduxnekeag Valley Nature Preserve, 46.1907°N, 67.6740°W, 4.V.2006, conifer forest area, in moldy conifer duff at base of large white pine, R.P. Webster



**Figures 9a–g.** *Mocyta givicollis* (Scheerpeltz) [images based on Types, Austria] (= *M. negligens*): **9a** habitus in dorsal view **9b** median lobe of aedeagus in lateral view **9c** male tergite VIII **9d** male sternite VIII **9e** spermatheca in lateral view **9f** female tergite VIII **9g** female sternite VIII. Broken line indicates original border of bulbus which was distorted during preparations. Scale bar for habitus = 1 mm, and the remaining scale bars = 0.2 mm.

(RWC) 1 female; “Two Mile Brook Fen”, 46.3619°N, 67.6733°W, 5.VIII.2004, calcareous fen, in sphagnum moss & litter, J. Edsall & R. Webster (RWC) 1 sex undetermined; Restigouche Co., Berry Brook P.N.A., 47.81399°N, 66.75778°W, 26.V.2007, R.P. Webster // Old-growth eastern white cedar swamp, in moss near brook (RWC) 1 male. **Ontario:** 52 mi N Hurkett, Black Sturgeon Lake, 28.VI.1973, R. Parry and



**Figures 10–14.** *Mocyta negligens* Mulsant & Rey (= *M. givicollis*) [habitus images in dorsal view, based on types, France]: **10** lectotype **11** paralectotype 1 **12** paralectotype 2 **13** paralectotype 3 **14** paralectotype 4 [abdomen]. Scale bar for habitus = 1 mm.

J.M. Campbell (LFC) 1 male; Mt. Tremblant Pk., 27.VI.1971, E.J. Kiteley (LFC) 1 female. **Quebec:** Gaspé Co., Mt-Albert, Sommet nord, 1000 m, 18.Vii.1985, sweeping field, F. Génier (LFC) 1 male.

**Non-types.** Canada, **New Brunswick:** York Co., Canterbury Brown's Mtn. Fen., 45.8965°N, 67.6344°W, 5.VIII.2004, mixed forest on decaying fungi, J. Ed-

sall and R. Webster (LFC) 1 sex unknown. **Quebec:** Gaspé Co., Mt-Jacques-Cartier, 24.VII.1985, caribou dung, F. Génier and J. Klimaszewski (LFC) 1 male.

**Etymology.** The specific name *sphagnorum* is an adjective, which derives from the generic name of *Sphagnum*, in the genitive plural, meaning “of the *Sphagnum* plant”, a dominant plant of the habitat where the species was found.

**Diagnosis.** Body narrowly oval (Fig. 8a), length 2.4–2.7 mm; uniformly brown to almost black, legs and palps yellowish to reddish-brown and antennae uniformly light brown to brown; antennal articles I–IV elongate and V–X variable in length from subquadrate to slightly transverse (Figs 8a, e); pronotum transverse, variable in width, from slightly-to-distinctly broader than elytra [pronotum usually broader in females than in males, Fig. 8e], strongly rounded laterally, and arcuate basally; elytra transverse and slightly shorter than pronotum; abdomen broadly arcuate laterally and with strong macrosetae apically. MALE: median lobe of aedeagus as illustrated with distinct apical structures of median lobe (Fig. 8b); tergite VIII truncate apically (Fig. 8c); sternite VIII slightly produced and rounded apically and with numerous strong macrosetae in apical part of disc, space between base of disc and antecostal suture narrow, antecostal suture arcuate (Fig. 8d). FEMALE: spermatheca pear-shaped with small and shallow apical invagination, stem thin and irregularly coiled posteriorly (Fig. 8f); tergite and sternite VIII truncate apically (Figs 8g, h).

This species may be distinguishable from other *Mocyta* species by its large and dark brown to black pronotum, shape of spermatheca and apical structures of internal sac.

**Distribution.** This nearctic species is known from Newfoundland, New Brunswick, Quebec and Ontario.

**Natural history.** In New Brunswick, adults were found in sphagnum moss and litter in calcareous eastern white cedar fens and in a black spruce forest. One individual was collected from moldy conifer duff at the base of a large pine in a mixed forest. Adults were found in April and May in New Brunswick, and June to August elsewhere. This species seems to be associated with moist sphagnum moss.

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types of *Eurypronota discreta* Casey and other Casey types. Anthony Davies (CNC) arranged several specimens for study from the CNC collection in Ottawa. Pamela Cheers (LFC) edited and corrected the first draft of the manuscript and Jim Hammond (NoFC) prepared the maps. Natural Resources Canada provided the funding for this study.

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# No need to replace an “anomalous” primate (Primates) with an “anomalous” bear (Carnivora, Ursidae)

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## Abstract

By means of mitochondrial 12S rRNA sequencing of putative “yeti”, “bigfoot”, and other “anomalous primate” hair samples, a recent study concluded that two samples, presented as from the Himalayas, do not belong to an “anomalous primate”, but to an unknown, anomalous type of ursid. That is, that they match 12S rRNA sequences of a fossil Polar Bear (*Ursus maritimus*), but neither of modern Polar Bears, nor of Brown Bears (*Ursus arctos*), the closest relative of Polar Bears, and one that occurs today in the Himalayas. We have undertaken direct comparison of sequences; replication of the original comparative study; inference of phylogenetic relationships of the two samples with respect to those from all extant species of Ursidae (except for the Giant Panda, *Ailuropoda melanoleuca*) and two extinct Pleistocene species; and application of a non-tree-based population aggregation approach for species diagnosis and identification. Our results demonstrate that the very short fragment of the 12S rRNA gene sequenced by Sykes et al. is not sufficiently informative to support the hypotheses provided by these authors with respect to the taxonomic identity of the individuals from which these sequences were obtained. We have concluded that there is no reason to believe that the two samples came from anything other than Brown Bears. These analyses afforded an opportunity to test the monophyly of morphologically defined species and to comment on both their phylogenetic relationships and future efforts necessary to advance our understanding of ursid systematics.

## Keywords

Mitochondrial DNA, phylogenetics, *Ursus maritimus*, *Ursus arctos*, Himalayas, yeti, cryptozoology

## Introduction

Sykes et al. (2014) conducted mitochondrial 12S rRNA sequencing on 30 hair samples from several geographic regions and that had been anecdotally attributed to “anomalous primates” (“yeti”, “almasty”, “orang pendek”, and “bigfoot”). All but two of these samples, both said to originate in the Himalayas, were identified by Sykes et al. as coming from domestic animals, well-known wild animals of the present day, or a human. Those two samples, however, were characterized as representing what could be termed an “anomalous carnivore” – a bear of the genus *Ursus*, with a “100% match with DNA recovered from a Pleistocene fossil more than [sic] 40 000 BP of *U. maritimus* (polar bear) [...] but not to modern examples of the species”. In their text they noted that one of the hair samples was golden-brown and the other reddish-brown but also that white bears had been reported anecdotally from Central Asia and the Himalayas and that the genetic affinities of Himalayan bears are unknown. Sykes et al. stated that the hairs had been “thoroughly cleaned”, by some unspecified process, “to remove surface contamination”. We wonder if the hairs could have become discolored below the surface. One sample was said to be about 40 years old and the age of the other was unspecified, although Melton et al. (2015) stated that the latter had been represented as being about 10 years old. No information was given as to the conditions to which these hairs may have been exposed prior to the study by Sykes et al. These authors concluded that it seemed likely that the hairs were “from either a previously unrecognized bear species, colour variants of *U. maritimus*, or *U. arctos*/*U. maritimus* hybrids”, and, if hybrids, that they “are probably descended from a [...] hybridization event during the early stages of species divergence between *U. arctos* and *U. maritimus*”. One of the samples was said to have come “from an animal shot by an experienced hunter [...] who reported that its behavior was very different from [that of] a brown bear *Ursus arctos*, with which he was very familiar”. According to Sykes et al., “If these bears are widely distributed in the Himalayas, they may well contribute to the biological foundation of the yeti legend, especially if, as reported by the hunter who shot the [...] specimen, they behave more aggressively toward humans than known indigenous bear species”. What strikes us as odd is that an “experienced hunter”, who was very familiar with the Brown Bear, could mistake the animal that he had shot for anything other than a bear of some sort and, specifically, for a “yeti”. Corroboration and documentation of, as well as other information concerning, the anecdote of this bear being shot by the hunter and the subsequent history of the hair that was saved would be most welcome. More documentation concerning the origin and subsequent history of the other sample, stated by the authors as having been “a nest of a migyhur, the Bhutanese equivalent of the yeti” would also be helpful. According to Edwards and Barnett (2015), rather than this sample being represented by a “nest”, it consisted only of a single hair. Although Sykes et al. take the accuracy of the stated locations for origination of the supposedly Himalayan bear hairs for granted, they reported certain tested samples from Russia as being from an American Black Bear (*Ursus americanus*) and a North American Raccoon (*Procyon lotor*), “even though they are native to North America”. The raccoon fur from Russia is not much of



a surprise, because raccoons have been introduced, with varying degrees of success, to a variety of places in the former Soviet Union (Heptner et al. 2001, p. 1380).

According to various journalistic accounts (e.g. Hill 2014), “Sykes plans to [...] organize an expedition to the Himalayas next year to look for a live specimen of the anomalous bear”. However, owing to uncertainties and omissions in the interpretations made by Sykes et al. of their data, we questioned their conclusion that there was reason to believe that there was some sort of bear, unknown to science, in the Himalayas. Accordingly, to test the inferences made by these authors, we carried out comparisons of 12S rRNA sequences of *Ursus maritimus* and *U. arctos* with the two bear sequences of Sykes et al.; replicated their comparison utilizing the Basic Local Alignment Search Tool (BLAST); conducted phylogenetic analyses incorporating sequences from the two specimens studied by Sykes et al. and of all extant species of Ursidae (except for the Giant Panda, *Ailuropoda melanoleuca*) and two extinct Pleistocene species; and employed the non-tree-based population aggregation approach for species diagnosis and identification. The phylogenetic analyses afforded an opportunity to test the monophyly of morphologically defined species and to comment on their phylogenetic relationships.

## Methods

Analyses we present herein were based on sequences of the mitochondrial 12S ribosomal RNA gene obtained from GenBank ([www.ncbi.nlm.nih.gov/GenBank](http://www.ncbi.nlm.nih.gov/GenBank)), some available as part of whole mitochondrial genomes from which we extracted them. GenBank accession numbers of these sequences are as follows: AB302321, AJ428577, AP012559–AP012597, AY012153, EF667005, EU327344, EU497665, FM177759, FM177760, FM177763–FM177765, FN390842–FN390859, FN390861–FN390872, GU573485–GU573491, JX196366–JX196392, KJ155697–KJ155699, KJ155710, KJ155713, KJ155717, KJ155718, KJ155722, KJ155723, KJ607607, L21882, L21884, L21889–L21891, NC011112, NC011116, NC011118, NC003426–NC003428, NC008753, NC009331, NC009968, NC009970, NC009971, U12854, U78349, Y08519, Y08520. We carried out direct comparisons of 12S rRNA sequences of the bear species *Ursus maritimus* and *U. arctos* with the two sequences produced and identified by Sykes et al. (2014) as representative of either “a previously unrecognized bear species, colour variants of *U. maritimus*, or *U. arctos*/*U. maritimus* hybrids.” These sequences are hereinafter referred to as “the focal sequences”. The GenBank accession numbers of these sequences are KJ155697 and KJ155722. These sequences were obtained from samples allegedly from India (ref. no. 25025 in Sykes et al. 2014) and Bhutan (ref. no. 25191), respectively. We also subjected the focal sequences to a BLAST analysis, thus replicating the comparison that Sykes et al. (2014) conducted against GenBank sequences. We conducted this analysis via the National Center of Biotechnology and Information’s website for standard BLAST of nucleotide sequences (<http://www.ncbi.nlm.nih.gov/blast>; Zhang et al. 2000, Morgulis et al. 2008), using the *blastn* method and the *nucleotide collection (nr/nt)* database, which we assume were also used by Sykes et al. (2014).

As an alternative method for taxonomic identification of the focal sequences, we inferred their phylogenetic relationships with respect to complete 12S rRNA sequences of representatives of the bear species *Helarctos malayanus* (3 sequences), *Melursus ursinus* (3), *Ursus americanus* (11), *U. arctos* (50), *U. maritimus* (32), *U. spelaeus*<sup>†</sup> (33), and *U. thibetanus* (8). All of these species have been previously recovered in a well-supported monophyletic group sister to the bear species *Tremactos ornatus* (1) and *Arctodus simus*<sup>†</sup> (1), both designated here as outgroups (Krause et al. 2008). Sequences were aligned using default options of MAFFT v.7.017 (Katoh et al. 2013) as implemented in Geneious v.7.1.5. We acknowledge that partitioning data for model-based phylogenetic analyses improves model fit by dividing alignments into relatively homogeneous sets of sites; however, for the purpose of this paper (primarily focused on the identity of the short focal sequences) we follow previous studies in which 12S rRNA data have not been subdivided (e.g. Lloyd 2003, Chambers et al. 2009, Westerman et al. 2012, Almeida et al. 2014). Thus, we used PartitionFinder ver. 1.0.1. (Lanfear et al. 2012) only for the purpose of determining the best-fit model of nucleotide substitution based on the corrected Bayesian Information Criterion (BIC). PartitionFinder considered only models that can be applicable in MrBayes.

Two optimality criteria were used for phylogenetic analyses, Bayesian inference (BI) and maximum likelihood (ML). The Bayesian topology was inferred with MrBayes v. 3. 2 (Ronquist et al. 2012). The search started with a random tree; the Markov chains ran for 100,000,000 generations, and trees were sampled every 1000 generations. The first 25,000 trees were discarded as burn-in, and the Bayesian posterior probability estimates were obtained based on the remaining 75,000 trees. The resulting parameter files were combined and assessed for stationarity and suitable effective sample size (ESS) values, using Tracer 1.6 (Rambaut et al. 2014). For this analysis, we consider as *strong* (*significant*) support only Bayesian posterior probability (BPP) values  $\geq 0.95$ ; as *moderate* (*nearly significant*) BPP values, those of 0.90–0.94; and as *negligible* BPP values, those of  $< 0.90$ . For obtaining the best topology under the ML criterion, we conducted 20 independent searches in the Genetic Algorithm for Rapid Likelihood Inference (GARLI 2.0; Zwickl 2006), using the default settings. Nodal support for the ML tree was assessed with nonparametric bootstrapping (Felsenstein 1985) in GARLI 2.0, based on 1000 searches (i.e. 100 pseudoreplicated data matrices and 10 searches for each of them). The degree of support received by individual nodes in the ML bootstrap analysis is referred to in the results and discussion sections by the following categories: strong support for bootstrap values  $\geq 75\%$ ; moderate support for bootstrap values  $> 50\%$  and  $< 75\%$ ; negligible support for values  $\leq 50\%$ .

Several studies have shown that a non-tree, character-based approach can help in species identifications that could not be accomplished with tree-based methods (DeSalle et al. 2005, Zou 2011, Van Velzen et al. 2012). Therefore, we also employed the non-tree-based population aggregation analysis approach (Davis and Nixon 1992) to detect if sequences of the 12S rRNA gene contain unique combinations of nucleotides that would allow diagnoses of *Ursus arctos* and *U. maritimus* and subsequent assignment of the focal sequences to either species.

## Results

### Sequence comparisons and BLAST

Comparisons of the two sequence fragments of the mitochondrial 12S ribosomal RNA gene produced by Sykes et al. (2014) with homologous fragments for *Ursus arctos* (49 individuals) and *U. maritimus* (32 individuals) revealed few and inconsistent differences between these species. The focal sequences are identical to each other and possess a length of 104 base pairs, which correspond to positions 451–554 in complete sequences of the 12S rRNA gene (using as reference GenBank sequence NC003428). Four positions show differences between *U. arctos* and *U. maritimus*, with the former species being polymorphic in three positions, and the latter only in one (Table 1). The focal sequences differ with respect to most other sequences in two positions (Table 1). In position 474 (position 24 of fragment), one *U. maritimus* and all but nine *U. arctos* match the focal sequences in having a thymine. In position 550 (100 of fragment), all *U. maritimus* and nine *U. arctos* match the focal sequences in having a thymine. In the other two variable sites (positions 478 and 492), the nucleotide of the majority of sequences of both species matches that of the focal specimens (Table 1). The BLAST run retrieved as best matches of the focal sequences, two sequences of *U. maritimus* with hit scores of 193. With slightly lower hit scores (187), the second-best matches were 98 sequences, of which 94 corresponded to *U. arctos* and four to *U. maritimus*.

### Tree and non-tree, character-based approach

The maximum likelihood (ML) analysis recovered the focal sequences in a large haplogroup containing sequences of *Ursus maritimus* and *U. arctos* (Figure 1), which received moderate bootstrap support. Three haplogroups were recovered within it: (a) one containing the focal sequences and all but one sequence of *U. maritimus*, (b) one containing most sequences of *U. arctos*, and (c) one containing five sequences of *U. arctos*. Only

**Table 1.** Nucleotide variability of the fragment sequences of the 12S rRNA gene herein analyzed. Differences found in comparisons of the two fragment sequences (104 base-pairs long) produced by Sykes et al. (2014), and referred to in the text as focal sequences, with homologous fragments for *Ursus arctos* (49 individuals) and *U. maritimus* (32 individuals). The two focal sequences are identical to each other. The compared fragments correspond to positions 451–554 in complete sequences of gene 12S rRNA (using as reference GenBank sequence NC003428). Number of individuals is shown within parentheses.

Species	Corresponding positions in complete 12S gene sequences			
	474	478	492	550
<i>Ursus arctos</i>	T (40); C (9)	A (44); G (5)	A (1); G (48)	T (9); C (40)
<i>Ursus maritimus</i>	T (1); C (31)	A (32)	G (32)	T (32)
Focal sequences	T	A	G	T

**Figure 1.** The maximum-likelihood tree resulting from the analysis of sequence data for the mitochondrial 12S ribosomal RNA gene under its best-fitting model (GTR + G, ln-likelihood - 3123.29336). Only non-negligible nodal support is indicated. Bootstrap values for the maximum-likelihood analysis are indicated above branches, whereas Bayesian posterior probabilities are indicated below branches. See Acknowledgments for photo credits.

the latter haplogroup received non-negligible support. These three haplogroups formed a polytomy in which an additional sequence of *U. maritimus* was also found (not nested within either of the three haplogroups just described). The extinct *Ursus spelaeus* was recovered sister to this large haplogroup (*U. maritimus* + *U. arctos* + focal sequences) with strong support; however, the monophyly of *U. spelaeus* received only moderate bootstrap support. The clade containing the focal sequences, *U. maritimus*, *U. arctos*, and *U. spelaeus* was recovered sister, although with negligible support, to a clade containing a sister species pair formed by *U. americanus* and *Helarctos malayanus*. The latter two species were recovered as monophyletic, each with strong support. All of the species mentioned so far formed an unsupported clade that was recovered sister to *Melursus ursinus*, with moderate support. The monophyly of the latter species was moderately supported. All these taxa formed a clade that received negligible support, and which appeared sister to one sequence of *Ursus thibetanus japonicus*. All other sequences of *U. thibetanus* formed a moderately supported haplogroup sister to the rest of the ingroup. The ingroup was recovered monophyletic albeit with negligible support.

The Bayesian inference (BI) analysis yielded an even less resolved tree (topology not shown; but see nodal supports overlaid on ML tree in Figure 1). The major difference with respect to the ML tree was the position of *Ursus americanus*, found monophyletic, with strong support, sister to a clade containing all other ingroup taxa. The latter clade received negligible support, and its internal topology lacked resolution. By contrast with the ML tree, in the BI tree the focal sequences did not appear most closely related to any particular haplogroup or individual sequence. In this very large polytomy, only *Melursus ursinus*, *Helarctos malayanus*, and *U. thibetanus* were recovered monophyletic with strong nodal support.

The application of the non-tree-based population aggregation analysis (Davis and Nixon 1992) did not yield results that would allow identification of the focal sequences. In inspection of complete sequences of the 12S rRNA gene, we found no combination of nucleotides (and not even a single nucleotide) that would allow diagnosing *Ursus arctos* and *U. maritimus*.

## Discussion

### No evidence of a taxonomically unrecognized bear in the Himalayas

The molecular data obtained and analyzed by Sykes et al. (2014) are not informative enough to suggest the possibility that a taxonomically unrecognized type of bear exists in the Himalayas. The interpretations made by Sykes et al. with respect to the possible taxonomic identity of the focal sequences were based merely on the results of a BLAST run against GenBank sequences. The short fragment sequences of the mitochondrial 12S rRNA gene obtained by Sykes et al. from their hair samples and homologous fragment sequences of *Ursus arctos* and *U. maritimus* are all identical except in four positions. In these four positions either one or both known species are polymorphic, and



in all of them at least some individuals of both species have the same nucleotide. More importantly, because in complete sequences of the 12S rRNA gene not even a single nucleotide consistently allows discrimination between *U. arctos* and *U. maritimus*, it is impossible to unambiguously assign a taxonomic identification, based on this gene, to the focal sequences. The results of a BLAST analysis could not rule out the possibility that the focal sequences belong to *U. arctos*, which is known to occur in the Himalayas. In congruence with this fact, the results of our BLAST analysis showed that numerous sequences of both *U. maritimus* and *U. arctos* yielded highly similar hit scores to those with the highest hit score, two sequences of *U. maritimus* (see Results). Unfortunately, Sykes et al. did not report any hit scores resulting from their analyses.

Our phylogenetic analyses do not provide evidence to rule out the possibility that the focal sequences might belong to *Ursus arctos*. Although in the ML analysis the focal sequences were recovered within a haplogroup with part of the sequences of *U. maritimus*, this haplogroup received negligible support. If we consider only relationships that received either moderate or strong nodal support, then not even the haplogroups containing sequences of *U. arctos* and *U. maritimus* would be distinguished from each other. This is an expected result considering that male-mediated dispersal and sex-biased gene flow have been reported between *U. arctos* and *U. maritimus* (Nakagome et al. 2008, Cahill et al. 2013 and 2014, Cronin et al. 2013, Bidon et al. 2014, Liu et al. 2014). Our phylogenetic analyses indicate that even complete sequences of the 12S rRNA gene do not consistently recover with moderate or strong support the monophyly of other ursid species, despite their monophyly having been established in previous studies. Based on mitochondrial DNA, previous studies found *U. arctos* paraphyletic with respect to *U. maritimus* and suggested past hybridization or incomplete lineage sorting as possible explanations (Bon et al. 2008, Lindqvist et al. 2010, Miller et al. 2012, Cronin et al. 2013, Hirata et al. 2013 and 2014; see also Hailer et al. 2013). Nevertheless, analyses of amplified fragment length polymorphisms (AFLP) data recovered *U. arctos* and *U. maritimus* as reciprocally monophyletic species (Cronin et al. 2013), and additional analyses of ca. 9100 nucleotides from 14 independent nuclear loci across the genome of 45 individuals yielded the same result, while also dating the split from the common ancestor of this sister-species pair as far back as from the Middle Pleistocene (Hailer et al. 2012; see also Kutschera et al. 2014, Liu et al. 2014). Given that hybridization between *U. arctos* and *U. maritimus* has been documented (see citations above), and that this precludes analyses of mitochondrial DNA being capable of recovering their reciprocal monophyly (even when complete mitochondrial genomes are analyzed; Bon et al. 2008, Lindqvist et al. 2010), it could not be expected that the fragment of the 12S rRNA gene sequenced by Sykes et al. would contain phylogenetic signal that could rule out the possibility that the focal sequences belong to *U. arctos*. Sykes et al. did not consider this possibility, and lacked evidence to support the scenarios they considered likely – i.e. that the focal sequences belong to individuals of “a previously unrecognized bear species, colour variants of *U. maritimus*, or *U. arctos/U. maritimus* hybrids”. The most parsimonious hypothesis regarding the identity of the Himalayan samples of Sykes et al. is that they are from *U. arctos*.

Based on different methods, Edwards and Barnett (2015) have recently concluded that the focal sequences most likely belong to *Ursus arctos isabellinus*. However, in the absence of modern revisionary work delimiting subspecies of *U. arctos*, we consider it appropriate to refer to Himalayan populations of the Brown Bear simply as *U. arctos*, and to take the opportunity to call the attention of the community of mammalian systematists to the need for such studies. In their study, Edwards and Barnett (2015) also demonstrated that the focal 104-bp long sequences do not match a homologous fragment of ancient *U. maritimus*, as asserted by Sykes et al. (2014), but rather that of a recent sample of that species, from Diomedé, Little Diomedé Island, Alaska (GenBank accession number GU573490). In addition, these authors suggested that the sequences produced by Sykes et al. (2014) could have resulted from artifacts due to the use of degraded DNA obtained from samples that were not freshly preserved, but Melton et al. (2015) consider this possibility unlikely.

Because financial and human resources are limited, it is necessary that they are invested in addressing well-founded scientific questions. If further resources were to be invested in determining the taxonomic identity of the bear populations from the Himalayas, the first step should be to obtain nuclear sequence data from museum specimens from that region. A query through the Global Biodiversity Information Facility (GBIF; <http://www.gbif.org>) indicated that at least 16 museum specimens identified as being of *Ursus arctos* from the Himalayas and nearby areas are housed in four North American and one European institution, namely the American Museum of Natural History, the Field Museum, the Museum of Comparative Zoology of Harvard University, the National Museum of Natural History, and the Natural History Museum of Geneva. Because many institutions do not yet share their data through GBIF, we expect that more specimens are readily available. Pyrosequencing has made the use of museum specimens to obtain large amounts of DNA sequence data a common, reliable practice (see Guschanski et al. 2013, Fabre et al. 2014). In our opinion, the use of pyrosequencing would be preferable to meeting the high costs of an expedition to attempt to obtain a freshly preserved tissue sample from a living animal (with no guarantee of success). By contrast, Melton et al. (2015; see also Hill 2014) seem to advocate for conducting an expedition. Aside from this methodological consideration, we emphasize that no evidence has ever been presented to suggest that an unknown bear species occurs in the Himalayas (contra Sykes et al. 2014 and Melton et al. 2015).

### **Species monophyly and interspecific phylogenetic relationships**

Although it is necessary to employ data obtained from multiple, independently inherited sources (e.g. sequence data from mtDNA and nDNA from different chromosomes) in order to reliably infer interspecific phylogenetic relationships, the gene tree resulting from our analyses provides insights on species monophyly and interspecific relationships that might be useful in planning future studies on bear systematics. In this regard, it is noteworthy that by using the 12S rRNA gene, we were able to analyze

more individuals per species than has been done in previous studies, thus allowing us to assess both whether a deeper sampling enables detection of relationships previously unreported and to test whether morphologically defined species are recovered as monophyletic. We limit our discussion to relationships that received non-negligible support from either of the two analyses conducted.

Four out of the seven species of our ingroup were recovered in monophyletic haplogroups, the exceptions being *Ursus arctos*, *U. maritimus*, and *U. thibetanus*. The fact that neither of the first two species was recovered as monophyletic might result from possible ancestral polymorphism or past hybridization events (see Edwards et al. 2011, Cahill et al. 2013 and 2014; and citations above). On the other hand, the non-monophyly of *U. thibetanus* resulted from the exclusion of a single sequence, representing an individual of *U. t. japonicus*, from a strongly supported haplogroup that included all other sequences of *U. thibetanus*. This result might be of taxonomic interest because populations of *U. t. japonicus* might have experienced substantial isolation from mainland populations of *U. thibetanus*.

With regard to interspecific relationships, in congruence with results from numerous previous studies (e.g. Bon et al. 2008, Lindqvist et al. 2010, Cronin et al. 2013), our analyses found *Ursus arctos* and *U. maritimus* to form a monophyletic group; however, the internal topology of this clade was not resolved, which is not surprising, given instances of gene flow between these two species (see citations above) and that their reciprocal monophyly was recovered only with the use of nuclear data (Hailer et al. 2012, Cronin et al. 2013, Kutschera et al. 2014, Liu et al. 2014; see also Hailer et al. 2013). Similarly, the sister relationship between the clade just described (i.e. *U. arctos* + *U. maritimus*) and the extinct *U. spelaeus* was also found in other studies in which *U. spelaeus* was included (Bon et al. 2008, Krause et al. 2008). In addition, we recovered *Melursus ursinus* as sister to an (unsupported) clade that included all other ingroup species except *U. thibetanus*. This position for *M. ursinus* is incongruent with results from previous studies, which placed the species as sister to either all of our ingroup species (Yu et al. 2004 p. 488, Bon et al. 2008, Krause et al. 2008) or to *U. malayanus* (Li et al. 2004 (p. 486), Kutschera et al. 2014). Similarly, *U. thibetanus* (excluding *U. t. japonicus*) was found to be sister to the rest of the ingroup of our gene tree. This position is incongruent with results of previous studies that have found the species either sister to *U. americanus*, based on mtDNA (Krause et al. 2008), or *U. malayanus*, based on nDNA (Kutschera et al. 2014).

Despite conflicting results among studies that have looked at interspecific phylogenetic relationships, we believe that further efforts on ursid systematics should also focus on assessing geographic variation, phylogeographic patterns of widespread species, and taxonomy. The hypothetical non-monophyletic nature of *Ursus thibetanus*, exposed in our results, represents an example of the kinds of problems meriting attention by taxonomists. The use of DNA from museum specimens and techniques such as Restriction site Associated DNA (RAD) tags that gather data from throughout genomes could significantly advance our understanding of this recent carnivore radiation, including clarification of the taxonomic position of nominal forms that have never been subjected to a modern systematic revision.

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