

# First record of *Rhoptrocentrus piceus* Marshall (Hymenoptera, Braconidae, Doryctinae) as parasitoid of *Psacotheta hilaris hilaris* (Pascoe) (Coleoptera, Cerambycidae)

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## Abstract

The species *Rhoptrocentrus piceus* Marshall (Hymenoptera: Braconidae) was reared from the larvae of the xylophagous beetle *Psacotheta hilaris hilaris* (Pascoe) (Coleoptera: Cerambycidae), an exotic pest of *Ficus* and *Morus* species native to eastern Asia. It was recorded in the north of Italy in September 2005. This discovery is the first report of this species as parasitoids of the yellow spotted longicorn beetle all over the world.

## Keywords

Ectoparasitoid, new record, biocontrol, exotic pest

## Introduction

The invasion of new exotic species is an increasing phenomenon in all European countries. One of the main reason is the great increase of import and export goods, including living plant material, throughout the world. Italy is particularly vulnerable due to the

structure of its territory. It extends over a wide latitude, with numerous mountain ranges along its length. Such territory structure creates a great variability in micro-climatic conditions. The presence of many different ecosystems in such a rich geo-morphological and climatic context can facilitate the settlement of new invasive species (Frasconi et al. 2013). It has been estimated that approximately 200 exotic species have settled in Italy since 1970 and the highest number of new records, 111 new species, was registered in the decade 1991-2000 (Longo 2009, Jucker and Lupi 2011).

The initial success of an exotic pest is due to the interaction of the biological performance of the species with habitat characteristics (Gröbler and Lewis 2008, Jucker and Lupi 2011). When an exotic pest colonizes a new habitat, native potential natural parasites need time to find, recognize, and adapt to the new host species.

Among the pests recently detected in Italy, there is the yellow spotted longicorn beetle *Psacothaea hiliaris hiliaris* (Pascoe) (Coleoptera: Cerambycidae: Lamiinae: Lamiini), an exotic pest of *Morus* and *Ficus* trees. The insect is native to eastern Asia (Kim et al. 2009) and was detected in Europe for the first time in Italy in 2005, where it has now become established (Jucker et al. 2006, Lupi et al. 2013). In 2012 the beetle was also recorded in Germany (EPPO 2012). In the native countries the insect is mostly associated with mulberry trees, whereas in Italy it prefers fig trees (Lupi et al. 2013). The pest larvae tunnel into the xylem of host trees after a first period of feeding under the bark. This results in considerable damage to the tree, which is progressively weakened until death. The adults feed on the leaves and on the tender bark of the smaller branches. Studies of the biology in the native countries indicated that *P. h. hiliaris* is generally univoltine, but depending on the time of oviposition, it could be also bivoltine (Watari et al. 2002).

As studies on natural enemies are few also in its native countries (Hong et al. 2008), a long-term study has been carried out to improve the knowledge on *P. h. hiliaris* relationships with autochthonous natural enemies in Italy. The present paper reports the results of a survey that was carried out in an area where *P. h. hiliaris* is present since 2006.

## Materials and methods

In order to acquire data on the presence of autochthonous natural enemies, surveys were carried out on plants infested by *P. h. hiliaris* in summer 2013, at two sites in the locality of Erba (Como municipality, Italy) [45°49'40.06"N, 9°13'07.44"E; 45°48'06.78"N; 9°13'02"E].

A visual analysis of the infested fig trees was first performed. The observation of sawdust was the evidence of the presence of *P. h. hiliaris* preimaginal instars. Branches were cut from infested plants in different sites, transferred to the laboratory, and stored inside cages at room temperature. Some larvae were removed and checked with the stereomicroscope to confirm *P. h. hiliaris* presence using the key proposed by Pennacchio et al. (2012). Cages were controlled weekly to check the presence of parasitoids and the emergence of *P. h. hiliaris* or other bark beetles from the logs.

The emerged specimens of Hymenoptera were collected, stored as dry material as well as in alcohol (70%) and classified to species level following Marsh (1997) and Belokobylskii (2001).

## Results and discussion

From the logs collected in one locality in Erba (Como municipalities) [45°48'06.78"N; 9°13'02"E] on 10 September 2013, 29 females (no males) emerged of *Rhoptrocentrus piceus* Marshall (Hymenoptera: Braconidae: Doryctinae): four specimens in November 2013 and the others in April 2014. In the same logs only adults of *P. h. hilaris* were registered.

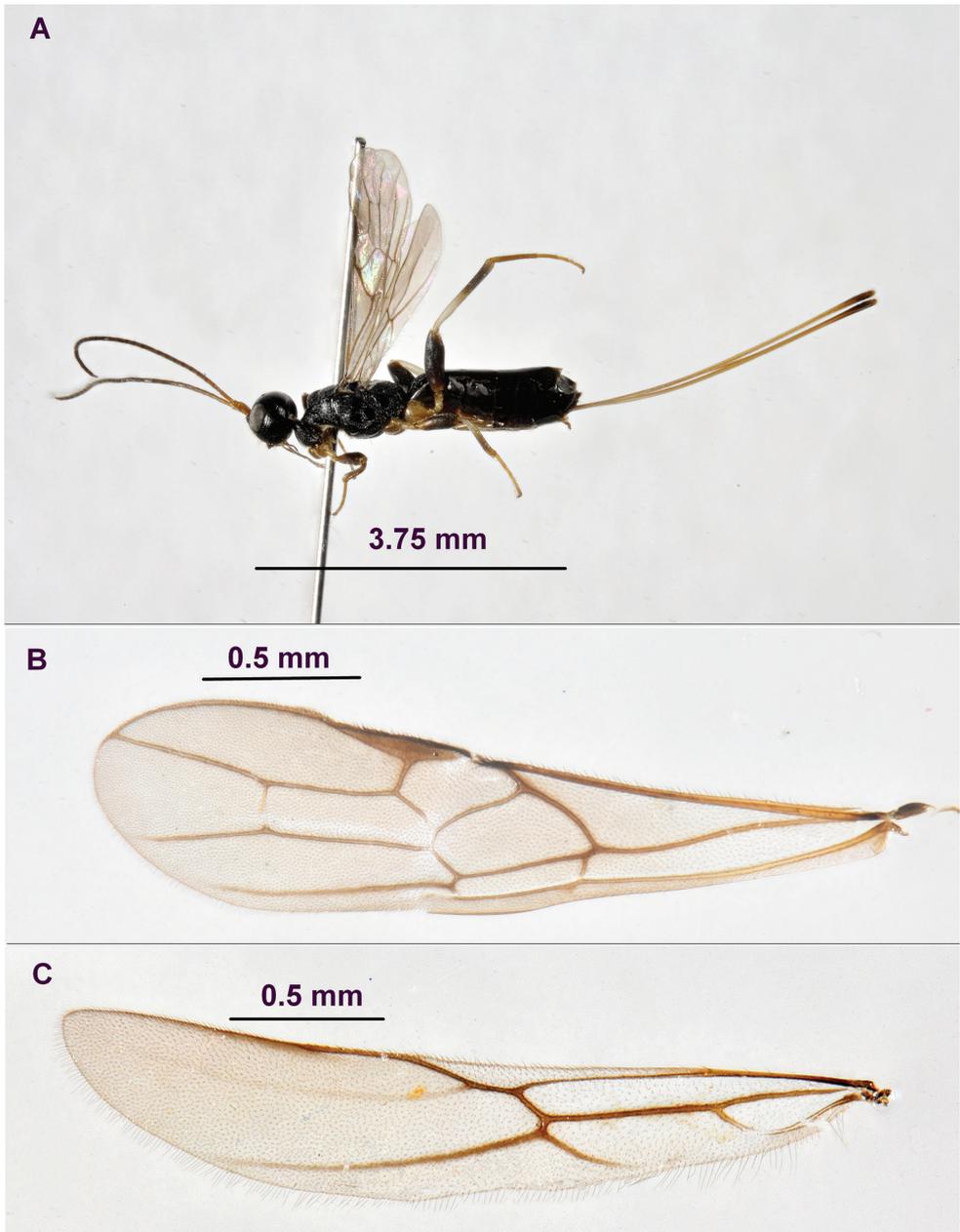
The body length of *R. piceus* ranged from 2.75 mm to 4.86 mm, confirming the high variability of the body size for this species (Becker 1979, Belokobylskij 2001) (Table 1). The main features of the genus and the species were confirmed by consulting the most recent keys (Marsh 1997, Belokobylskij 2001, Belokobylskij and Maetô 2009). Terminology adopted for morphological features and measurements follows Belokobylskij and Maetô (2009) (Figs 1 and 2).

The genus *Rhoptrocentrus* belongs to the tribe Doryctini including approximately 35 Palearctic genera (Belokobylskij et al. 2004). This is a moderately large subfamily of the family Braconidae with more than 1000 described species worldwide. Most of the known doryctine species are idiobiont gregarious ectoparasitoids of the larvae of xylophagous or bark-boring Coleoptera, while some species live on Lepidoptera or Hymenoptera-Symphyta (sawfly) larvae. Exceptionally they were reared from adults of Embiopter or living within termites nests and several Neotropical genera behave as phytophagous or gall-associated wasps (Marsh 1997, Belokobylskij et al. 2004, Zaldivar-Riveron et al. 2014).

The genus *Rhoptrocentrus* includes only three described species, *R. piceus* Marshall with a Holarctic distribution (Yu et al. 2012), *R. cleopatrae* Belokobylskij, so far known only from Egypt (Belokobylskij 2001), and *R. yarramanensis* Belokobylskij, Iqbal et Austin, recently described from Australia (Belokobylskij et al. 2004). *Rhoptrocentrus piceus* is relatively common in the western Palearctic, but in its eastern distribution, this species was recorded only from Japan (when it was secondarily described under the name *Doryctomorpha chlorophori*: Watanabe 1951), with large gaps of its distribution in the eastern part of Russia between the Urals and Japan. Interestingly, *R. piceus* again appeared in north Vietnam (first record: 1 female, "Vietnam: Hoa Binh Province, Yen

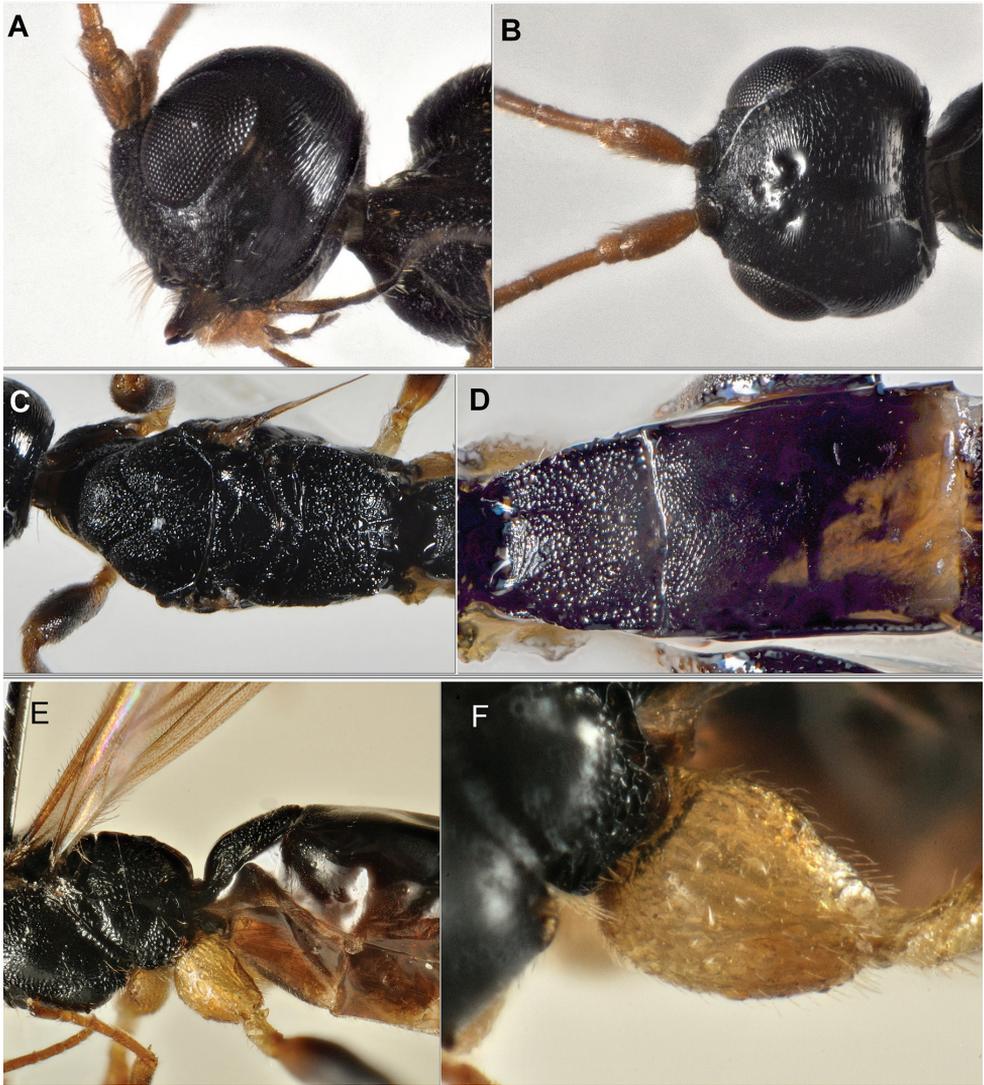
**Table 1.** Body size variability of the *Rhoptrocentrus piceus* specimens emerged from larvae of *Psacotheta hilaris hilaris*.

	Body length (mm) (N = 29)	Ovipositor length (mm) (N = 23)
Mean ± SD	3.7 ± 0.63	3.15 ± 0.62
Maximum value	4.865	4.49
Minimum value	2.75	2.04



**Figure 1.** *Rhotrocentrus piceus* Marshall: **A** habitus, lateral view **B** fore wing **C** hind wing.

Thuy District, Da Phuc, 20°18'N 105°35'E, h=100 m, 3–4.05.2002, S. Belokobylskij"; 1 female, "Vietnam: Vinh Phuc Prov., Me Linh District, Ngoc Thanh, Tam Dao foothill, 21°24'N 105°43'E, h=400 m, 12-13.05.2002, S. Belokobylskij"; both specimens from Zoological Institute, St Petersburg, Russia). This species was also discovered



**Figure 2.** *Rhoptrocentrus piceus* Marshall: **A** head, lateral view **B** head, dorsal view **C** mesosoma, dorsal view **D** metasoma, first three segments, dorsal view **E** propodeum and base of metasoma, lateral view **F** hind coxa, lateral view.

in the Nearctic region (several states of the the USA). The genus *Rhoptrocentrus* was already referred to from Mexico (Coronado-Blanco 2013), but without species names; here we record *R. piceus* from Mexico for the first time: 1 female, “Mexico. Tamaulipas, Altamira, Ej. Aquiles Serdan, Trampa Malaise 3, 22°33'2.78"N, 97°54'13.11"O, 15–30 Marzo, 2013”; 1 female, “Monterrey, Nuevo Leon, 20-IV-86, E. Ruiz C.” (both specimens from the collection of the Universidad Autónoma de Tamaulipas, Cd. Victoria, México).

This species has a wide range of hosts mainly belong to the orders of Coleoptera [families Anobiidae, Bostrichidae, Buprestidae, Cerambycidae, and Curculionidae (including Scolytinae)], but also to Hymenoptera (Xiphydriidae) and Lepidoptera (Coleophoridae and Tortricidae) (Belokobylskij and Maeto 2009, Belokobylskij and Žikić 2009, Yu et al. 2012, Žikić et al. 2013). The host range of this parasitoid, as well as its wide distribution across all the Holarctic region, with penetration into the Oriental region, suggest a high ability in adapting to different ecological conditions. All these characteristics make it a very suitable parasitoid for the containment of new wood-boring invasive species representing an increasing problem across the Italian territories (Loni et al. 2012). Our finding of this wasp on the new exotic pest *P. b. hilaris* seems to validate such a consideration and encourages further studies regarding the biology of *R. piceus* as well as the possibility to mass rear it (Turgeons and Smith 2013).

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# Description of a new species of *Apterotoxitiades* Adlbauer, 2008 (Cerambycidae, Dorcasominae, Apatophyseini) and the female of *A. vivesi* Adlbauer, 2008, with notes on the biology of the genus

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## Abstract

Following the description of the Apatophyseini genus *Apterotoxitiades* Adlbauer, 2008 (Cerambycidae: Dorcasominae) from South Africa, a new species has now been discovered in the eastern Drakensberg range of the country. The holotype female is here described as *A. aspinosus* **sp. n.** Also, a small series collected at Hogsback, in the Amathole range, has allowed the description of the previously unknown female of the type species, *A. vivesi* Adlbauer, 2008. Both species are high altitude dwellers, occurring above 1300 m asl and their habitat consists mainly of mountain grassland interspersed with mistbelt forest pockets. All specimens were recorded in the austral winter to early spring, when these mountain ranges are occasionally covered in snow and night temperature plummet below 0 °C. They appear to be nocturnal and their complete lack of wings indicates a remarkable adaptation to cold conditions at high altitude.

## Keywords

Cerambycidae, Dorcasominae, Apatophyseini, *Apterotoxitiades*, new species, habitat, South Africa

## Introduction

The genus *Apterotoxitiades* Adlbauer, 2008 was described on the basis of a single male from Hogsback in the Amathole mountains of the Eastern Cape Province of South Africa. It was collected in August 1992, under a large log on gently sloping grassland terrain. In early September 2014, the type locality was revisited, resulting in several new specimens including the hitherto unknown female of the only described species, *A. vivesi* Adlbauer, 2008. This survey also provided further details on the habitat characteristics and ecology of this species.

A female specimen of what is obviously a representative of the genus *Apterotoxitiades* has for some time been in the ABPC collection. It had been collected in the Drakensberg mountains of KwaZulu-Natal in October 1972, by an unknown collector. Because of a lack of knowledge of the degree of sexual dimorphism within the genus prior to the new Amathole collection, it was not possible to conclude with confidence as to whether this was the unknown female of *A. vivesi* or a different species. The new material from Hogsback however, clearly shows that the Drakensberg specimen represents an entirely different species which is hereby described.

A brief outline of the generic diagnostic characters is given below. The generic description of *Apterotoxitiades* was provided by Adlbauer (2008), but the discovery of the new species, *A. aspinosus* sp. n. necessitates a slight amendment of the original description, mainly in virtue of a total absence of lateral pronotal spines in the new species.

## Methods

Specimen length was measured from the anterior margin of the head to the elytral apex. Specimen width represents the maximum width of the elytra. Photos of set specimens were taken using a Canon Eos 5D camera fitted with a Canon MP-E 65 Macro 2.8-1.5× objective. Components of male genitalia were photographed under a Nikon SMZ 25 stereomicroscope, using a Nikon Digital Sight DS-Fi2 camera. *In situ* photos were taken using a Ricoh CX1 camera with macro setting.

Collections are abbreviated as follows: TMSA, Ditsong National Museum of Natural History (formerly Transvaal Museum), Pretoria, South Africa; ISAM, Iziko South African Museum, Cape Town, South Africa; NHMO, Natural History Museum, Oslo, Norway; ABPC, Anders Bjørnstad Private Collection, Skien, Norway; KAPC, Karl Adlbauer Private Collection, Graz, Austria; RPPC, Renzo Perissinotto & Lynette Clennell Private Collection, Port Elizabeth, South Africa. Geographical abbreviations are as follows: RSA, Republic of South Africa; KZN, KwaZulu-Natal Province, South Africa; EC, Eastern Cape Province, South Africa.

## Taxonomic account

### Genus *Apterotoxiades* Adlbauer, 2008

The major characters are the wingless body with strongly atrophic (nearly absent) shoulders, short head with small, coarsely faceted eyes and long palpi with terminal segment expanded in male. Pronotum armed or not (amended from the original description). Legs are long and slender, coxae are rather large and prominent. In the light of the recent work undertaken by Villiers et al. (2011), on the Dorcasominae of Madagascar, it is clear that the male genitalia of *Apterotoxiades* fall within the range described for this subfamily.

Only a single male of the remarkable type species *A. vivesi*, which seemingly occurs rarely and locally, was hitherto known from the genus. The new material recently found allows the description of the female.

### *Apterotoxiades vivesi* Adlbauer, 2008

Figures 1–4

**Material examined.** Four female and two male specimens: South Africa, EC, Hogsback, 1300 m, 7 Sep 2014, R. Perissinotto & L. Clennell leg. (TMSA, ISAM, KAPC, RPPC). Only one male and one female were found alive, while the other four specimens were dead, two with soft tissue consumed by spiders.

**Description.** ♀. Length: 10–11.5 mm; width: 3.5–4 mm (n = 4). General habitus as in male (Figure 2), but with shorter antennae and legs and wider elytra (Figures 1–3).

**Coloration.** Dark greyish brown, apices of the elytra slightly lighter brown. Palpi, antennae, legs and ventral side light yellow brown. Mandibles light yellow brown, with the exception of the apices which are black.

**Body surface.** Whole surface covered in short depressed silky tomentum. Long, thin, hairlike whitish grey bristles present especially on the lateral side of the mandibles, scapus and pronotal sides (Figure 1A).

**Head.** Broad with strong, falciform mandibles. Palpi moderately long, terminal segment only very weakly enlarged. Eyes coarsely faceted, strongly protuberant and broadly separated, small, oblique, not emarginate and far behind antennal tubercles. Frons between the eyes broad and flat. Antennae reaching to the second half of the elytra. Antennomeres becoming shorter towards the end, but not very different in length from each other.

**Pronotum.** As long as wide with long, rather acute lateral spines pointed strongly obliquely upwards (Figure 1A). Surface like in male (Figure 2). Disc convex in the middle. Unlike in male, the anterior edge is not broader than the posterior.

**Scutellum.** Very small, hardly visible, wider than long.

**Elytra.** Fused, somewhat broader than in male, widest in the anterior third. Strongly convex, both laterally and dorsally. Slightly more than half of the anterior part sparsely punctate. Apices broadly rounded.



**Figure 1.** *Apterotoxitiades vivesi*: Female dorsal (A) and ventral (B) habitus, 11 mm TL (photos Lynette Clennell).

*Legs.* Long and slender, but shorter than in male (Figures 2 and 3). Coxae large and projecting (Figure 1B).

*Ventral surface.* All coxae well separated from each other, especially the metacoxae. The first visible abdominal sternite is the longest, with the following becoming progressively shorter until the fifth visible (Figure 1B).

*Male.* A general description is provided in Adlbauer (2008). Only further details of the genitalia, along with photos of whole genitalia as well as tegmen and aedeagus separately are provided here (Figure 4A–C). Aedeagus with heavily sclerotized acute dorsal lobe bearing an acuminate apex. Ventral lobe with a rounded, weakly truncate apex, much shorter than dorsal lobe, and decidedly less sclerotized. Apophyses long, strap-shaped and constituting more than 50% of total aedeagus length (Figure 4B). Tegmen with relatively long and slender, slightly diverging parameres with apical brushes of very long setae (Figures 4A, C). Presence of sheath-like appendage between the base of the parameres and the “tegmen ring”, on both sides. When the aedeagus is in its position inside the tegmen, the apex of the dorsal lobe reaches almost to the apices of the parameres, while the ventral lobe reaches just beyond the point of diversion of the parameres (Figure 4A).



**Figure 2.** *Apterotoxitiades vivesi*: Male specimen in its natural habitat, Hogsback Forestry, September 2014 (photo Lynette Clennell).



**Figure 3.** *Apterotoxitiades vivesi*: Female specimen in its natural habitat, Hogsback Forestry, September 2014 (photo Lynette Clennell).



**Figure 4.** *Apterotoxitiades vivesi*: Dorsal view of whole male genitalia (A), aedeagus (B) and tegmen (C) (photos Lynette Clennell).

***Apterotoxitiades aspinosus* Björnstad, sp. n.**

<http://zoobank.org/704D5D2E-5099-43E7-9478-5EBE9EC9B30A>

Figure 5

**Type.** Holotype (HT) ♀: RSA, Natal 1500/2000 m [Royal] Nat[al] Nat. Park X/1972 [collector unknown] (NHMO).

**Diagnosis.** The most obvious difference from *A. vivesi* is the total lack of lateral spines on the pronotum. Both sexes of *A. vivesi* have pronotum with “langen, zahnförmigen Seitendornen” (Adlbauer 2008). The new species also differs by its greater size (17 mm vs. 10–11 mm in *A. vivesi* female), and by the somewhat more elongate body outline.

**Etymology.** The word “*aspinosus*” refers to the lack of lateral spines on the pronotum, which are very prominent in the type species, *A. vivesi*.

**Description.** HT ♀. Length: 17 mm; width 5.8 mm. Habitus rather slender, long legged, flightless with fused elytra (Figure 5).

**Coloration.** Head and pronotum dark reddish brown, elytra slightly lighter. Legs, antennae and palpi yellow to brownish yellow. Eyes black with bronze lustre.

**Body surface.** Head and pronotum finely, but densely punctate/granulate. Elytra with scattered, shallow pit-like punctation, each pit bearing a pale yellowish bristle.



**Figure 5.** *Apterotoxiades aspinosus* sp. n.: Holotype female dorsal (A) and ventral (B) habitus, 17 mm TL (photos Karsten Sund and Hallvard Elven).

Elytra surface with short, curved  $\pm$  adpressed silky tomentum. The same type of tomentum occurs on palpi, head, scape and pronotum, but there with interspersed long, stiffly erect pale yellowish-hyaline bristles, particularly distinct on anterior part of head and lateral part of pronotum.

*Head.* Both labial and maxillary palpi long and slender and with ultimate joints narrowly triangular. Mandibles strong, sickle-shaped with curved, glabrous and shiny apices. Front of head with moderately raised antennal tubercles, and without a longitudinal furrow between them. Eyes small, strongly protuberant, far apart from antennal socket, only slightly emarginate. Antennae reaching elytral midlength; scapus widened apically; pedicellus almost globular, but shorter than wide. Antennomere 5 of same length as scape, following antennomeres shorter than these and gradually tapering and shortening distally; antennomeres 5–11 with minute, but dense greyish tomentum.

*Pronotum.* Shorter than wide (length/width ratio = 0.8) and with posterior margin wider than anterior. Both edges are only weakly thickened or rimmed. Small constriction on anterior end, at about one fifth of the length, otherwise smoothly convex both dorsally and laterally.

*Scutellum.* Short, broadly triangular with a broad, slightly thickened black border.

*Elytra*. Fused, strongly convex both laterally and dorsally and with evenly rounded apices. Shoulders only weakly marked.

*Legs*. Long and slender with only weakly thickened femora; straight tibiae gradually widening apically; tarsi long and slender, especially the metatarsi.

*Ventral surface*. Gula glabrous, all other parts finely granulate and rather densely covered in curved, silky, adpressed tomentum as on dorsal side (Fig. 5B). Procoxae strong and conical, separated by a narrow prosternal process slightly widened and truncate at apex. Procoxal cavities more or less circular in outline but antero-laterally with a small and short acute extension. Metasternum narrow with a truncated triangular process (Fig. 5B). Visible abdominal sternites 1–5 with a finely granulate microstructure and progressively narrowing posteriorly. Sternite 5 with a straight to weakly concave truncation apically.

*Male*. Unknown.

### Biology of the genus *Apterotoxitiades*

Both *Apterotoxitiades* species currently known have been collected in grassland terrain at high altitudes, above 1300 m asl, in the Amathole range of the Eastern Cape (Figure 6) and the eastern Drakensberg of KwaZulu-Natal (Figure 7). The vegetation units that characterize these areas are typically Amathole Montane Grassland (Gd 1, habitat of *A. vivesi*) and Northern Drakensberg Highland Grassland (Gd 5, presumed habitat of *A. aspinosus* sp. n.). Both are part of the Drakensberg Grassland Bioregion (Mucina and Rutherford 2006). The Amathole Montane Grassland unit exhibits short grassland dominated by a variety of grass species, mainly *Themeda triandra*, and a high species richness of forbs, especially those of the family Asteraceae (e.g. *Helychrysum* spp., *Senecio* spp.) (Mucina and Rutherford 2006). Although this vegetation unit is generally not regarded as highly threatened, in the area of Hogsback, which constitutes the only known habitat of *A. vivesi*, most of it has already experienced large-scale transformation to pine plantations (Figure 6).

The generally steep slopes of the Northern Drakensberg Highland Grassland support short sour grassland rich in forbs. Scattered trees of *Protea caffra* and *P. roupelliae* are also a typical feature of this vegetation unit, as are small patches of mistbelt forest occasionally growing in wet ravines. Unlike the previous unit, the Northern Drakensberg Highland Grassland vegetation currently faces little conservation threat, particularly in the relatively large uKhahlamba Drakensberg Park, which enjoys status of UNESCO World Heritage Site since 2000 (Mucina and Rutherford 2006). The Royal Natal National Park, where the holotype of *A. aspinosus* sp. n. was collected in 1972 (Figure 7), currently falls within this wider Park.

All specimens of *A. vivesi*, including the holotype male collected in August 1992 (Adlbauer 2008), have so far been found under 1–2 year old pine logs lying on the ground, adjacent to the grassland (Figure 6). Three pine species are cultivated in the area by the Amathole Forestry Company, including *Pinus elliotii*, *P. patula* and *P. radiata* (Chapman 2011). However, no evidence of *A. vivesi* using this pine wood as



**Figure 6.** *Apterotoxitiades vivesi*: Typical habitat of mountain grassland with shrub pockets and pine plantations on the slopes of the Hogsback mountain range (photo Lynette Clennell).

boring or larval development medium could be found. All adult specimens were simply hiding under the logs, at the interface between bark and grass or leaf litter, where moisture levels were significantly higher than elsewhere and no light penetration occurred. It is likely that larval development may occur either on the stems of the short shrubs that occur within the grassland, or on the roots of the grass itself. The larvae of some Palearctic genera of Cerambycidae, such as *Vesperus* and *Dorcadion* for instance, are well known for their underground development, feeding on the roots of a variety of grasses and shrubs (Pesarini and Sabbadini 1994).

Given their extremely reduced compound eyes, adult *A. vivesi* are probably nocturnal in activity. During the period of their activity, this area does not receive any major rainfall, but some surface moisture is maintained by night-time mist and/or fog. As this dries out in the heat of the day, however, the beetles would need to return underground or find a suitable shelter for the day at the surface, ideally rich in moisture and protected from light and visual predators. Thus, tree logs lying on the ground at the edge of the grassland, and possibly also large stones, may provide an ideal hideout for adults to spend the day. However, this habitat is also shared by ground beetles (Carabidae) and spiders, with the latter actually consuming *A. vivesi*, judging by the state of the carcasses retrieved in their silk wrapping.



**Figure 7.** *Apterotoxitiades aspinosus*: The Amphitheatre of the Royal Natal National Park, as a likely representative of the typical Drakensberg habitat of this species (photo Gerald Camp).

The following observations were made directly in the field by R.P. during the survey of September 2014. Remarkably, the only two specimens found still alive in their habitat (all the other specimens were already dead and partly decomposed) died very rapidly once removed from their wet and dark hideout under the wood. They immediately entered a state of muscular spasm, developing a shivering-type of reaction followed by the folding of their legs and death within a period of less than 1 hour. This reaction could possibly have been caused by sudden exposure to intense light, as their compound eyes are extremely reduced (Figures 1, 3, 5) and reminiscent of those observed in some cave beetles. A more likely possibility is, however, that they may have suffered thermal shock, by being suddenly exposed to temperatures much higher than those prevailing under the logs. The air temperature on the day of the collection was in fact particularly high in comparison to seasonal averages, with almost 30 °C attained around midday.

Even more intriguing appears to be the period of adult activity during mid-late winter. The already dead specimens, and a few more consumed carcasses found on site, clearly indicate that adults were already on their way out in early September and probably at peak activity about a month earlier. This is unusual for high altitude areas of southern Africa, where adult cerambycids generally start emerging only in the spring, after substantial rainfall events. At Hogsback, in particular, rainfall exhibits a bimodal pattern, with spring and late summer peaks, and annual precipitation can reach 1000 mm. Minimum temperatures often plummet below zero in winter and frost occurs with frequency of up to 80 days per year (Leroux 1994, Mucina and Rutherford 2006). Occasional, light snowfalls are also a regular feature of the winter season. Thus, the winter activity of *A. vivesi*, combined with its apparent intolerance for high temperatures, may be indicative of an unusual adaptation to cold climatic conditions.

Unfortunately, no habitat data was reported on the label accompanying the holotype specimen of *A. aspinosus* sp. n., and thus it is not possible to draw conclusions about its ecology. Nevertheless, it seems likely that its main traits may be similar to those observed in *A. vivesi*, with the exception that in this case the period of adult activity is clearly in the spring, as the fresh holotype specimen was found in October.

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# Two new species of *Pseudancistrus* (Siluriformes, Loricariidae) from the Amazon basin, northern Brazil

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## Abstract

Two new species of *Pseudancistrus*, a genus diagnosed by non-evertible cheek plates and hypertrophied odontodes along the snout margin, are described from two drainages of the Brazilian Shield: *P. kayabi* from the rio Teles Pires (rio Tapajós basin) and *P. asurini* from the rio Xingu. The new species are distinguished from congeners (*P. barbatus*, *P. corantijniensis*, *P. depressus*, *P. nigrescens*, *P. reus*, and *P. zawadzskii*) by the coloration pattern. *Pseudancistrus kayabi* has dark bars on the dorsal and caudal fins which are similar to that of *P. reus* from the Caroní River, Venezuela. *Pseudancistrus asurini* is unique among *Pseudancistrus* in having whitish tips of the dorsal and caudal fins in juveniles to medium-sized adults.

## Keywords

Ancistrini, Neotropical fish, freshwater, Brazilian Shield, taxonomy

## Introduction

With 892 species, the suckermouth armoured catfish family Loricariidae is the fifth most species-rich family of vertebrates and one of the most species-rich groups among Neotropical fishes (Eschmeyer and Fong 2014). The loricariids are easily distinguished by having a ventral oral disk, the body covered with ossified dermal plates, and the presence of small external teeth known as odontodes. Within this family, all species that have highly evertible clusters of cheek odontodes are placed within the subfamily

Hypostominae, the tribe Ancistrini (Armbruster 2004a, 2008). Morphology-based studies by Armbruster (2004a, 2008) showed Ancistrini as a monophyletic group; however, recent molecular studies supported the conclusion that the tribe was polyphyletic (e.g. Covain and Fish-Muller 2012; Lujan et al. 2015). Ancistrini was redefined by Lujan et al. (2015) and currently includes only ten valid genera but stays the second most genus-rich of the nine tribe-level clades of Hypostominae.

*Pseudancistrus* Bleeker, 1862 was known to contain 15 valid species (Eschmeyer and Fong 2014) but recent publications (e.g. Chambrier and Montoya-Burgos 2008; Covain and Fisch-Muller 2012; Silva et al. 2014; Lujan et al. 2015) revealed that the genus is not monophyletic and that the type species, *P. barbatus* (Valenciennes, 1840), is closely related only with four species known as the *P. barbatus* species group: *P. corantijnensis* de Chambrier & Montoya-Burgos, 2008, *P. depressus* (Günther, 1868), *P. nigrescens* Eigenmann, 1912, and *P. zawadzki* Silva, Roxo, Britzke & Oliveira, 2014, the latter being the only species described to date from rivers flowing from the Brazilian Shield into the Amazon. Other species not included in these works were considered to possibly belong to *Pseudancistrus*: *P. guentheri* (Regan, 1904) *P. kwinti* Willink, Mol & Chernoff, 2010 (Covain and Fisch-Muller 2012), and *P. reus* Armbruster & Taphorn, 2008 (Lujan et al. 2015). This last work retained *P. reus* as the only species belonging to this group from the eastern Orinoco basin. The genus *Pseudancistrus* is diagnosed by a combination of characters state as follows: a depressed body, hypertrophied odontodes along the lateral margin of the snout (regardless of either sex or season), and hypertrophied cheek odontodes which are evertible to less than 45° from the body (Lujan et al. 2015).

Recently, an examination of the fish collections at the LBP (Laboratório de Biologia e Genética de Peixes de Botucatu) and MZUSP (Museu de Zoologia da Universidade de São Paulo) revealed the existence of two undescribed species of *Pseudancistrus* from the rio Xingu (the first species of *Pseudancistrus* for this basin) and the rio Teles Pires (the second species of *Pseudancistrus* for rio Tapajós basin), both of which are tributaries of the Amazon basin draining the Brazilian Shield. In the present paper these two new species are described.

## Material and methods

After capture, fishes were anesthetized using 1% benzocaine in water, fixed in 10% formaldehyde, and preserved in 70% ethanol. Vouchers and tissues were deposited in the collection of AUM (Auburn University Natural History Museum, Auburn, USA), LBP (Laboratório de Biologia e Genética de Peixes, Botucatu, Brazil), and MZUSP (Museu de Zoologia da Universidade de São Paulo, São Paulo, Brazil). Measurements and counts were taken from the left side. Body plate follows Schaefer (1997) and measurements were taken point to point to the nearest 0.1 mm using digital calipers on left side of specimens following Armbruster (2003). Morphometrics are given as percentages of standard length (SL), except for subunits of the head region that are expressed as percentages of head length (HL). Dorsal-fin ray counts

include the spinelet as the first unbranched ray. Zoological nomenclature follows the International Code of Zoological Nomenclature (International Commission on Zoological Nomenclature 1999).

## Results

### *Pseudancistrus kayabi* sp. n.

<http://zoobank.org/F8B055A4-C576-4FC5-B0CF-8021F0B7DD93>

Figure 1, Table 1

**Holotype.** MZUSP 116322, male, 88.4 mm SL. Brazil: Mato Grosso State: municipality of Itaúba: rio Teles Pires (Tapajós River basin), 10°58'30"S, 55°44'03"W, 01 October 2007, JLO Birindelli, P Hollanda-Carvalho.

**Paratypes.** All from Brazil: Mato Grosso State: rio Teles Pires (Tapajós River basin): Amazon basin. AUM 65641 2, 74.5–80.3 mm SL, municipality of Itaúba, 11°03'44"S, 55°19'08"W, 26 September 2007, JLO Birindelli, P Hollanda-Carvalho. LBP 19552, 2, 79.1–87.1 mm SL, municipality of Itaúba, 11°03'44"S, 55°19'08"W, 26 September 2007, JLO Birindelli, P Hollanda-Carvalho. MZUSP 95851, 1, 60.9 mm SL, collected with holotype. MZUSP 95912, 54, 27.1–86.5 mm SL, municipality of Itaúba, 11°03'44"S, 55°19'08"W, 26 September 2007, JLO Birindelli, P Hollanda-Carvalho. MZUSP 96157, 34, 29.5–85.8 mm SL, municipality of Paranaíta, 09°26'58"S, 56°29'19"W, 28 September 2007, LMS Souza, AL Netto-Ferreira.

**Diagnosis.** *Pseudancistrus kayabi* differs from all congeners except *P. reus* by having caudal and dorsal fins with dark bars (vs. with white spots in caudal and dorsal fins). Also, the new species differs from all *Pseudancistrus* except *P. nigrescens* by having a dark brown body with whitish spots that fade along the posterior portion of the dorsal fin and forming mottled pattern (vs. either dark brown with conspicuous rounded spots not covering more than one plate in *P. barbatus*, *P. corantijnensis*, *P. depressus*, *P. asurini*, and *P. zawadzki* or with dark brown bars in *P. reus*). It further differs from *P. barbatus* and *P. depressus* by having the snout with yellowish hypertrophied odontodes (vs. reddish-brown odontodes) (see Fig. 3 in De Chambrier and Montoya-Burgos 2008 for comparison). In addition, *P. kayabi* is distinguished by having a shorter pectoral spine, 22–30% SL (vs. 29–34% in *P. nigrescens*, 31–33% in *P. zawadzki*, and 30–34% in *P. barbatus*); a shorter dorsal-fin base, 20–28% SL (vs. 28–29% in *P. nigrescens*, 29–31% in *P. zawadzki*, and 28–31% in *P. barbatus*); a greater internares width, 13–19% HL (vs. 10.5–12.9% in *P. nigrescens*); head depth, 60–66% HL, greater than in *P. nigrescens* (56–57%) and in *P. barbatus* (41–53%) but smaller than in *P. zawadzki* (67–73%); and a greater adipose-anal distance (17–25% SL vs. 15–17% in *P. nigrescens* and 12–15% in *P. barbatus*).

**Description.** Morphometric data is presented in Table 1. In lateral view, dorsal profile convex from snout tip to dorsal-fin origin; straight, gradually descending from dorsal-fin origin to posterior insertion of adipose fin; straight, steeply ascending to



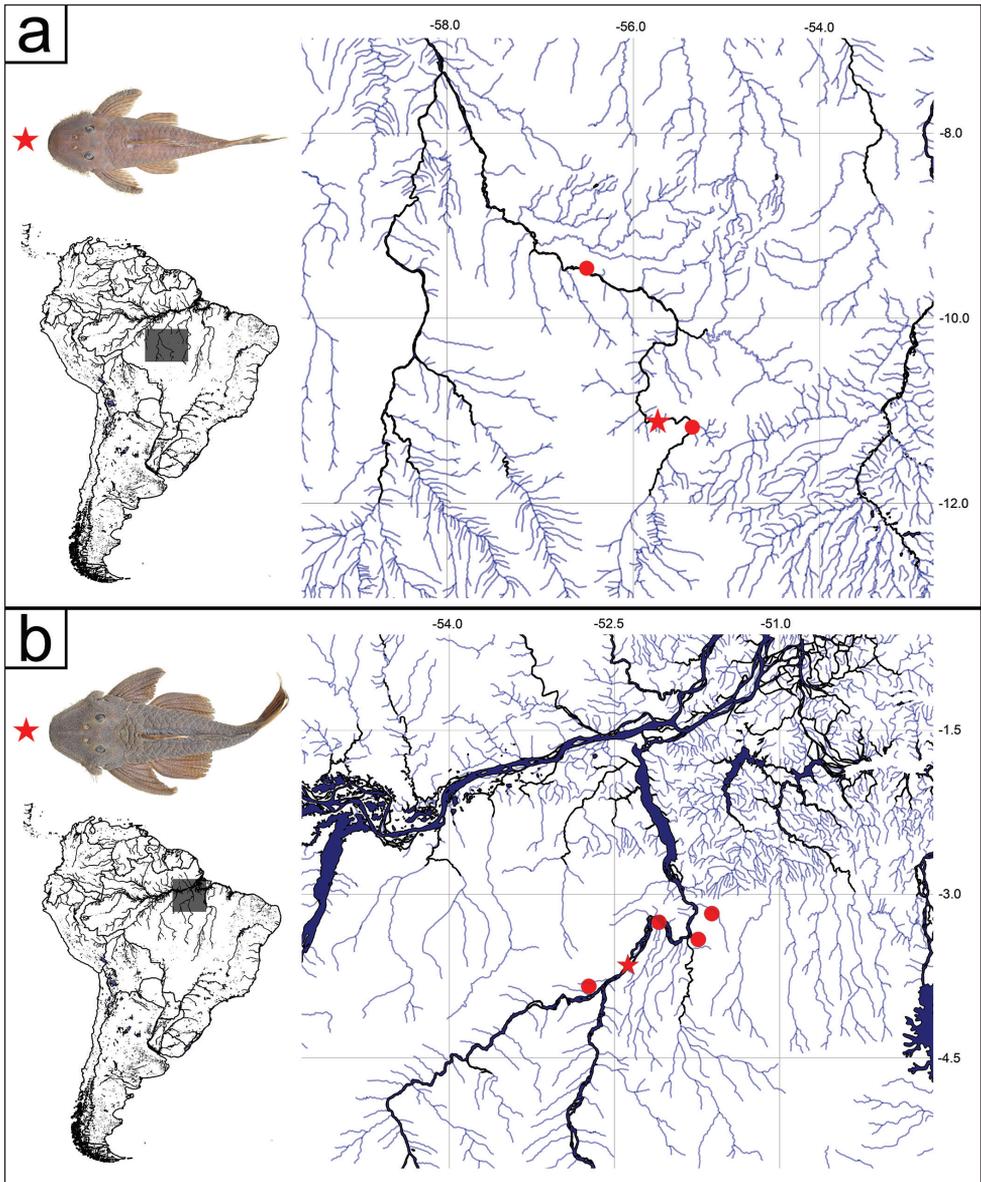
**Figure 1.** *Pseudancistrus kayabi*, holotype, MZUSP 116322, male 88.4 mm SL, from rio Teles Pires (Amazon basin), municipality of Itaúba, Mato Grosso State, Brazil.

insertion of caudal fin; ventral profile flat from snout tip to anal-fin origin; shallowly concave from anal-fin insertion to lower caudal-fin spine; greatest body depth at dorsal-fin origin. In dorsal view, greatest body width across cleithral region; snout broadly elliptical; body progressively narrow from opercular region to caudal fin. Cross-section of body between pectoral and pelvic fins rounded dorsally and flattened ventrally; cross-section of caudal peduncle ellipsoid.

**Table 1.** Morphometric data for *Pseudancistrus kayabi* and *P. asurini*. SD = standard deviation.

	<i>Pseudancistrus kayabi</i> n = 21				<i>Pseudancistrus asurini</i> n = 21			
	Holotype	Range	Mean	SD	Holotype	Range	Mean	SD
<b>SL</b>	88.4	61.5–87.7	78.5	7.2	195.8	195.8–45.9	85.9	37.9
<b>Percentage of SL</b>								
Predorsal length	42.7	39.4–48.5	43.8	1.9	39.5	39.1–42.7	40.9	1.2
Head length	34.6	30.2–40.2	34.9	1.9	33.6	31.9–35.8	33.9	0.9
Head-dorsal length	8.0	7.1–11.0	9.3	1.0	7.5	5.3–8.2	6.9	0.7
Cleithral width	33.4	31.2–38.6	33.5	1.7	35.8	30.9–35.8	32.8	1.4
Head-pectoral length	29.1	24.5–33.6	29.6	2.0	31.7	21.9–31.7	28.3	1.8
Thorax length	22.8	19.6–25.6	22.2	1.6	20.1	20.1–25.5	22.7	1.5
Pectoral spine length	30.0	22.3–29.7	27.7	1.7	36.2	27.8–36.7	31.6	2.5
Abdominal length	24.2	20.3–30.4	24.3	2.2	20.5	20.5–26.0	23.9	1.4
Pelvic spine length	25.9	20.3–29.8	23.7	2.0	27.0	23.8–27.4	25.9	1.0
Postanal length	32.3	25.9–35.9	31.3	2.5	29.2	29.2–35.3	32.8	1.6
Anal-fin spine length	9.6	5.4–12.9	10.1	1.7	16.6	7.8–16.6	10.1	1.9
Dorsal-pectoral depth	26.4	20.2–29.4	25.9	1.9	24.0	23.3–26.5	24.8	0.9
Dorsal spine length	24.3	17.7–29.2	23.0	2.1	22.5	22.5–32.7	20.0	2.2
Dorsal-pelvic depth	22.4	15.2–26.7	21.2	2.3	19.3	17.2–26.5	20.1	2.0
Dorsal-fin base length	28.1	20.4–28.1	26.0	1.7	29.9	24.9–30.6	27.4	1.6
Dorsal-adipose distance	14.3	9.0–14.3	12.0	1.9	13.3	13.1–17.4	15.4	1.2
Adipose-spine length	10.1	6.3–16.9	9.1	2.4	8.6	7.7–10.3	8.6	0.6
Dorsal adipose-caudal distance	16.0	13.4–22.0	16.3	2.3	12.1	12.1–16.5	15.0	1.0
Caudal peduncle depth	11.3	10.0–16.7	11.0	1.5	10.6	9.1–11.0	10.2	0.5
Ventral adipose-caudal distance	22.6	20.3–25.6	22.2	1.2	19.5	19.5–22.9	21.3	1.0
Adipose-anal distance	18.9	16.9–24.8	19.6	1.9	18.8	16.9–19.9	18.8	0.8
Dorsal-anal distance	33.1	29.3–35.4	32.8	1.4	12.6	12.1–19.1	13.3	1.5
Pelvic-dorsal distance	27.6	17.4–27.6	21.1	1.8	28.2	18.3–29.4	25.7	2.7
<b>Percentage of HL</b>								
Head-eye length	26.4	25.8–31.4	28.8	1.5	27.7	25.9–33.1	29.2	1.8
Orbital diameter	13.8	12.7–20.3	15.5	1.7	13.1	13.1–19.9	16.8	1.7
Snout length	67.4	62.3–69.3	65.4	1.6	69.5	56.6–72.4	62.2	4.5
Internares width	14.8	13.2–18.7	15.8	1.3	15.5	11.9–16.3	14.5	1.2
Minimal interorbital distance	30.6	27.4–35.7	29.1	1.9	31.9	24.0–32.6	28.2	2.4
Mouth length	48.8	48.8–62.3	57.5	2.5	49.7	39.8–51.9	45.9	3.5
Barbel length	10.9	4.2–10.9	8.0	1.6	5.5	4.6–8.7	7.2	1.3
Dentary tooth cup length	20.8	15.4–24.6	20.5	2.6	20.1	16.1–22.4	19.8	1.7
Premaxillary tooth cup length	19.5	16.5–25.6	19.5	2.2	18.1	17.8–24.3	20.5	1.9
Head depth	64.2	59.7–65.7	62.4	1.8	64.3	56.6–66.2	62.6	2.4

Body almost entirely covered with plates except on ventral portions of head, abdomen, and dorsal-fin base. Five lateral rows of dermal plates, dorsal plates 21–22, lateral mid-dorsal plates 21–22, lateral median plates 22–23, lateral mid-ventral plates 21–22, lateral ventral plates 19–20. Three predorsal plates; eight plates below dorsal-fin base; four plates between dorsal fin and adipose fin; five rows of plates on caudal peduncle. Dorsal spinelet present.



**Figure 2.** Distribution maps. **a** *Pseudancistrus kayabi*. Star shows holotype locality, rio Teles Pires, 10°58'30"S, 55°44'03"W. Circle shows paratype locality **b** *Pseudancistrus asurini*. Star shows holotype locality, rio Xingu, 03°39'05"S, 52°22'42"W. Circles show paratypes localities.

Body plates and cleithrum with minute odontodes. Odontodes slightly hypertrophied on pectoral-fin spines, gradually larger towards tips. Numerous yellowish hypertrophied odontodes along lateral margins of head including snout; odontodes small on tip of snout increasing gradually in length from anterolateral margin of snout to

cheeks; longest odontodes on posteriormost portion of non-evertible cheek plates. Eye small (orbital diameter 13–20% HL), dorsolaterally positioned. Oral disk transversely ellipsoid. Lower lip not reaching transverse line between gill openings. Lower lip covered with numerous small papillae. Maxillary barbel developed. Mouth relatively large. Premaxillary teeth 33–70 per ramus; dentary teeth 39–74 per ramus. Teeth bifid, medial cusp large and rounded, lateral cusp minute and rounded. Jaws wide, dentaries forming oblique angle, premaxillaries almost co-linear.

Dorsal fin I,7, origin approximately at midpoint between pectoral- and pelvic-fin origins, last dorsal-fin ray reaching adipose fin when depressed. Pectoral fin I,6, spine tip slightly curved inward, covered with enlarged odontodes distally; depressed tip reaching one-third length of pelvic-fin spine. Pelvic fin I,5, spine tip curved inward, almost reaching anal-fin origin when depressed. Anal fin I,5, spine tip straight, reaching sixth plate posterior to its origin. Caudal fin I,7–7I, distal margin concave, inferior lobe longer than superior. Adipose fin with straight spine, preceded by single median preadipose plate.

**Color in alcohol.** Ground color dark brown on back and sides of body, and lighter brown ventrally. Anterior portion of head to posterior margin of orbits with many small, crowded, white spots; spots getting abruptly larger on posterior portion of head, continuing on body, fading along posterior portion of dorsal fin and forming mottled pattern. Dorsal-fin spine rays and membranes with 6–7 dark bars. Pectoral, pelvic, anal with 4–5 dark bars and caudal-fin with four dark bars. Hypertrophied odontodes along head margin yellowish.

**Sexual dimorphism.** Males possess a papilla posterior to urogenital opening, an attribute absent in females. Both sexes in *P. kayabi* exhibit highly hypertrophied odontodes along snout margin, as well as in other species of *Pseudancistrus* (Armbruster 2004b).

**Etymology.** The specific name “kayabi” is a reference to the Kayabi indigenous people that inhabited the region of the rivers Arinos, dos Peixes and Teles Pires, in Mato Grosso State, Brazil. A noun in apposition.

**Distribution.** *Pseudancistrus kayabi* is known from the rio Teles Pires, rio Tapajós basin, municipality of Itaúba and Paranaíta, Mato Grosso State, Brazil (Fig. 2a).

***Pseudancistrus asurini* sp. n.**

<http://zoobank.org/02D58958-6DD0-441A-8755-96F8387F2C33>

Figures 3, 4, Table 1

*Pseudancistrus* sp. L17: Covain and Fisch-Muller 2012: 232–233 (Table 1), 235 (Fig. 2), 237 (Fig. 3), 242 (Fig. 4). – Silva et al. 2014: 6 (Fig. 2), 14 (Fig. 6), 16 (Table 3), 17 (Fig. 7).

*Pseudancistrus* sp. L67: Lujan et al. 2015: 281 (Fig. 3).

**Holotype.** MZUSP 116323, male, 195.8 mm SL. Brazil: Pará State: municipality of Altamira: rio Xingu (Amazon basin), Cachoeira do Espelho, 03°39'05"S, 52°22'42"W, 18 November 2011, OT Oyakawa, JLO Birindelli, C Moreira, A Akama, LMS Souza.



**Figure 3.** *Pseudancistrus asurini*, holotype, MZUSP 116323, male 195.8 mm SL, from rio Xingu (Amazon basin), municipality of Altamira, Pará State, Brazil.

**Paratypes.** All from Brazil: Pará State: municipality of Altamira: Amazon basin. AUM 65640, 2, 79.1–82.9 mm SL, rio Xingu, Cachoeira da Mucucura, 03°24'31"S, 51°44'40"W, 09 November 2011, OT Oyakawa, JLO Birindelli, C Moreira, LMS



**Figure 4.** *Pseudancistrus asurini*, paratype, LBP 16551, female 100.5 mm SL, from rio Xingu (Amazon basin), showing the dorsal and caudal fins tips whitish.

Souza. LBP 16551, 2, 75.6–101.4 mm SL, rio Xingu, 03°15'24"S, 52°05'47"W, 28 September 2012, C Oliveira, R Britzke, LMS Souza. MZUSP 107174, 4, 45.9–123.4 mm SL, rio Xingu, Cachoeira de Mucura, 03°24'51"S, 51°44'23"W, ECIX team. MZUSP 107179, 2, 62.3–68.7 mm SL, rio Xingu, Cachoeira do Mucura, 03°24'51"S, 51°44'23"W, 07 July 2010, ECIX team. MZUSP 107435, 3, 74.6–105 mm SL, rio Xingu, 03°10'40"S, 51°36'58"W, 26 September 2007, FCT Lima, AK Zeinad. MZUSP 111285, 2, 84.4–106.6 mm SL, rio Iriri (trib. rio Xingu) Cachoeira Grande, 03°50'37"S, 52°44'02"W, OT Oyakawa, JLO Birindelli, C Moreira, A Akama, LMS Souza. MZUSP 111441, 6, 49.5–152.3 mm SL, rio Xingu, Cachoeira da Mucucura, 03°24'31"S, 51°44'40"W, 09 November 2011, OT Oyakawa, JLO Birindelli, C Moreira, LMS Souza. MZUSP 111558, 1, 91.4 mm SL, collected with holotype.

**Diagnosis.** The new species differs from all congeners by having the dorsal-and caudal-fin tips whitish (Fig. 4) (vs. entirely dark). It further differs from *P. reus* and *P. kayabi* by having conspicuous whitish spots on the body (vs. body mottled or with bars in *P. reus* and with whitish spots that fade along the body and can cover more than one plate in *P. kayabi*). It is also distinguishable from *P. depressus* and *P. barbatus* by having the snout with yellowish odontodes (vs. reddish-brown) (see Fig. 3 in De Chambrier and Montoya-Burgos 2008 for comparison) and from *P. nigrescens*, *P. corantijniensis*, and *P. zawadzki* by having smaller whitish spots covering the body which increase gradually in size on the head (diameter 0.3–0.8 mm) and further on the body (diameter 0.7–1.3) (vs. spots abruptly increasing size between the head (diameter 1.1–1.3) and the body (diameter 2.6–2.3 mm)). In addition, the new species is distinguished by a shorter predorsal length, 39–43% SL (vs. 43–46% in *P. zawadzki* and 43–45% in *P. nigrescens*), a smaller dorsal pectoral depth, 23–27% SL (vs. 27–31% in *P. zawadzki*); a smaller caudal peduncle depth, 9–11% SL (vs. 13–14% in *P. zawadzki* and 13% in *P. nigrescens*), a shorter barbel, 5–9% HL (vs. 10–11 in *P. nigrescens*), and head depth, 57–66% SL, which is smaller than in *P. zawadzki* (67–73%) but greater than in *P. barbatus* (41–53%).

**Description.** Morphometric data is presented in Table 1. In lateral view, dorsal profile convex from snout tip to dorsal-fin origin; straight, gradually descending from dorsal-fin origin to posterior insertion of adipose fin; straight, steeply ascending to insertion of caudal fin; ventral profile flat from snout tip to anal-fin origin; shallowly concave from anal-fin insertion to lower caudal-fin spine; greatest body depth at dor-

sal-fin origin. In dorsal view, greatest body width across cleithral region; snout broadly elliptical; body decreasing in width from opercular region to caudal fin. Cross-section of body between pectoral and pelvic fins rounded dorsally and flattened ventrally; cross-section of caudal peduncle ellipsoid.

Body almost entirely covered with plates, except on ventral portions of head, abdomen, and dorsal-fin base. Five lateral rows of dermal plates, dorsal plates 21–22, lateral mid-dorsal plates 18–22, lateral median plates 22–23, lateral mid-ventral plates 23–24, lateral ventral plates 18–19. Three predorsal plates; seven plates below dorsal-fin base; four plates between dorsal fin and adipose fin; five rows of plates on caudal peduncle. Dorsal spinelet present.

Body plates and cleithrum with minute odontodes. Odontodes gradually getting larger towards tips on pectoral-fin spines. Numerous whitish hypertrophied odontodes along lateral margins of head including snout; homogenous in length excepting in anterior portion of snout where odontodes are smaller; longest odontodes on posteriormost portion of non-evertible cheek plates. Eye small (orbital diameter 13–10% HL), dorsolaterally positioned. Oral disk transversely ellipsoid. Lower lip not reaching transverse line between gill openings. Lower lip covered with numerous small papillae. Maxillary barbel poorly developed. Mouth relatively large. Premaxillary teeth 38–77 per ramus; dentary teeth 39–86 per ramus. Teeth bifid, medial cusp large and rounded, lateral cusp minute and rounded. Jaws wide, dentaries forming oblique angle, premaxillaries almost co-linear.

Dorsal fin II,7, origin approximately at midpoint between pectoral- and pelvic-fin origins, last dorsal-fin ray not reaching adipose-fin when depressed. Pectoral fin I,6, spine tip not curved inward; depressed tip reaching one-third length of pelvic-fin spine. Pelvic fin I,5, spine tip curved inward, almost reaching anal-fin origin when depressed. Anal-fin I,5, spine tip straight, reaching fifth plate posterior to its origin. Caudal fin I,7–7I, distal margin concave, inferior lobe longer than superior. Adipose fin with almost straight spine, preceded by single median preadipose plate.

**Color in alcohol.** Ground color dark brown on back and sides of body, and lighter brown ventrally. Anterior portion of head to posterior margin of orbits with many small, crowded, white spots; spots increasing slightly and gradually in size between snout to body. Dorsal plate series usually with two or three spots per plate in anterior portion of body and one spot on posterior portion of body. Mid-dorsal plates usually with two or three spots per plate. Lateral median plates with one or two spot per plate. Mid-ventral plates and ventral plates with two or three spots per plate. Dorsal-fin spine, rays and membranes with small round spots. Adipose fin with three small spots on spine and membrane. Pectoral, pelvic, anal and caudal fins with numerous and white spots of equal size. Dorsal and caudal fin tips whitish. Hypertrophied odontodes along head margin yellowish.

**Color in life.** Similar to pattern described for alcohol individuals, but with ground color dark greenish-brown, and with yellow spots on body and on tips of dorsal and caudal fins.

**Sexual dimorphism.** Males possess a papilla posterior to urogenital opening, an attribute absent in females. Both sexes in *P. asurini* exhibit highly hypertrophied

odontodes along snout margin, as well as in others species of *Pseudancistrus* (Armbruster 2004b).

**Etymology.** The specific name “asurini” is a reference to the Asurini indigenous peoples who inhabit the right margin and median portions of rio Xingu, close to the municipality of Altamira in Pará State, Brazil. A noun in apposition.

**Distribution.** *Pseudancistrus asurini* is known from the rio Xingu, municipality of Altamira, from the Xingu river basin, Pará State, Brazil (Fig. 2b).

## Discussion

The two new species, *P. kayabi* and *P. asurini*, are typical *Pseudancistrus* (sensu Chambrier and Montoya-Burgos 2008), recognized by non-evertible cheek plates and the presence of hypertrophied odontodes along the snout margin. This last character is shared with species of *Lithoxancistrus* and *Pseudolithoxus*. However, in *Pseudancistrus*, the odontodes along the snout are quite well developed, especially in *P. kayabi*. Additionally, *Pseudolithoxus* (Armbruster and Provenzano 2000) can be distinguished from *Pseudancistrus* by the presence of three rows of plates on the caudal peduncle (vs. five), and *Lithoxancistrus* can be distinguished from *Pseudancistrus* by the presence of three buccal papillae (vs. one; Isbrücker et al. 1988).

The most conspicuous character used to distinguish the two new species from all other described *Pseudancistrus* is the coloration pattern. *Pseudancistrus kayabi* has a pattern of dark bars on dorsal and caudal fins (Fig. 1) as in *P. reus* from the Caroní River, Venezuela. However, *P. reus* possesses dark brown bars also on the body. This character is absent in *P. kayabi*, which has a dark brown base color with whitish spots fading posterior to the dorsal fin and are large enough to cover more than one lateral body plate, a pattern that is similar to that found in *P. nigrescens*.

*Pseudancistrus asurini* has whitish tabs on the dorsal- and caudal-fin tips (Fig. 4) in juveniles and medium-sized adults (to approximately 100 mm SL), a pattern unique among *Pseudancistrus*. This character is similar to that found in *Baryancistrus xanthellus* (Py Daniel et al. 2011) and *B. chrysolomus* (Py Daniel et al. 2011), both of which are also from the rio Xingu basin and live sympatrically with *P. asurini*. Additionally, the new species *P. asurini* has a color pattern consisting of spots that increase in size from the head (diameter 0.3–0.8 mm) to posterior part of body (diameter 0.7–1.3). The species *P. nigrescens*, *P. corantijniensis*, and *P. zawadzki* present a similar coloration pattern; however, the size of the spots increase abruptly from the head (diameter 1.1–1.3) to posterior part of body (diameter 2.6–2.3 mm).

## Comparative material examined

*Guyanancistrus brevispinis* (Heitmans, Nijssen & Isbrücker, 1983): LBP 5253, 2, 58.5–83.8 mm SL, MZUSP 103488, 23, 102.3–55.1 mm SL, Jari river, Brazil; ANSP

189128, 3, 56.8–125.7 mm SL, Marowini river, Sipalawini, Suriname. *Pseudancistrus zawadzki* Silva, Roxo, Britzke & Oliveira, 2014: Holotype, MZUSP 115056, 116.4 mm SL, Tapajós river, Brazil; Paratypes, LBP 15045, 2, 97.9–128.7 mm SL, LBP 17724, 1, 87.5 mm SL, LBP 16195, 1, 116.4 mm SL. *Pseudancistrus barbatus* (Valenciennes, 1840): ANSP 177366, 2, 76.5–103.7 mm SL, Burro Burro river, Water Dog Falls, Essequibo river basin, Guyana; ANSP 189119, 3, 75.1–151.5 mm SL, Lawa river, Sipalawini, Suriname. *Pseudancistrus nigrescens* Eigenmann, 1912: ANSP 177379, 5, 96.4–133.5 mm SL, Burro Burro river, Water Dog Falls, Essequibo river basin, Guyana. *Lithoxancistrus orinoco* (Isbrücker, Nijssen & Cala, 1988): ANSP 160600, 6, 68.0–78.5 mm SL, Orinoco river, Venezuela. *Pseudancistrus pectegenitor* Lujan, Armbruster & Sabaj, 2007: ANSP 190755, 1, 206.2 mm SL, Ventuari river, Orinoco river basin, Venezuela. *Pseudancistrus sidereus* Armbruster, 2004b: ANSP 185321, 4, 148.6–154.1 mm SL, Casiquiari river, Venezuela.

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# The Maghreb – one more important biodiversity hot spot for tiger beetle fauna (Coleoptera, Carabidae, Cicindelinae) in the Mediterranean region

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## Abstract

The tiger beetle fauna of the Maghreb region is one of the richest in the Palaearctic, including 22 species and 5 subspecies and 19% of all Palaearctic species of Cicindelinae. Assembled by their chorotypes, the Maghreb tiger beetles fall into eight different groups that include Maghreb endemics (26% of fauna), Mediterranean (7%), West Mediterranean (40%), North African (4%), Mediterranean-Westturanian (4%), West Palaearctic (4%), Afrotropico-Indo-Mediterranean (4%), and Saharian (11%) species. The Mediterranean Sclerophyl and Atlas Steppe are the Maghreb biogeographical provinces with the highest species richness, while the Sahara Desert has the lowest Cicindelinae diversity. Twenty-five cicindelid species and subspecies (93% of Maghreb fauna) are restricted to only one or two habitat types in lowland areas. Only *Calomera littoralis littoralis* and *Lophyra flexuosa flexuosa* are recognized as eurytopic species and occur in three types of habitat. The highest tiger beetle diversity characterizes salt marshes and river banks (in both cases 11 species and subspecies or 41% of Maghreb fauna). Approximately 85% of all Maghreb tiger beetle species and subspecies are found in habitats potentially endangered by human activity.

## Keywords

Coleoptera, Cicindelinae, tiger beetles, zoogeography, biodiversity, species richness, habitat preferences, Mediterranean region, North Africa, Morocco, Algeria, Tunisia

## Introduction

Tiger beetles (Carabidae: Cicindelinae) include approximately 2600 species of small to medium-sized beetles (Pearson and Cassola 2005). They are predatory with world-wide distributions, excepting some of the oceanic islands and polar regions (Cassola and Pearson 2000; Pearson and Vogler 2001). Most prefer various sandy habitats where both larvae and adult beetles live. Many recent studies from different continents show that most cicindelid taxa have very narrow habitat specialization and can be found only in one or at most in few very similar types of macrohabitats. As a consequence, tiger beetles have become a very important global flagship group for beetle and insect conservation, often used as biological indicators for determining both regional and global patterns of biodiversity (Knisley and Hill 1992; Pearson and Cassola 1992, 2005; Kitching 1996; Carroll and Pearson 1998a, 1998b; Andriamampianina et al. 2000; Pearson and Vogler 2001; Arndt et al. 2005; Jaskuła 2011). Moreover, as both adults and larvae of cicindelid beetles are predators that prey on different small invertebrates, they can be used for biological control of pests causing important economic destruction (Rodríguez et al. 1988).

The Maghreb is a part of the Mediterranean region, which is known as one of the 25 most important world biodiversity hot spots (Myers et al. 2000; Cuttelod et al. 2008). Concluding from the recent studies upon different plant and animal groups it is also a very important terrestrial Pleistocene glacial refugium, both on the local scale (Husemann et al. 2014) and for the whole Western Palaearctic (Hewitt 1996, 1999; Thomson 2005; Blondel et al. 2010; Habel et al. 2010). High levels of biodiversity in the Maghreb region can be explained by the mosaic heterogeneous landscapes occurring in this area as well as by relatively high climatic stabilization of this region (Blondel et al. 2010). Moreover, Maghreb served as an important natural bridge for historical and present dispersal between Africa and Europe, mainly via the Gibraltar and Sicily sea straits which are known as important biogeographical links between both continents at different times (Habel et al. 2010).

The first data on tiger beetle fauna of the Maghreb region were published in the second half of 18<sup>th</sup> and at the beginning of 19<sup>th</sup> centuries (e.g. Linnaeus 1758; Fabricius 1781, 1787, 1801; Vigors 1825; Dejean 1831). Since then, more than 80 papers have been published on this topic. Unfortunately, in most cases they include only single faunistic records or data on a single species. Till recently the knowledge on diversity and distribution of tiger beetle fauna was summarized for Tunisia by Korell and Cassola (1987) and Jaskuła and Rewicz (in prep.) and for Morocco by Cassola (1973) and Jaskuła et al. (in prep.).

The paper is the second part of wider studies concerning biodiversity and zoogeography of tiger beetle fauna of the Mediterranean region (Jaskuła 2011). Its aim is to summarize the knowledge on diversity of tiger beetles in the Maghreb region with particular emphasis on the group diversity, distribution, zoogeographical composition as well as the macrohabitat preferences of cicindelid taxa.

## Study area

Here, the Maghreb region is defined as a part of northwestern Africa with its northern boundary made up of the Mediterranean Sea, the western boundary at Atlantic coast, the southern at Sahara Desert, and the eastern at the political border of Tunisia and Libya (Michard et al. 2008, Fig. 1). Politically the area includes four countries, three of them completely confined to the Maghreb region (Tunisia, Algeria, and Morocco) as well as the two small enclaves (Ceuta and Melilla) belonging to Spain. The region has a total area of 2,991,933 km<sup>2</sup>, which is nearly 10% of the entire African continent and some 5.5% of the Palaearctic ecozone.

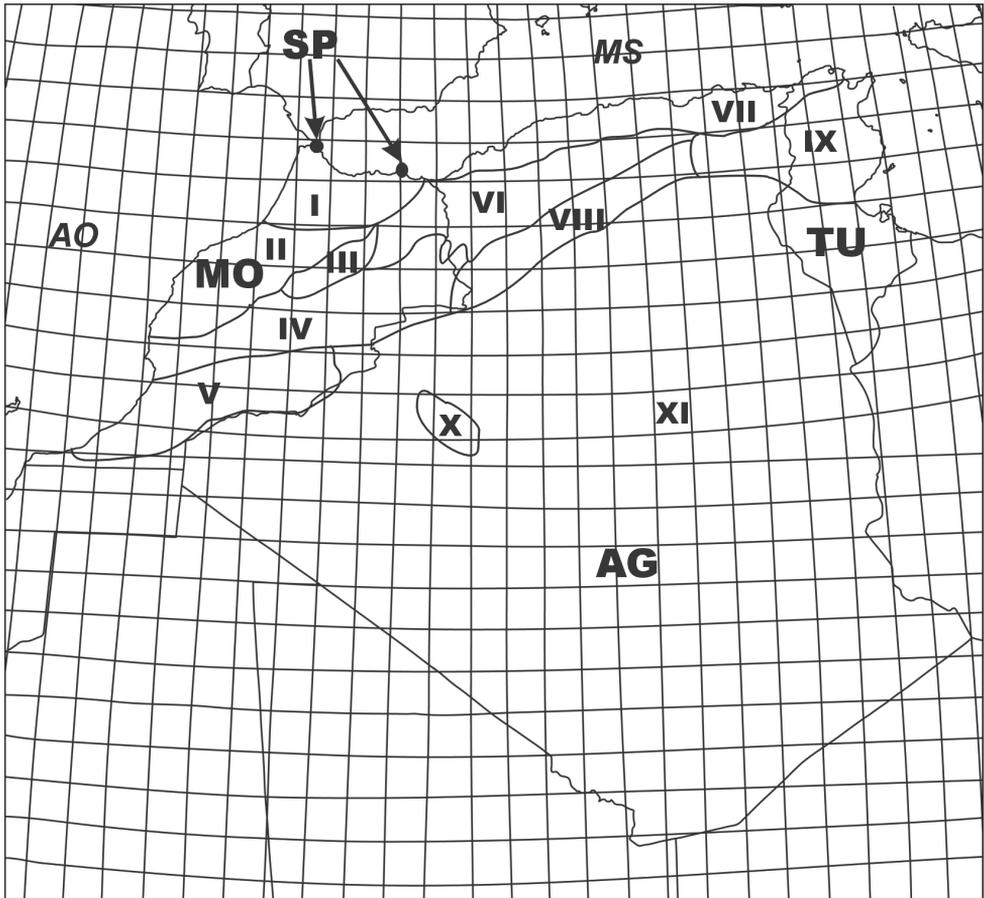
The largest surface of the Maghreb region is montane. Lowlands extend only along the lower reaches of rivers that are grouped into two drainages of the Mediterranean Sea and of the Atlantic Ocean (Woodward 2009). Geographically the Maghreb is divided into the following main regions: Rif, Central Massif, Anti-Atlas, Middle Atlas, Tell Kabyllas, High Plateaus, Tunisian Atlas, Saharan Atlas, High Atlas, Ougarta, and Saharan Platform (Michard et al. 2008; Fig. 1).

According to biogeographical divisions by Udvardy (1975) the Maghreb region belongs to three provinces (Fig. 2): Mediterranean Sclerophyl – which includes Mediterranean coasts of Tunisia, Algeria, and Morocco as well as entire areas of Spanish enclaves, Ceuta and Melilla; the Atlas Steppe – with the highest montane areas of Tunisia, Algeria, and Morocco; and the Sahara Desert – the biggest area of Maghreb with the southernmost parts of Algeria and Tunisia.

## Material and methods

The basis for the analysis of tiger beetle fauna of the Maghreb region comes from published literature data, museum collections (Museum and Institute of Zoology, Polish Academy of Science, Warsaw, Poland; Museum of Natural History, Vienna, Austria; Royal Belgium Institute of Natural Sciences, Brussels, Belgium), and the author's collections gathered during two scientific trips covering almost entire areas of Morocco and Tunisia (2<sup>nd</sup> and 4<sup>th</sup> TB-Quest Expeditions) in 2009 and 2010. Additionally, single specimens were studied thanks to Dr. J. Ch. Habel (Germany). Recently all these faunistic data were summarized in two papers on tiger beetle species of Tunisia and Morocco (Jaskuła and Rewicz in prep., Jaskuła et al. in prep.).

All the statistical analyses used in this paper follow my previous work on tiger beetles occurring in the Mediterranean region (Jaskuła 2011) to enable proper comparison. The tiger beetle species richness and distribution of taxa were analyzed based on squares of 1° longitude and latitude. In each square the total number of all species recorded was summarized. Similarities among tiger beetle fauna between geographical divisions of the Maghreb region were measured using the Bray-Curtis



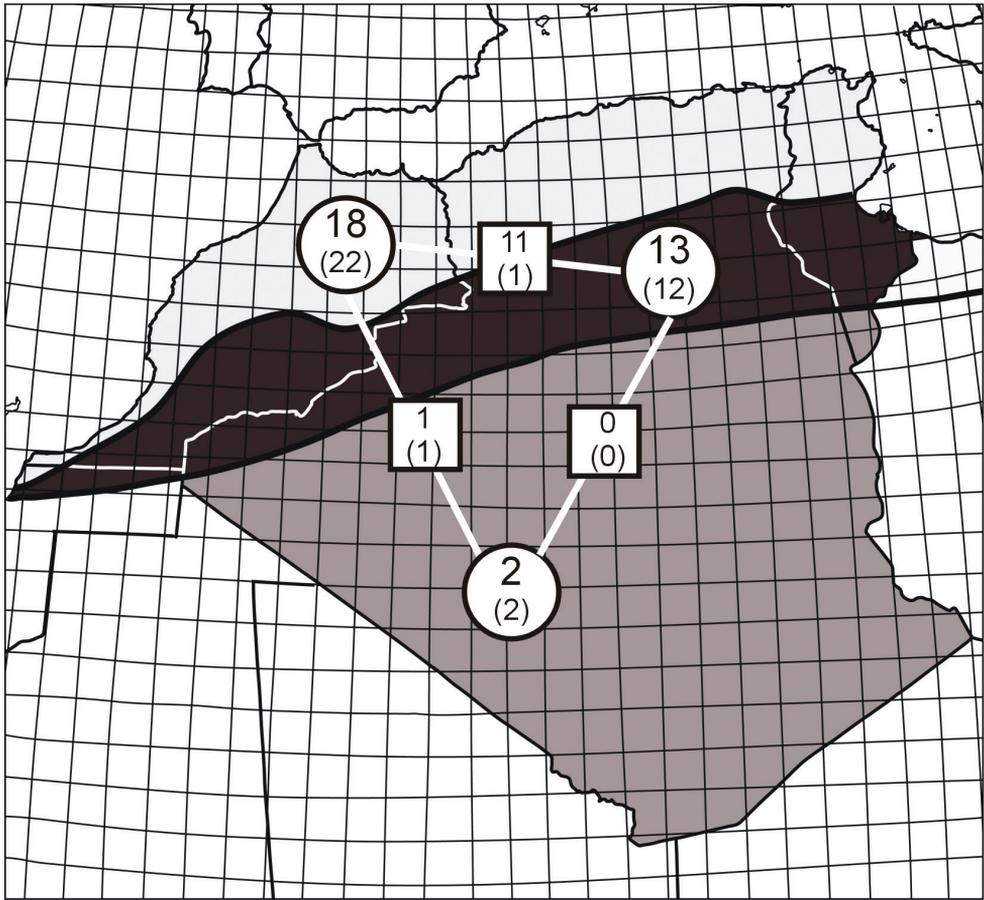
**Figure 1.** Geographical and administrative divisions of the Maghreb region: I – Rif, II – Central Massif, III – Middle Atlas, IV – High Atlas, V – Anti-Atlas, VI – High Plateaus, VII – Tell Kabyllas, VIII – Saharan Atlas, IX – Tunisian Atlas, X – Ougarta, XI – Saharan Platform, MO – Morocco, AG – Algeria, TU – Tunisia, SP – Spain (Ceuta and Melilla), AO – Atlantic Ocean, MS – Mediterranean Sea.

index for presence/absence data (Primer v. 5.0) as well as Jaccard's (1902) index was used to present the degree of dissimilarity between zoogeographic regions proposed by Udvardy (1975):

$$R = 100c/a+b-c$$

where: a – number of species in the richest fauna, b – number of species in the poorest fauna, c – number of species common to both faunas.

Chorotype definition follows Vigna Taglianti et al. (1999).



**Figure 2.** Tiger beetle faunas in the biogeographical provinces of the Maghreb region (division after Udvardy 1975): light grey – Mediterranean Sclerophyl, black – Atlas Steppe, dark grey – Sahara Desert. Numbers in the circles indicate the number of cicindelid taxa for the separate regions and the squares give the number of taxa common to the provinces shared (large – species, small in brackets – subspecies).

## Results

### Diversity of tiger beetles in Maghreb region

According to Werner (1991, 1992), Putschkov and Matalin (2003), Lopéz et al. (2006), Cassola and Wiesner (2009), and Deuve (2011, 2012) approximately 110 tiger beetle species occur in Palaearctic (species recorded by Putschkov and Matalin (2003) in the oriental part of China and in Taiwan were excluded). Out of that, 22 species and 5 subspecies have been found in the area of Maghreb region (Table 1) which is approximately 19% of all the Palaearctic tiger beetle species.

**Table 1.** Chorotypes of Maghreb tiger beetles (based on Vigna Taglianti et al. 1999).

Region	Species
Maghreb endemics	<i>Platydelia coquerelii coquerelii</i> , <i>Platydelia coquerelii theryi</i> , <i>Platydelia segonzaci</i> , <i>Neolaphyra leucosticta leucosticta</i> , <i>Neolaphyra leucosticta simulans</i> , <i>Neolaphyra peletieri</i> , <i>Neolaphyra truquii</i>
West Mediterranean	<i>Calomera littoralis littoralis</i> , <i>Calomera lunulata</i> , <i>Cassolaia maura maura</i> , <i>Cassolaia maura cupreothoracica</i> , <i>Cephalota circumdata imperialis</i> , <i>Cephalota littorea goudotii</i> , <i>Cephalota luctuosa</i> , <i>Cicindela campestris atlantis</i> , <i>Cicindela maroccana maroccana</i> , <i>Cylindera trisignata trisignata</i> , <i>Cylindera trisignata siciliensis</i>
North African	<i>Cephalota tibialis lyonii</i>
Mediterranean	<i>Calomera aulica aulica</i> , <i>Lophyra flexuosa flexuosa</i>
Mediterranean-Westturanian	<i>Grammognatha euphratica euphratica</i>
West Palaearctic	<i>Cicindela campestris campestris</i>
Afrotropico Indo-Mediterranean	<i>Myriochila melancholica melancholica</i>

The Maghreb cicindelid species belong to eleven genera (92% of the Mediterranean or 61% of the Palaearctic fauna) including: *Grammognatha* (1 species, 100% of both Mediterranean and Palaearctic), *Myriochila* (3 species, 75% of Mediterranean and 27% of the Palaearctic), *Habrodera* (1 species, 50% of both Mediterranean and Palaearctic), *Calomera* (3 species, 50% of Mediterranean and 19% of Palaearctic), *Lophyra* (1 species, 50% Mediterranean and 8% of Palaearctic), *Cephalota* (4 species, 40% Mediterranean of and 21% of Palaearctic), *Cassolaia* (1 species, 50% of both Mediterranean and Palaearctic), *Neolaphyra* (3 species, 75% of both Mediterranean and Palaearctic), *Platydelia* (2 species, 100% of both Mediterranean and Palaearctic), *Cylindera* (1 species, 8% of Mediterranean and 3% of Palaearctic), and *Cicindela* (1 species, 17% of Mediterranean and 2% of Palaearctic). Comparing to the total list of tiger beetle genera occurring in the Mediterranean region, only the genus *Homodela* (distributed in Syria and the southern part of Turkey) is not present in Maghreb.

Seven tiger beetle taxa belonging to five species (*Platydelia coquerelii coquerelii*, *P. c. theryi*, *P. segonzaci*, *Neolaphyra leucosticta leucosticta*, *Neolaphyra l. simulans*, *N. peletieri*, and *N. truquii*) are endemic to the Maghreb region. Additionally, for three taxa (*Habrodera leucoptera leucoptera*, *Myriochila dorsata*, and *M. mirei*) Maghreb is the only place of occurrence in the Palaearctic ecozone (distributed also south of Sahara) and for four others, this area is the only one in the African part of the Palaearctic (they are known from south-western Europe and/or from south-western Asia).

Based on the chorotypes, tiger beetles of the Maghreb region can be included into eight different groups (Vigna Taglianti et al. 1999; Table 1). Except Maghreb endemics, which constitute 26% of all tiger beetle taxa (species and subspecies) noted from this area, representatives of West Mediterranean (40%), North-African (4%), Mediterranean (7%), Mediterranean-Westturanian (4%), West Palaearctic (4%), Afrotropico Indo-Mediterranean (4%), and Saharian (11%) taxa can be found in this region.

The number of Maghreb tiger beetle species is high if compared with the number noted from other regions of the West Palaearctic with other areas of similar size (Ta-

**Table 2.** Comparison of area and tiger beetle species richness of Maghreb and some other regions from Western Palearctic (data compiled from different sources).

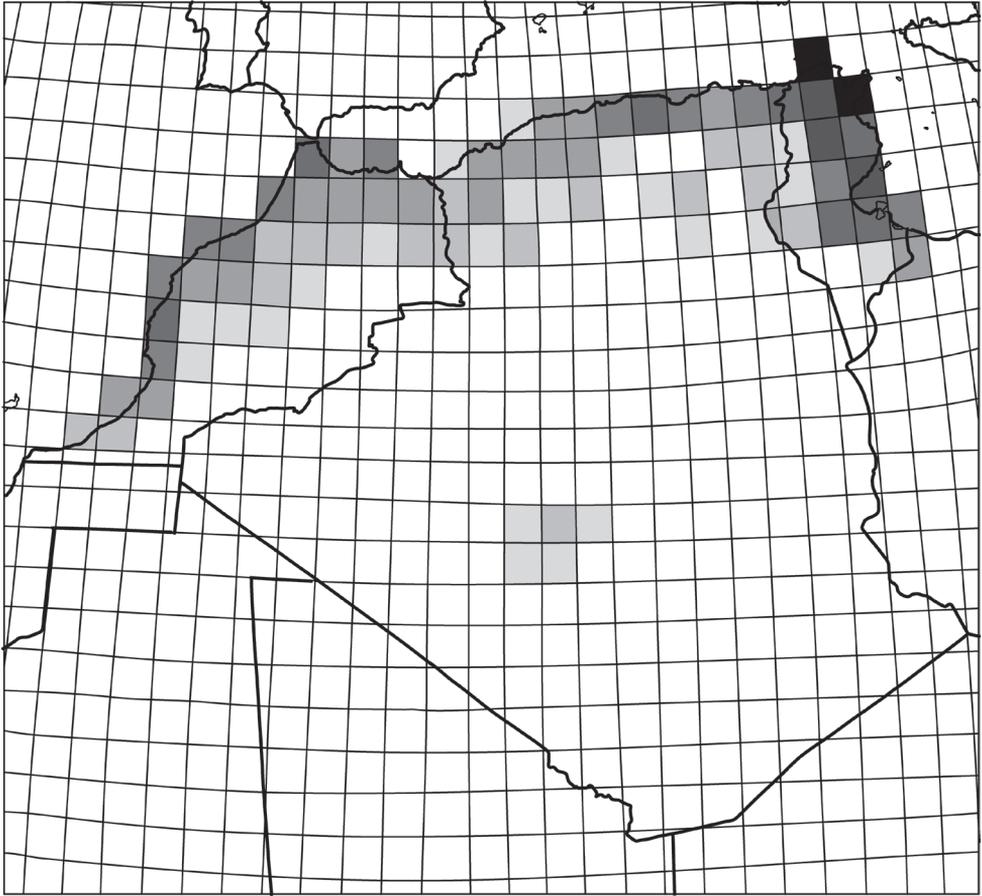
Region	Area (km <sup>2</sup> )	Number of species
Maghreb	2 991 933	22
Maghreb (excluding biogeographical province – Sahara Desert)	ca. 714 500	21
Iberian Peninsula	580 000	19
Balkan Peninsula	550 000	19
Italian Peninsula	150 000	13
France (mainland)	675 000	14
Scandinavian Peninsula	800 000	5
Ukraine	603 700	19
Turkey	783 562	26
Russia (European part)	4 268 850	28

ble 2), especially when the large part of Algerian Sahara is excluded (a great part of the Sahara desert is so dry that there are no habitats which would be attractive for Cicindelinae). In this case, the diversity and species richness of the Maghreb tiger beetle fauna is similar not only to the faunas of all the other most important glacial refugia in Europe (Iberian, Balkan, and Italian Peninsula) and in south-western Asia (Turkey), but even to the fauna known from the entire territory of the European part of Russia.

### Distribution of tiger beetles in the Maghreb region

Records from the literature and from my own observations within squares of 1° latitude and longitude show that the species richness of particular regions within the Maghreb differs both in species composition and in number of taxa. The highest number of tiger beetle taxa is found along the sea coasts of the Mediterranean Sea and of the Atlantic Ocean, both according to the geographical divisions and biogeographic regions defined by Udvardy (1975, Figs 2–3). The greatest Cicindelinae species richness in the Maghreb can be found in two biogeographic provinces which are similar in their surface area: the Mediterranean Sclerophyl (18 species or 22 species and subspecies, 82% of the Maghreb fauna) and the Atlas Steppe (13 species or 15 species and subspecies, 56% of fauna). The lowest species richness characterizes the Sahara Desert, where only two species (7% of fauna) have been noted, despite the fact that the Sahara Desert covers a part of Maghreb that is larger than both previous provinces combined.

The Bray-Curtis analysis of similarities among the tiger beetle faunas from different Maghreb geographical regions shows the presence of four main groups (Fig. 4). One of them includes the Saharan Platform, Anti-Atlas, and Ougarta regions belonging to the southernmost part of Maghreb and covering a great part of Udvardy's (1975) Sahara Desert and a small part of the Atlas Steppe. The second group composes of the Middle Atlas and the High Atlas regions which include the highest mountains within Maghreb, mentioned in biogeographic studies as the western part of the Atlas Steppe.

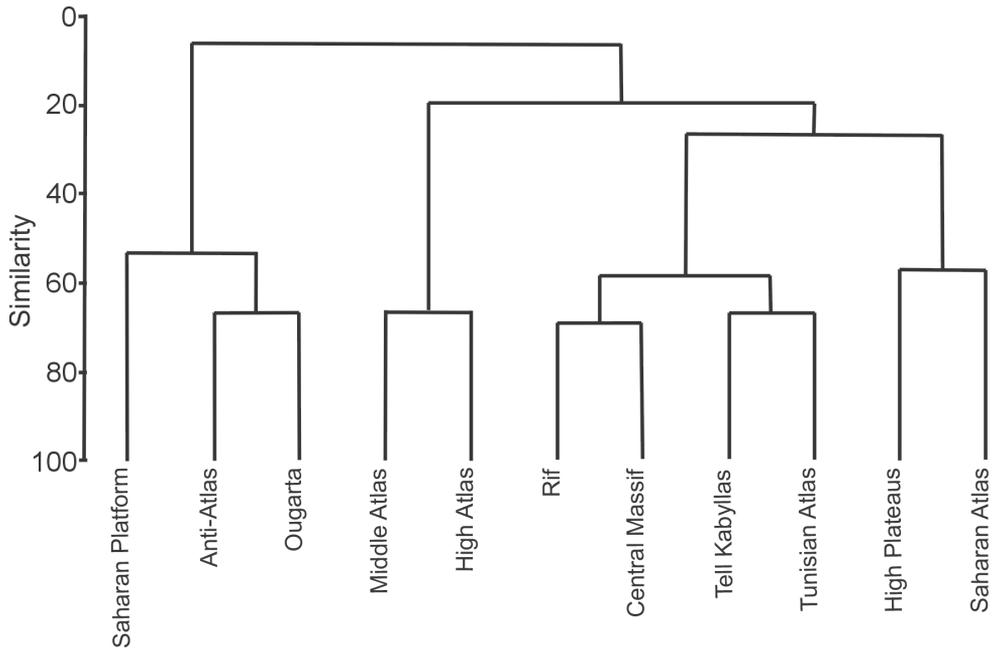


**Figure 3.** Species richness of tiger beetles within the Maghreb region. The colour gradient indicates an enhanced diversity from zero species (white square) to seven (black square).

The third group includes four regions located mainly in lowlands and highlands along the Mediterranean and Atlantic coasts: Rif, Central Massif, Tell Kabyllas and Tunisian Atlas. All these geographical regions belong to Udvardy's (1975) Mediterranean Sclerophyl. The last region is composed of the High Plateaus and of the Saharan Atlas (both being part of the central part of the Atlas Steppe) and covers the greater part of mountain areas in northern Algeria. The Jaccard's similarity index for Mediterranean Sclerophyl – Atlas Steppe was 42%, for Mediterranean Sclerophyl – Sahara Desert was 4%, and for Atlas Steppe – Sahara Desert was null.

### Ecotypes of Maghreb tiger beetles

In the tiger beetle fauna of Maghreb the most eurytopic taxa are *Calomera littoralis littoralis* and *Lophyra flexuosa flexuosa* (Table 3), both of them occurring in three types of



**Figure 4.** Similarities among tiger beetle faunas inhabiting regions of the Maghreb (Bray-Curtis similarity index for presence/absence data).

macrohabitats. Five other species/subspecies have been found to occupy two types of habitats, including *Calomera aulica aulica*, *Cassolaia maura maura*, *Cicindela campestris atlantis*, *Cylindera trisignata trisignata*, and *C. t. siciliensis*. Twenty other taxa (74% of Maghreb fauna) are known only from one type of habitat, including *Habrodera leucoptera leucoptera*, *Grammognatha euphratica euphratica*, *Myriochila myriochila myriochila* and all four *Cephalota* species from salt marshes, seven taxa restricted to river banks (*Cicindela maroccana maroccana*, *Myriochila dorsata*, *M. mirei*, and all *Neolaphyra*), four found exclusively in mountain and highland pastures and meadows (*Cicindela campestris campestris*, and all *Platydelia*), and one taxon known only from sandy sea beaches (*Calomera aulica aulica*). Among all these tiger beetles, 23 species and subspecies (85%) can be classified as coastal and riverine taxa, occupying habitats close to water, such as salt marshes, banks of rivers and lakes, and sea coasts, while four other taxa (19%) are typical mountain beetles occurring in sandy areas in meadows and pastures at higher elevations.

## Discussion and conclusions

### Diversity and distribution of tiger beetles in the Maghreb region

Compared to the surface area of other regions of the Palaearctic, the diversity of tiger beetles of the Maghreb region is high and constitutes about 19% of all Cicindelinae

**Table 3.** Tiger beetles of the Maghreb region and their ecological distribution: 1 – salt marshes, 2 – sandy sea beaches, 3 – sandy-rocky sea beaches, 4 – banks of rivers, 5 – banks of lakes, 6 – oases, 7 – mountain and highland pastures and meadows.

No.	Taxon	Macrohabitat type						
		1	2	3	4	5	6	7
1.	<i>Calomera aulica aulica</i> (Dejean, 1831)		+	+				
2.	<i>Calomera littoralis littoralis</i> (Fabricius, 1787)	+	+		+			
3.	<i>Calomera lunulata</i> (Fabricius, 1781)		+					
4.	<i>Cassolaia maura cupreothoracica</i> Korell & Cassola, 1987					+		
5.	<i>Cassolaia maura maura</i> (Linnaeus, 1758)				+	+		
6.	<i>Cephalota circumdata imperialis</i> (Klug, 1834)	+						
7.	<i>Cephalota littorea goudotii</i> (Dejean, 1829)	+						
8.	<i>Cephalota luctuosa</i> (Dejean, 1831)	+						
9.	<i>Cephalota tibialis lyonii</i> (Vigors, 1825)	+						
10.	<i>Cicindela campestris atlantis</i> Mandl, 1944				+			+
11.	<i>Cicindela campestris campestris</i> Linnaeus, 1758							+
12.	<i>Cicindela maroccana maroccana</i> Fabricius, 1801				+			
13.	<i>Cylindera trisignata trisignata</i> (Dejean, 1822)	+	+					
14.	<i>Cylindera trisignata siciliensis</i> (W. Horn, 1891)	+	+					
15.	<i>Grammognatha euphratica euphratica</i> Latreille & Dejean, 1822	+						
16.	<i>Habrodera leucoptera leucoptera</i> (Dejean, 1831)	+						
17.	<i>Lophyra flexuosa flexuosa</i> (Fabricius, 1787)	+			+		+	
18.	<i>Myriochila dorsata</i> (Brullé, 1834)				+			
19.	<i>Myriochila melancholica melancholica</i> (Fabricius, 1798)	+						
20.	<i>Myriochila mirei</i> Rivalier, 1961				+			
21.	<i>Neolaphyra leucosticta leucosticta</i> (Fairmaire, 1859)				+			
22.	<i>Neolaphyra leucosticta simulans</i> (Bedel, 1895)				+			
23.	<i>Neolaphyra peletieri</i> (Lucas, 1848)				+			
24.	<i>Neolaphyra truquii</i> (Guérin-Méneville, 1855)				+			
25.	<i>Platydelia coquerelii coquerelii</i> (Fairmaire, 1867)							+
26.	<i>Platydelia coquerelii theryi</i> (Alluad, 1930)							+
27.	<i>Platydelia segonzaci</i> (Bedel, 1903)							+
Total		11	5	1	11	2	1	5

species known from this biogeographic realm (Putchkov and Matalin 2003; Lopéz et al. 2006; Cassola and Wiesner 2009; Deuve 2011, 2012). This clearly proves an important role of Maghreb as diversity hot spot for tiger beetles, noted earlier for many other different taxonomic groups, including plants, terrestrial and freshwater invertebrates, and vertebrates (eg. Schleich et al. 1996; Beauchard et al. 2003; Omodeo et al. 2003; Thompson 2005; Delforge 2006; Blondel and Médail 2009; Blondel et al. 2010). The high diversity of tiger beetle fauna in this area can be explained by two main factors. First is the topographic position of Maghreb within the West Palaearctic realm as the area was (and still is, mainly because of Gibraltar and Sicily sea straits) an important natural bridge between European and African faunas (eg. Harris et al. 2002;

Paulo et al. 2002; Carranza et al. 2004, 2006; Veith et al. 2004; Fritz et al. 2006; Weingartner et al. 2006; Recuero et al. 2007; Habel et al. 2008, 2010; Skog et al. 2009). As a result of these biogeographical links between both continents at different times, presently Maghreb region is inhabited by a mixed tiger beetle fauna with representatives of 22 species belonging to eight different groups according to their chorotypes (Table 1). Some of these taxa presently occur both in Northern Africa and in southern Europe (eg. all Maghreb species of *Calomera*, *Cephalota*, *Cylindera*, and *Grammognatha*) (Putchkov and Matalin 2003; Serrano 2013). Similar patterns in faunal elements have been noted also among other groups of invertebrates, including some groups of insects (Weingartner et al. 2006; Riservato et al. 2009; Habel et al. 2008), scorpions (Gantenbein and Largiadèr 2003), amphibians and reptiles (Busack 1986; Schleich et al. 1996; Alvarez et al. 2000; Cox et al. 2006), mammals (Dobson 1998; Cosson et al. 2005; Temple and Cuttelod 2008; Skog et al. 2009) and plants (Thompson 2005).

The second reason of high level species richness of Maghreb tiger beetle fauna is the high diversity of habitats preferred by this beetle group, including sandy sea beaches, salt marshes, river banks, as well as oases and sandy areas in the mountains.

A relatively high level of landscape mosaic and heterogeneity may also explain the general distribution patterns of tiger beetle species within the Maghreb region with higher diversity and species richness in the lowlands. The reason is that sandy habitats preferred both by larvae and adult cicindelid beetles are much more diverse at the sea coasts than in the montane areas. This pattern appears to be typical for this beetle group and it is very similar in other regions of the Mediterranean area (Cassola 1970, 1973; Lisa 2002; Jaskuła 2011; Jaskuła and Rewicz 2014) and also in other regions of the world, including western and northern Australia, and the Indian subcontinent (Pearson and Cassola 1992). In contrast, at higher elevations, the percentage of habitat opportunists can be much higher, it was shown by Bhargav et al. (2008) in studies on tiger beetles of Shivalik in Himachal Pradesh in north western India. In these studies, habitat specialists were found only in few of the studied habitats. Probably it can be explained by much higher homogeneity of that landscape when compared with lowland areas.

### Ecological preferences in Maghreb tiger beetles

The analysis of macrohabitat preferences of Maghreb tiger beetles show that most species have very narrow habitat specialization and occur only in one or at most in two very similar types of habitat. Only two of all the 27 taxa known from this region occupy three different habitats – *Calomera littoralis littoralis* and *Lophyra flexuosa flexuosa* (Table 3). Similar observations were made also in other areas of the Mediterranean region, as well as in some other regions of the world. For example, of 19 tiger beetle species and subspecies noted in the Balkans, only two – *Calomera littoralis nemoralis* and *Calomera aulica aulica* – were recorded respectively from four and three different habitat types (Jaskuła 2011). In Australia, among 29 studied species only two (*Myriochila mastersi* and *M. semicincta*) were found as occurring in several habitat types (Freitag 1979). In the Sulphur Springs Valley

(Arizona, USA) only *Cicindelidia nigrocoerulea*, one of 20 species noted during studies, was recorded from more than one habitat type (Knisley and Pearson 1984) and in the Colfax County (New Mexico, USA) only four of 19 species (*Cicindela fulgida*, *C. tranquebarica*, *Cicindelidia punctulata*, and *C. nigrocoerulea*.) were noted as habitat generalists occurring in seven different macrohabitat types (Knisley 1984). Similar results were provided also by Acciavatti and Pearson (1989) from the Indian subcontinent where among 151 tiger beetle species only *Calochroa flavomaculata* was noted from several different habitat types. Pearson (1984) noted *Odontocheila annulicornis* as the only one cicindelid taxon (of 29 species) inhabiting more than one forest habitat type in the Tambopata Reserve Zone in Peru. Also data from Japan by Satoh et al. (2006) show that usually only single tiger beetle species are eurytopic. In their studies on riparian Cicindelinae in the Tedoru River System only *Cicindela transbaicalica* was distributed widely along the river while two other taxa were restricted to only one habitat type. Moreover, the habitat specialization can be so narrow that species occurrence can be restricted to only a small part of a particular habitat. Sometimes, a different type of habitat/microhabitat is occupied by adult beetles and by the larvae. Ganeshiah and Belavadi (1986), during their studies of four Asian riverine Cicindelinae species, showed that tiger beetles were segregated distinctly along the river beds according to separate habitats. Similar observations were made also in the USA by Schultz and Hadley (1987) who noted that *Cicindela tranquebarica* preferred dry areas while *Cicindela oregona* occupied mainly stream edges, and by Jaskuła (2011) who observed in the different parts of the Balkans that *Calomera littoralis nemoralis* preferred mainly wet sand on edges of water reservoirs while the drier salt marsh substrate was inhabited by *Cephalota chiloleuca*, *C. c. circumdata* and *Cylindera trisignata hellenica*. Interesting results were also provided by Satoh and Hori (2005) who found spatial segregation during the larval stage of six Japanese tiger beetles. Each of the studied taxa preferred specific type of microhabitat. Moreover, in most of the species the habitat type was different for larvae and for adult beetles.

Many authors explain such narrow cicindelid specialization to habitat/microhabitat type by morphological (Pearson and Murry 1979; Schultz and Hadley 1987; Satoh et al. 2003; Satoh and Hori 2005; Dangalle et al. 2013), physiological (Schultz and Hadley 1987; Hadley et al. 1990), or behavioural (Knisley and Pearson 1981; Pearson and Lederhouse 1987) adaptations of adults and larvae. Moreover, at least in some cases, the opportunistic feeding behaviour can play an important role in colonization of different habitat types by some eurytopic tiger beetle species. A good example comes from the Balkan Peninsula, where a species previously known as typical predatory beetle and habitat generalist, *Calomera littoralis nemoralis*, was observed on sandy sea beach feeding on plant material (Jaskuła 2013). As the same species (but another subspecies – *C. l. littoralis*) is also one of the only two habitat generalists known from the Maghreb region, it cannot be excluded that similar feeding behaviour may occur also in the North African population of this species.

Underwood et al. (2009a, 2009b) noted that Mediterranean type of habitats are among the rarest globally and are restricted to only 2% of the Earth's land surface.

Most of these areas are endangered by human activity. Within the Mediterranean region, including Maghreb, less than 1% of the land surface is legally protected. Moreover, presently almost all habitat types occupied by the Maghreb tiger beetles (eg. salt marshes, sandy sea beaches, and banks of freshwater reservoirs) are significantly altered and are recognised as globally threatened (eg. Silliman et al. 2009). According to the ecological distribution of Maghreb Cicindelinae (Table 3), at least 85% of the recorded taxa occur in these threatened environments as a result, are potentially threatened. Additionally, three other taxa (all belonging to *Platydelia*) have very restricted world distributions as they are endemics occurring only in small parts of the Moroccan Atlas mountains. All the above, as well as the fact that the Maghreb is a very important transition zone between Africa and Western Europe where faunal elements of various origin meet, clearly prove the unique character of this region as an important biodiversity hot spot for tiger beetle fauna both in the Mediterranean region and in the Western Palaearctic.

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# A new species of *Paracreptotrema* (Digenea, Plagiorchiiformes, Allocreadiidae) infecting two species of poeciliids in Río Malila of the Río Pánuco basin, Hidalgo, México, with a key to the species of the genus

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## Abstract

*Paracreptotrema rosenthali* sp. n. was discovered in the intestine of *Xiphophorus malinche* and *Pseudoxiphophorus jonesii*, collected from the headwaters of Río Malila, tributary of Río Conzintla, in the Río Pánuco basin, Hidalgo, México, during 2008–2009. The new species differs from the five known species of *Paracreptotrema* Choudhury, Pérez-Ponce de León, Brooks & Daverdin, 2006 by having vitelline follicles that extend from a level anterior to the pharynx to mid-testes, the seminal vesicle which is more extensively folded, and a wider cirrus sac. The new species resembles *P. heterandriae* in the length of its ceca, which surpasses the posterior margin of the ovary but do not reach the testes. A key to the species of *Paracreptotrema* is provided.

## Keywords

*Paracreptotrema*, *Xiphophorus malinche*, helminth parasite, endemic species, key

## Introduction

Despite an increase in our knowledge of the helminth parasites of the species of fish in México, Pérez-Ponce de León and Choudhury (2010) recently suggested that regions characterized by high biodiversity, such as the drainage basin of the Río Pánuco, need more intensive sampling. Their study indicated that the Poeciliidae, a family with many species endemic to México but with a limited range (Miller et al. 2005), could provide new information on the biodiversity of helminth parasites of freshwater fishes. *Xiphophorus malinche* Rauchenberger, Kallman & Morizot is such a poeciliid with a distribution restricted to the Río Pánuco basin. At present, it is known to inhabit only six isolated highland headwater streams (Culumber et al. 2011). Relatively little is known about the parasite communities of *X. malinche*; however, a recent study compared parasite communities between two populations of this species and reported differences in the helminth communities that the authors attributed to geographic isolation (Bautista-Hernández et al. 2014b). As part of that study, an undescribed species of *Paracreptotrema* Choudhury, Pérez-Ponce de León, Brooks & Daverdin, 2006 was recovered in one of these populations; it is described herein and a key to the known species is presented.

## Materials and methods

Adult specimens of *Xiphophorus malinche* (60 individuals; May 2008 to July 2009) and *Pseudoxiphophorus jonesii* (Günther, 1874) (*sensu* Agorreta et al. 2013) (= *Heterandria jonesii*) (30 individuals; August 2012) were collected from the Río Malila, a tributary of the Río Conzintla, northeastern Hidalgo, México. Fish were collected using minnow traps, brought live to the laboratory of the Centro de Investigaciones Científicas de las Huastecas Aguazarca (CICHAZ) field station in Calnali, Hidalgo, and examined within 24 h after capture. Fish were fixed in ethyl alcohol (EtOH 96%) for confirmation of their identification. Trematodes were collected live, killed in warm water and fixed for 24 h in alcohol-formalin-acetic acid. Specimens were stained with Mayer's carmalum or Delafield's hematoxylin, mounted whole in Canada balsam, and examined using bright-field and differential interference contrast optics. Illustrations were made with a drawing tube attached to the microscope; measurements are given in micrometers ( $\mu\text{m}$ ) and are expressed as the range of measurements followed by the mean  $\pm$  standard deviation in parentheses. Comparisons of other members of the genus with the new species are made from the original descriptions, but full data on each species from all published works are given in Table 1; reported measurements are given exactly as in the original work because all of the original specimens were not available to be re-measured.

## Results

### Systematic account

#### Family Allocreadiidae (Looss, 1902)

#### Genus *Paracreptotrema* Choudhury, Pérez-Ponce de León, Brooks & Daverdin, 2006

**Type species.** *Paracreptotrema blancoi* Choudhury, Pérez-Ponce de León, Brooks & Daverdin, 2006

#### *Paracreptotrema rosenthali* sp. n.

<http://zoobank.org/CD6087D6-0AA7-40B1-B06B-0756B52E2681>

Figure 1

**Type material.** Holotype (CNHE 9263), 3 paratypes (CNHE 9264 to 9266), and 3 paratypes (HWML 75051 to 75054).

**Other material examined.** *Paracreptotrema blancoi* Choudhury, Pérez-Ponce de León, Brooks & Daverdin, 2006 (CNHE-5315, Costa Rica; CNHE-7682, México); *P. heterandriae* Salgado-Maldonado, Caspeta-Mandujano & Martínez-Ramírez, 2012 (CNHE-8242); *P. mendezi* (Sogandares-Bernal, 1955) Choudhury, Pérez-Ponce de León, Brooks & Daverdin, 2006 (HWML-22193, 22194); and *P. profundulusi* Salgado-Maldonado, Caspeta-Mandujano & Martínez-Ramírez, 2011 (CNHE-7684).

**Type host.** *Xiphophorus malinche* Rauchenberger, Kallman & Morizot (Poeciliidae). Vouchers deposited in MZNA fish collection, University of Navarra, Spain (Galicía et al. 2014).

**Type locality.** Río Malila, tributary of Río Conzintla, northeastern Hidalgo, México (20°44'N; 98°43'W).

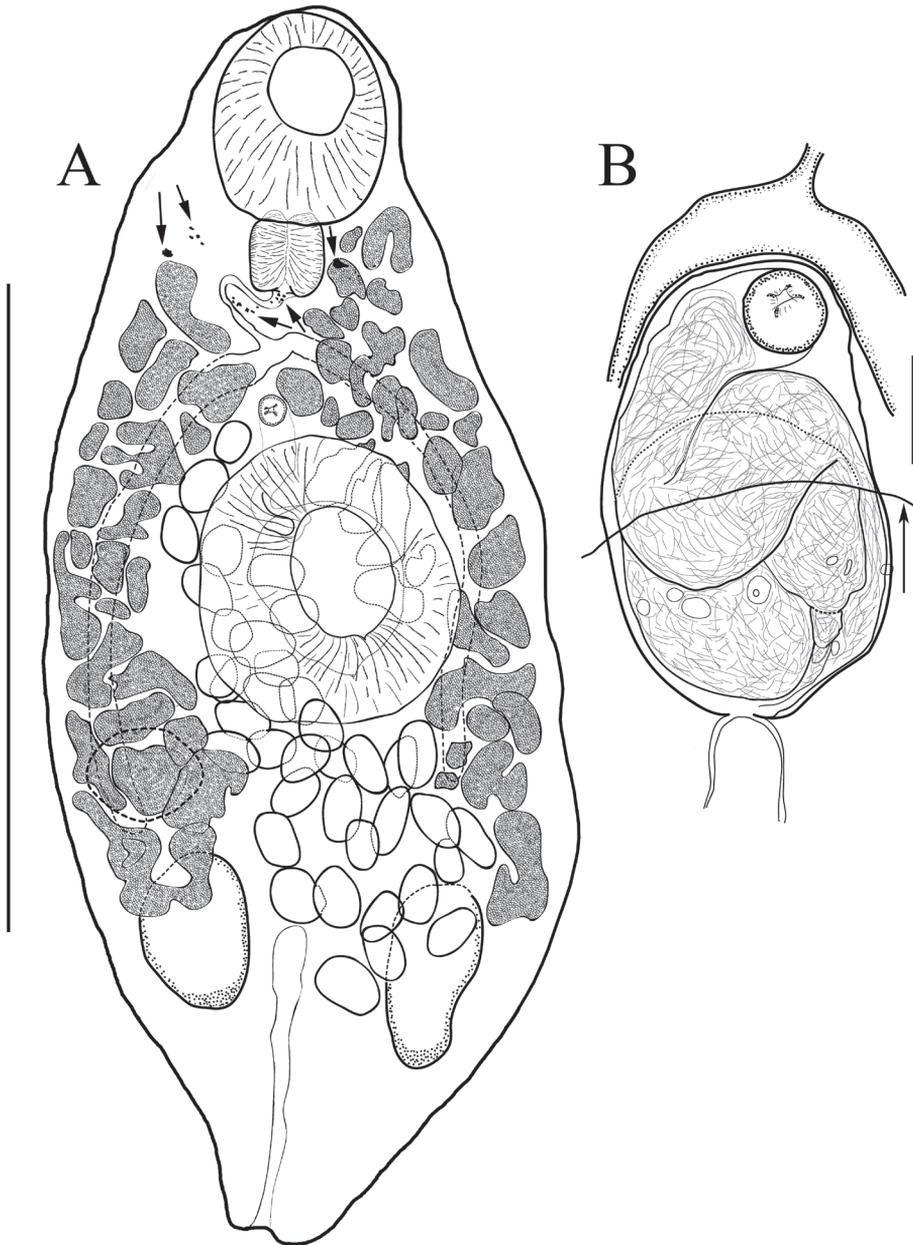
**Site in host.** Intestine.

**Other host.** *Pseudoxiphophorus jonesii* (Günther, 1874) (*sensu* Agorreta et al. 2013; = *Heterandria jonesii*). Vouchers deposited in MZNA fish collection, University of Navarra, Spain (Galicía et al. 2014).

**Prevalence.** In *X. malinche*, 7 of 88 infected (7.9%). In *P. jonesii*, 1 of 36 infected (2.77%).

**Etymology.** The species is named in honor of Gil G. Rosenthal, Department of Biology, Texas A&M University, College Station, Texas, and co-founder of the CICHAZ field station, for his friendship, contributions to the knowledge of species of *Xiphophorus*, and in recognition of his efforts to promote science in the Huasteca region of México.

**Description.** [Based on 8 specimens] Body 720–940 (830 ± 83 n = 7) long, robust, aspinose. Anterior end rounded; body 350–550 (417 ± 66 n = 7), widening gradually, reaching maximum width at level of middle to posterior margin of acetabulum, terminating in narrower posterior end. Few, small, pigment spots in forebody. Oral sucker wider than long, subterminal, 105–160 (125 ± 20 n = 7) long, 130–175 (140 ± 16



**Figure 1.** *Paracreptotrema rosenthali* sp. n. **A** Ventral view of holotype; arrows indicate fragments of eyespot pigment **B** Cirrus sac; arrow indicates anteriormost margin of acetabulum. Scale bars: **A** = 250  $\mu\text{m}$ ; **B** = 25  $\mu\text{m}$ .

$n = 7$ ) wide, with 2 papillae on posterior margin and several papillae along outer edge; opening subterminal, antero-ventrally directed. Average length of acetabulum, 170–230 ( $203 \pm 18$   $n = 8$ ) slightly greater than width, 180–225 ( $205 \pm 15$   $n = 7$ ), strongly

muscular, sunken, visible externally by its rounded opening; tegument of acetabulum with fine striations radiating outward from acetabular opening. Ratio of length of oral sucker to length of acetabulum 1:1.4–1:2.0 (1:1.6) and width of oral sucker to width of acetabulum 1:1.3–1:1.7 (1:1.5). Prepharynx absent. Pharynx muscular, well developed, 45–55 ( $52 \pm 4$ ,  $n = 6$ ) long, 38–70 ( $56 \pm 11$ ,  $n = 6$ ) wide. Esophagus short, winding, 45–75 ( $57 \pm 16$ ,  $n = 3$ ) long, 5–10 ( $n = 2$ ) wide. Cecal bifurcation short distance anterior to acetabular margin. Ceca, mostly obscured by vitelline follicles, extend posterior to acetabulum, 725 (right side) to 800 (left side) long ( $n = 1$ ), following curve of body, just surpassing posterior margin of ovary but not reaching testes (Fig. 1). Ovary 63–135 ( $104 \pm 25$ ,  $n = 8$ ) long, 98–145 ( $111 \pm 16$ ,  $n = 7$ ) wide, entire, dextral (4 of 8) or sinistral (4 of 8), 350–600 ( $435 \pm 85$ ,  $n = 8$ ), 48%–64% ( $54\% \pm 6\%$ ,  $n = 7$ ) from anterior end of body, overlapping posterior margin of acetabulum in some specimens. Mehlis' gland comprised of loose aggregate of gland cells, 25–63 ( $43 \pm 12$ ,  $n = 7$ ) long, 25–68 ( $48 \pm 15$ ,  $n = 7$ ) wide, partially obscured by vitelline follicles but more visible from dorsal perspective. Seminal receptacle postovarian, muscular. Laurer's canal not observed. Uterus with loop extending to posterior margin of testes. Vitellarium follicular, in 2 lateral fields, each consisting of a roughly-formed double row of follicles, 1 row more lateral and 1 partially overlapping acetabulum dorsally. Vitelline follicles extend from level anterior to pharynx to middle of testes, to posterior margin of testes in some specimens. Lateral fields of vitellarium loosely confluent antero-dorsal to acetabulum, dorsally overlapping ceca, lateral margins of acetabulum, ovary, and testes. Follicles consist of granular vitelline cells; vitelline ducts connect to large median vitelline reservoir filled with vitellocalcy cells. Eggs number about 20 to 40, well developed, ovoid, operculate, 40–70 ( $52 \pm 7$ ,  $n = 40$ ) long, 25–45 ( $32 \pm 4$ ,  $n = 40$ ) wide. Testes 2, irregular in form but not lobed, longer than wide, post-equatorial, posterior to and separated from ovary. Right testis 110–188 ( $137 \pm 30$ ,  $n = 8$ ) long, 50–155 ( $88 \pm 37$ ,  $n = 7$ ) wide, anterior margin 460–700 ( $571 \pm 83$ ,  $n = 8$ ), 63%–78% ( $71\% \pm 5\%$ ,  $n = 7$ ) from anterior end of body. Left testis 105–188 ( $136 \pm 32$ ,  $n = 8$ ) long, 68–168 ( $96 \pm 38$ ,  $n = 7$ ) wide, anterior margin 490–760 ( $591 \pm 88$ ,  $n = 8$ ), 69%–84% ( $73\% \pm 6\%$ ,  $n = 7$ ) from anterior end of body. Cirrus sac elongate, median, dorsal, 75–110 ( $91 \pm 18$ ,  $n = 3$ ) long, 68–103 ( $80 \pm 20$ ,  $n = 3$ ) wide, containing coiled tubular seminal vesicle that occupies most of space in cirrus sac (Fig 1b). Genital pore median, between cecal bifurcation and anterior margin of acetabulum. Excretory vesicle I-shaped, tubular, narrow, reaching anteriorly to or slightly beyond level of mid-testes. Excretory pore terminal.

## Remarks

The genus *Paracreptotrema* includes four species: *P. blancoi* Choudhury, Pérez-Ponce de León, Brooks & Daverdin, 2006, *P. mendezi* (Sogandares-Bernal, 1955), *P. profundulusi* Salgado-Maldonado, Caspeta-Mandujano & Martínez-Ramírez, 2011, and *P. heterandriae* Salgado-Maldonado, Caspeta-Mandujano & Vázquez, 2012. The specimens of *P. rosenthali* sp. n. from *X. malinche* share the features established in the

original concept of the genus (Choudhury et al. 2006). In general, there are five primary features that can be used to distinguish *P. rosenthali* sp. n. from the extant species: the shorter length of the ceca, the extent of the vitelline follicles, the extensive folding of the seminal vesicle, the width of the cirrus sac, and the extension (area occupied) of the uterus. *Paracreptotrema rosenthali* resembles *P. mendezi*, *P. blancoi*, and *P. profundulusi* in having a well-developed cirrus sac, but the new species stands out by having a seminal vesicle that is more extensively folded and the cirrus sac which is wider than those of the other three taxa. *Paracreptotrema rosenthali* sp. n. and *P. heterandriae* have ceca that extend past the ovary but not to the testes; however, in the latter species the body is longer and narrower than that of *P. rosenthali* sp. n. The vitellarium of the new species extends from a level anterior to the pharynx to the middle of the testes, and in some specimens reach but do not pass the posterior margin of the testes, and the follicular rows partially overlap the acetabulum dorsally. In *P. mendezi*, the vitellarum extends posteriorly from the oral sucker but does not pass the anterior margin of the testes. In *P. blancoi* it extends from the cecal bifurcation to the anterior edge of the testes. In *P. profundulusi*, the vitellarium extends to the posttesticular area, and in *P. heterandriae* the vitelline follicles extend from the cecal bifurcation to the posterior margin of the testes. The extent of the uterus of *P. rosenthali* sp. n. is similar to the uterine distribution of *P. blancoi* and *P. heterandriae* in that the uterus extends to the posterior margin of the testes, often filling the post-testicular area; in *P. profundulusi* the uterus is mostly pretesticular. The mean size of the eggs of *P. rosenthali* sp. n. (52 long by 32 wide) is similar to that of *P. blancoi* (55 by 39) and *P. profundulusi* (57 × 31); the mean egg size of *P. mendezi* (46 × 37) is smaller and that of *P. heterandriae* (72 × 40) is larger. The number of eggs in the uterus ranged from 20–40 among the specimens of the new species; the specimens of *P. blancoi* that we examined had fewer than 10 eggs and those of the three other species that we observed had from 8–24 eggs in the uterus.

## Discussion

Geographic barriers play an important role in the isolation of fish populations and their helminth fauna (Pérez-Ponce de León and Choudhury 2010; Salgado-Maldonado et al. 2011; Bautista-Hernández et al. 2014b). Four of the five species of *Paracreptotrema*, including the one described in this paper, are parasites of poeciliid fish. Choudhury et al. (2006) suggested that *Paracreptotrema* spp. might be parasites exclusive to poeciliids in the Neotropical region. However, Salgado-Maldonado et al. (2011) described *P. profundulusi* from and reported *P. blancoi* in species of the Profundulidae, arguing that this was evidence that *Paracreptotrema* spp. could have a closer relationship with freshwater members of the Profundulidae than with the Poeciliidae because of the restricted distribution of the latter family in Central America. The geographic distribution of *Profundulus* is restricted to hydrological basins of Central America, extending northward only to the Isthmus of Tehuantepec (southeastern México), so the co-occurrence of the two species of *Paracreptotrema* in those fish could be due to recent contact between dif-

ferent host populations. The finding of the new species does not offer insights into the co-speciation of the members of the genus; i.e. the origin of each species and whether they originated in poeciliids or profundulids. For this reason, a phylogeny of the group is needed, ideally combined with a hypothesis regarding the taxa that host these species. Additionally, in cases where the localities of each species of helminth are widely separated, further studies are needed to verify the limits of the distribution of each.

The distribution of *X. malinche* is restricted to the more northern Hidalgo anticline, separated from southern populations of fish by the barrier range of the Mexican plateau (Kallman and Kazianis 2006), so it is not clear how the population of *P. rosenthali* sp. n. is linked to those species of Central America. Consistent with hypotheses regarding the orogeny and isolation of headwater populations, Bautista-Hernández et al. (2014b) reported differences in parasite communities between two populations of *X. malinche* (Chicayotla and Malila) that are separated only by two mountain ridges. Specifically, the Malila population was infected with three species of helminth, whereas the Chicayotla population was infected with four species. Our finding a new species restricted to the Malila population further supports the importance of host biogeographic factors with regard to the structure of helminths communities. Although helminth diversity is affected by the restricted distribution of their host, further studies are needed to evaluate the familial host specificity of species of *Paracreptotrema*. *Paracreptotrema mendezi* was collected from fish living in a lake but all other known species are from stream- and river-dwelling populations of fish; whether or not this factor is important for our understanding of the ecological relationships of the members of the genus is still unknown.

The papillae on the oral sucker were difficult to discern on our specimens. Two papillae on the posterior margin of the sucker were visible on some specimens, but only some of the papillae along outer edge were visible on a few specimens; thus, no papillae were included in the figure. We could discern several papillae along the outer edge of the oral sucker in specimens of *P. blancoi*, *P. profundulusi*, and *P. heterandriae*, but the entire complement of papillae was not visible in any specimens we examined. Study of specimens using scanning electron microscopy will be necessary for a full assessment of the number of papillae present, but the number of specimens available at this time is not sufficient for such a study.

All known species of *Paracreptotrema* have an oral sucker that is wider than long (Table 1). The new species is not different in this respect. However, one specimen we collected, the holotype (unfortunately), had an oral sucker longer than wide (Fig. 1). This specimen was processed differently to any of the others, and it was one of six specimens from single-worm infections, but it is the only one with the different sucker size ratio. Even with that worm removed from the comparison, the oral sucker of *P. rosenthali* sp. n. is the largest of the known species. Similarly, the average length of the acetabulum was greater than the width, but in some worms this was reversed.

The presence of Laurer's canal has been reported for the four previously known species. We were not able to discern the canal in specimens of the new species. The limited material precluded mounting of specimens in a more favorable position for

**Table 1.** Comparison of morphological characteristics of the five species described as *Paracrioptrema*. Data for *P. blancoi* (México), *P. blancoi* (Costa Rica), *P. mendesi* and *P. heterandriae* taken from Choudhury et al. (2006) and Salgado-Maldonado et al. (2012). Note: measurements are given exactly as in the original work with the same precision as reported and presented as the range followed by the mean.

	<i>P. blancoi</i>	<i>P. blancoi</i>	<i>P. mendesi</i>	<i>P. profundulus</i> (text)**
<b>Body length</b>	465–732 (519)	500–850 (688)	680	600–990 (788)
<b>Maximum width</b>	200–387 (263)	250–450 (349)	310	287–500 (364)
<b>Oral sucker length × width</b>	70–90 (82) × 82.5–110 (90.4)	100–155 (126.7) × 100–155 (126.2)	100 × 120	102–150 (125) × 112–177 (137)
<b>Ventral sucker length × width</b>	162.5–207 (175.9) × 125–210 (173.8)	120–175 (153.2) × 130–205 (174)	170 × 170	165–250 (201) × 145–225 (189)
<b>Sucker ratios</b>				
<b>Length</b>	1.7–2.4 (1:2.1)	1.2–1.21 (1:1.2)	1:1.4'	1.5–2.0 (1:1.6)
<b>Width</b>	1.4–2.5 (1:1.9)	1.2–1.7 (1:1.4)		1.1–1.5 (1:1.4)
<b>Pharynx length × width</b>	25–50 (40) × 30–62.5 (47.2)	40–60 (50) × 45–75 (57)	50 × 60	37–62 (48) × 37–70 (49)
<b>Ovary length × width</b>	37.5–77.5 (51.5) × 25–75 (40.7)	55–110 (86.2) × 35–62.5 (69.2)	27 × 74	47–125 (72) × 50–125 (90)
<b>Left testis length × width</b>	45–75 (64.2) × 37.5–70 (52.5)	90–170 (132) × 70–120 (94.7)	180 × 90	87–175 (124) × 75–125 (93)
<b>Right testis length × width</b>	42.5–87.5 (63.7) × 35–62.5 (52.5)	89–167 (134) × 74–115 (95.1)	170 × 90	87–175 (122) × 60–112 (92)
<b>Cirrus sac length × width</b>	62.5–137.5 (83.2) × 30–50 (37.5)	– × 35–62.5 (52)	100 × 60	92–175 (135) × 37–95 (67)
<b>Eggs length × width</b>	45–60 (52) × 25–37.5 (32.5)	52.5–62.5 (55.4) × 32.5–42.5 (38.5)	46 × 37	50–62 (57) × 25–37 (31)
<b>Locality</b>	Río Papagayo basin, Guerrero, México	Área de conservación, Guanacaste, Costa Rica	Lake Gatun, Panama	Río Tehuantepec basin, Oaxaca, México
<b>Host</b>	<i>Profundulus punctatus</i> (Profundulidae)	<i>Priapichthys amnetaris</i> (Poeciliidae)	<i>Brachyrhaphis episcopi</i> (Poeciliidae)	<i>Profundulus punctatus</i> (Profundulidae)
<b>Reference</b>	Salgado-Maldonado et al. 2011	Choudhury et al. 2006	Sogandares-Bernal 1955	Salgado-Maldonado et al. 2011

Table 1. Continued

	<i>P. profundulusi</i> (table)*	<i>P. heterandriae</i>	<i>P. rosenbali</i>
<b>Body length</b>	675–990 (820)	625–1,050 (783)	720–940 (830)
<b>Maximum width</b>	287–500 (380)	175–375 (252)	350–550 (417)
<b>Oral sucker length × width</b>	115–137 (124) × 117–150 (133)	100–160 (121) × 87–150 (113)	105–160 (125) × 130–175 (140)
<b>Ventral sucker length × width</b>	175–250 (205) × 145–225 (186)	112–195 (155) × 117–217 (163)	170–203 (203) × 180–225 (205)
<b>Sucker ratios</b>			
<b>Length</b>	1.5–2.0 (1:1.7)	0.9–1.6 (1:1.3)	1:1.6
<b>Width</b>	1.1–1.5 (1:1.3)	1.2–1.7 (1:1.4)	1:1.5
<b>Pharynx length × width</b>	37–62 (48) × 37–70 (51)	45–67 (54) × 50–75 (59)	45–55 (52) × 38–70 (56)
<b>Ovary length × width</b>	47–125 (82) × 75–125 (98)	55–112 (76) × 42–112 (72)	63–135 (104) × 98–145 (111)
<b>Left testis length × width</b>	87–155 (122.4) × 62–112 (92)	87–150 (119) × 52–125 (75)	105–188 (136) × 68–168 (96)
<b>Right testis length × width</b>	87–162 (123.4) × 60–112 (99)	87–150 (116) × 57–112 (79)	110–188 (137) × 50–155 (88)
<b>Cirrus sac length × width</b>	100–175 (141) × 37–87 (69)	100–145 (114) × 20–35 (28)	75–110 (91) × 68–103 (80)
<b>Eggs length × width</b>	52–60 (57) × 25–30 (27.8)	70–75 (72.5) × 35–41 (40)	47–70 (52) × 25–45 (32)
<b>Locality</b>	Río Tehuantepec basin, Oaxaca, México	Río la Antigua upper basin, Xalapa, Veracruz, México	Río Conzintla, Malilla, Hidalgo
<b>Host</b>	<i>Profundulus punctatus</i> (Profundulidae)	<i>Heterandria bimaquilata</i> (Poeciliidae)	<i>Xiphophorus malinche</i> (Poeciliidae)
<b>Reference</b>	Salgado-Maldonado et al. 2011	Salgado-Maldonado et al. 2012	Present study

\*Data taken from the table displayed in Salgado-Maldonado et al. (2011).

\*\*Data taken from the original description in text (Salgado-Maldonado et al. 2011).

observations of this structure, and no specimens were available for histological study. The populations of fish from which the specimens were collected are limited in size and fragile, and this helminth has not been found in other populations of fish close to the locality (Bautista-Hernández et al. 2014a; Bautista-Hernández et al. 2014b), but the presence of Laurer’s canal needs to be confirmed by future studies.

Razo-Mendivil et al. (2014) provided molecular evidence that *P. heterandriae* is a member of the Allocreadiidae, affording strong support for the familial relationship previously suggested by Choudhury et al. (2006) and Salgado-Maldonado et al. (2012). A more inclusive molecular study of the new species would provide additional information on the relationships of this species with *P. heterandriae* and the other members of the genus. Molecular evidence would also provide confirmation of the specific identification of the putative species which have been identified to date. Morphological characters, some of which can vary intraspecifically, have been the primary features used to identify species; molecular techniques could verify or falsify the appropriateness of the morphological features that have been used.

### Key to the identification of species of *Paracreptotrema*

- 1       Ceca do not surpass the anterior margin of the testes ..... **2**
- Ceca surpass the anterior margin of the testes ..... **4**
- 2       Anterior margin of the vitelline follicles does not reach the anterior margin of the pharynx..... ***P. heterandriae***
- Anterior margin of the vitelline follicles surpasses the anterior margin of the pharynx ..... **3**
- 3       Uterus extends to the posterior margin of the hindbody ..... ***P. mendezi***
- Uterus does not extend to the posterior margin of the hindbody... ***P. rosenthali***
- 4       Vitellarium extends posterior to the testes..... ***P. profundulusi***
- Vitellarium does not extend into the region posterior to the testes .... ***P. blancoi***

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# California dragonfly and damselfly (Odonata) database: temporal and spatial distribution of species records collected over the past century

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## Abstract

The recently completed Odonata database for California consists of specimen records from the major entomology collections of the state, large Odonata collections outside of the state, previous literature, historical and recent field surveys, and from enthusiast group observations. The database includes 32,025 total records and 19,000 unique records for 106 species of dragonflies and damselflies, with records spanning 1879–2013. Records have been geographically referenced using the point-radius method to assign coordinates and an uncertainty radius to specimen locations. In addition to describing techniques used in data acquisition, georeferencing, and quality control, we present assessments of the temporal, spatial, and taxonomic distribution of records. We use this information to identify biases in the data, and to determine changes in species prevalence, latitudinal ranges, and elevation ranges when comparing records before 1976 and after 1979. The average latitude of where records occurred increased by 78 km over these time periods. While average elevation did not change significantly, the average minimum elevation across species declined by 108 m. Odonata distribution may be generally shifting northwards as temperature warms and to lower minimum elevations in response to increased summer water availability in low-elevation agricultural regions. The unexpected decline in elevation may also be partially the result of bias in recent collections towards centers of human population, which tend to occur at lower elevations. This study emphasizes the need to address temporal, spatial, and taxonomic biases in museum and observational records in order to produce reliable conclusions from such data.

**Keywords**

Museum specimens, observational records, bias, change in distribution, species richness, digital catalog

**Introduction**

Natural history specimens are arguably the most valuable records of the historical occurrence of organisms. In contrast to scientific publications, which usually are most relevant for the first ten years following their appearance, information from specimens becomes more valuable with age (Winker 2004). Museum records that are backed by voucher specimens also allow researchers to verify species identification. In addition to their traditional use in taxonomy and biogeography studies, specimens can provide a wealth of information concerning changes in morphology, genetic and biochemical composition, and the distribution and diversity of organisms over time (Cao et al. 2013, Graham et al. 2004, O’Connell et al. 2004, Pyke and Ehrlich 2010, Winker 2004). However, large-scale applied and ecological studies using museum specimens are exceedingly difficult to conduct without a database of existing records. While the development of digital catalogs of natural history specimens began in 1970, by 2010 only ~ 3% of total records worldwide were estimated to be available online through the mobilization efforts of the Global Biodiversity Information Facility (GBIF 2014; Ariño 2010).

Many vertebrate collections have complete or near-complete databases of their specimens, along with ancillary information such as photos, field notes, and published manuscripts associated with particular specimens (e.g. Guralnick and Constable 2010, Pyke and Ehrlich 2010). However, databases for insects and other invertebrates have lagged far behind vertebrates (Schuh et al. 2010). This is largely because the task of databasing information from millions of small specimens, which represent the most diverse animal group on the planet, is enormous. In addition, these collections often lack the necessary resources to meet desired specimen curation because insects tend to undergo continual taxonomic revision (DeWalt et al. 2005). Therefore, many have considered digitization of huge collections of insects with tiny and highly abbreviated labels to be impossible (Schuh et al. 2010). However, in response to a growing need for specimen data in research, more insect and other large natural history collections are in the process of undergoing or beginning digitization (e.g. Abbott 2005, Favret and DeWalt 2002, Graham et al. 2004, Hill et al. 2012, Schuh et al. 2010). In the United States, the National Science Foundation (2014) has made such efforts possible through funding initiatives, including the Advancing Digitization of Biodiversity Collections (ADBC) and the Thematic Collections Network (TCN).

Along with digitization, however, comes the responsibility of database curators and data-users to acknowledge and address the many biases that exist in specimen data. Because the approach of natural history collection acquisition and management has traditionally focused on taxonomic work and the special interests of curators and enthusiasts (Graham et al. 2004), the data are usually biased in regards to the species collected and

the temporal and spatial distribution of records (Pyke and Ehrlich 2010). For example, collectors have often focused collecting efforts on rare, large, and charismatic species while neglecting more common or cosmopolitan species (Winker 2004). Collections also tend to occur along roads, railroad tracks, or near centers of human population (Graham et al. 2004, Pyke and Ehrlich 2010). There is usually a strong correlation between collection effort, or number of records, and the number of species documented for a given time period or region (Fattorini 2013). Therefore, well-sampled regions may have better species representation than less-sampled areas as a result of sampling effort. Such biases present in natural history collections can be reduced by incorporating as much data as possible in occurrence-based analyses of the data. For example, compiling records from multiple institutions may help reduce the problem of localized collecting from any one collection (Pyke and Ehrlich 2010, Soberon et al. 2000).

The present study summarizes a recently completed database of Odonata records from throughout the state of California, USA, including both specimens and observational records. This group of aquatic insects provided a good starting point for a state-wide database of insect specimens because they are less diverse than most insect orders, have well-known taxonomy (Clausnitzer et al. 2009), are charismatic to the general public, and have naturalist sightings that are available to supplement recent occurrence records (Abbott 2005, Odonata Central 2014). Odonata are also known to be useful indicators of freshwater ecosystem health, and are thus likely to contribute to our understanding of general response to changes in aquatic habitat and water quality (e.g. Clausnitzer 2003, Smith et al. 2007). Here, we outline the methods used in the development of the California Odonata database. We then present the spatial and temporal distribution of records to identify data gaps and biases. We determine contributions of different collection types (e.g. university and government institutions, observation-based records) to total number of records and unique county records. Finally, we assess the prevalence of records for each Odonata species before 1976 and after 1979 to determine both potential taxonomic biases and changes in species prevalence, altitude, and elevation ranges over time. We chose the time periods of before 1976 and after 1979 because they have approximately equal numbers of records, and the time period beginning in 1980 marks the beginning of accelerated temperature warming.

## **Methods**

### **Odonata specimen database**

We developed a database of Odonata occurrence records in conjunction with a larger project, known as Calbug, whose goal is to database over one million California arthropod specimens (Calbug 2014). Calbug is a collaborative project among the ten major entomology collections in California, including: the California Academy of Sciences (CASENT), California State Collection of Arthropods (CSCA), Los Angeles County Museum (LACM), San Diego Natural History Museum (SDNHM), Santa

Barbara Museum of Natural History (SBMNH), Essig Museum of Entomology of the University of California at Berkeley (EMEC), Bohart Museum of Entomology of the University of California at Davis (UCBME), Entomology Research Museum of the University of California at Riverside (UCRCENT), Museum of Natural History of the University of California at Santa Cruz (UCSC), and the Oakland Museum of California (OMC). The Odonata database includes records from CASENT, CSCA, LACM, EMEC, UCBME, SBMNH, SDNHM, UCRCENT, and OMC.

In addition to the Calbug institutions, we obtained specimen data from the two largest Odonata collections in the United States, the Museum of Zoology at the University of Michigan (UMMZ) and the Florida State Collection of Arthropods (FSCA), which includes records from International Odonata Research Institute (IORI), Louisiana State Arthropod Collection (LSUC), and the Museum of Zoology Pontifical Catholic University of Ecuador (QCAZ) collections. We then incorporated data from other online databases that contain California odonate material, including that of the Illinois Natural History Survey (INHS 2014), and the National Museum of Natural History (NMNH 2014). We also included California odonate occurrence records from the personal collections of D.R. Paulson (DRPC), R.W. Garrison (RWGC), S.D. Gaimari (SDGC), and the author (J.E.B-D, Ball-Damerow et al. 2014). Finally, the odonate records of C.H. Kennedy (1917), collected throughout central California in 1914–15 are incorporated as a private collection. These records are included in the Essig museum's online specimen database (Table 1, Essig Museum of Entomology Collections Specimen Database 2014).

Odonata was a high priority group for the Calbug project, which began in 2010. At the start of the project, we directly entered data from specimen labels into the Essig database, and assigned each specimen a Unique Identifier (UID) that is associated with the physical specimen and its database record. The Essig database uses Linux, Apache HTTP Server, MySQL, and Perl/PHP (LAMP) technology, and currently contains 117 fields based on Darwin Core standards. A Darwin Core-Archive is created monthly and made available to GBIF and other aggregators via the Berkeley Natural History Museums (BNHM) IPT service.

Since 2011, we have photographed specimens with their collection labels as the first stage of the data collection process. Further details on the imaging process are described on the Calbug website (2014). The images are then uploaded into the Essig database with species name and UID information, and stored in the database as part of the specimen record. Individuals may then enter label information for specimen records online through the Essig database, using the magnified specimen image.

### **Observation-based records**

In addition to specimen collections, we also included occurrence data from Odonata Central and CalOdes enthusiast observations, of which records have often been photo-vouchered and verified by odonate experts. Odonata Central (2014) is a North American

**Table 1.** All contributing data sources, abbreviations, and total number of specimens.

Source collection	Abbreviation	# Specimens
CalBug Institutions		14,207
California Academy of Science	CASENT	2,876
UC Riverside	CIS	531
California State Collection of Arthropods	CSCA	24
Essig Museum	EMEC	5,550
LA County Museum	LACMENT	2,032
Oakland Museum	OMC	107
Santa Barbara Museum of Natural History	SBMNHENT	153
San Diego Natural History Museum	SDNHM	88
UC Bohart Museum	UCBME	2,776
UC Riverside	UCRCENT	70
non-CalBug Institutions		5,803
Florida State Collection of Arthropods	FSCA	65
International Odonata Research Institute (at FSCA)	IORI	3,230
Louisiana State University	LSUC	48
Museum of Zoology - Pontifical Catholic University of Ecuador (P.U.C.E)	QCAZ	12
Illinois Natural History Survey	INHS	96
University of Michigan Museum	UMMZI	1,425
US National Museum	USNM	927
Personal		3,746
C.H. Kennedy	CHK	1,190
D.R. Paulson	DRPC	930
R.W. Garrison	RWGC	576
S.D. Gaimari	SDGC	132
J.E. Ball-Damerow field collections	JEBD	918
Observations		8,269
Cal Odes	Cal Odes	6,777
Odonata Central	Odonata Central	1,492
<b>Grand Total</b>		<b>32,025</b>

database with georeferenced records, and includes photo-vouchered sightings, records from literature, and some specimen-based data (Abbott 2005). CalOdes is a California statewide dragonfly enthusiast group composed of around 125 members who track and submit lists of species observed at specific locations and dates (Dragonflies of California 2014).

### Data quality

To facilitate quality control during data entry, the Essig database uses controlled vocabularies, such as dropdown lists, date range validation, and species name authority files to validate names. Hierarchical information is automatically filled in for geography and taxonomy.

Following data entry, we conducted a data checking procedure to minimize likely data-entry errors. This included an assessment of records with the same localities for spelling errors and to determine whether locations were associated with the correct county in the state. The data entry form of the database automatically filled information from one record to the next so that records with the same information in a series did not have to be entered multiple times. To minimize carry-over errors, we therefore checked records with adjacent UIDs for questionable repeated fields, such as collector or date. Finally, we spot checked all fields for a portion of specimens against the specimen label photograph.

Odonata have been relatively well-curated in these collections over time, so that correct specimen identification was assumed in most cases. An Odonata specialist, T. Manolis (2003), recently checked most taxonomic identifications of Odonata specimens from the Calbug institutions. Odonata specimens at UMMZI and FSCA have also been curated by odonate specialists, including L.K. Gloyd and M.F. O'Brien at UMMZI, and W.F. Mauffray at FSCA.

We compared all specimen records to current county records and known distribution ranges as a method to check for outliers. Each specimen that fell outside of current county records for the species was checked for accurate identification and potential data entry errors. From these records, we retained only those with verified species identification and locality information. Finally, we corrected any species with outdated names, based on taxonomic classifications in Odonata Central (2014).

## Georeferencing

We georeferenced occurrence localities using the standardized point-radius method (Wieczorek et al. 2004). This method outlines a series of rules to assign geographic coordinates to text descriptions of locations. Using this standard, we also assigned an uncertainty estimate (i.e. radius) based on common sources of uncertainty, such as the extent of a named place (e.g. Berkeley, California) and the distance precision provided for an offset direction (e.g. 4 miles north of Berkeley, California, which has a distance precision of 1 mile). In most cases, we used multiple online georeferencing tools, including Geolocate (Rios and Bart 2010), Georeferencing Calculator (Wieczorek et al. 2004), ACME Mapper (2014), Geographic Names Information System (GNIS; 2014), and Earth Point (2014).

After all records were georeferenced, we spot checked a portion of records for accuracy. In addition, we checked all localities with listed counties that did not match county polygons using ArcGIS Desktop, release 10.1 (ESRI 2012). We then corrected any aberrant records or further investigated related records, as needed.

## Taxonomic, temporal and spatial summary of records

We first summarized the number of species within each of the families found in the state. To demonstrate the temporal and spatial coverage of species occurrence records,

we then summarized records by decade, by county, and in maps of occurrence locations. For this and all subsequent analyses, we removed any species considered to be vagrant, with only one sighting in the state. We determined species richness and the total number of specimens before 1900 and by decade in the following years. We then calculated species richness and total number of records by county for the entire period of record. In order to assess the effect of effort on species richness by county, we plotted the total number of species against the number of records for each county. We also used this information to identify regions that are currently underrepresented in the collections. Finally, we mapped all *Odonata* occurrence locations before 1976 and after 1979 to illustrate the spatial distribution of records for these time periods.

### **Contribution of collection types to county records**

The four collection types included in the database were the Calbug institutions (California University and government collections), non-Calbug (non-California) institutions, private collections of odonate specialists, and observation-based records. We first summarized the total number of records from each data source. To illustrate how different collections have contributed to our knowledge of spatial distribution of odonates in the state, we determined the number of unique county records from each of the major collection types. We summarized the number of unique county records (by species and county) shared by one, two, three, or all four types.

### **Species occurrence records**

The final goal of this paper was to assess the prevalence of records for individual *Odonata* species before 1976 and after 1979 to determine both potential taxonomic biases and changes in species prevalence, altitude, and elevation ranges over time. We chose these time periods because they have comparable numbers of unique-species occurrence records (8,431 before 1976 and 9,156 after 1979). The four year gap, including the years of 1976–1979, separates the two time periods for temporal comparison while maximizing our ability to achieve similar numbers of records. Moreover, temperature began increasing rapidly starting around 1980 as a result of climate change (IPCC 2013). We removed all species that were recorded in fewer than two instances because these were considered to be vagrant species. We then determined the first and last year of documented occurrence, and the total number of records before 1976 and after 1979. We considered the total number of unique records for each time period to be a proxy for collection effort. To account for differences in collection effort, we divided the number of unique occurrences of each species by the total number of unique occurrences across all species for the respective time period. We then identified species with changes in occurrence records that are likely to result from taxonomic biases, and those that may have legitimately increased or declined in prevalence. Related studies

by Ball-Damerow et al. (2014) and Manolis (2003), and expert opinion were applied to distinguish between species with actual change in prevalence over time and species with change likely resulting from taxonomic collection biases.

To determine whether species have expanded to higher latitudes or elevations, we calculated the average and range of latitude and elevation for each species before 1976 and after 1979. Any records with greater than 4 km error radius were removed from this analysis. Wilcoxon signed-rank tests were performed to determine whether the median difference in latitude and elevation means between the two time periods were significantly different.

## Results

### Database summary

There were 32,025 records from all combined sources (Suppl. material 1, Table 2). The majority of records (21,648) came from Calbug efforts. CalOdes, Odonata Central, recent field collections (Ball-Damerow et al. 2014), and C.H. Kennedy's collections (Kennedy 1917) contributed 6777, 1492, 2016, and 1190 records, respectively (Table 2). Many of these records were not unique, and the summed total number of unique species, year, and locality combinations for all data sources was 19,000, and the total species, year, and county combinations was 13,255 (Table 2).

### Taxonomic, temporal and spatial summary of records

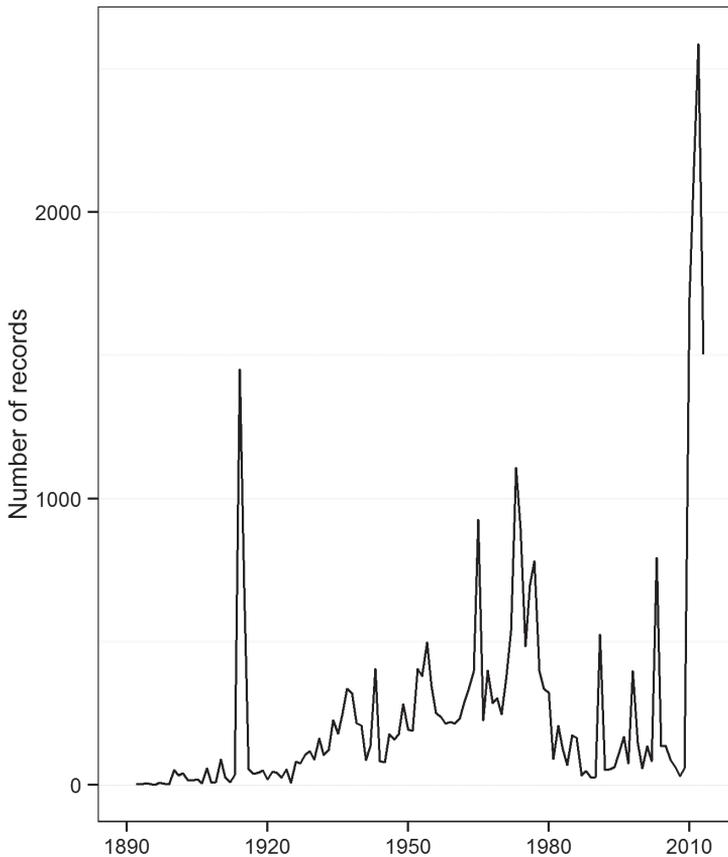
There are currently 106 species within nine families that are known to occur in the state, including nine species of Aeshnidae, two species of Calopterygidae, 30 species of Coenagrionidae, one species of Cordulegastridae, six species of Corduliidae, 12 species of Gomphidae, seven species of Lestidae, 38 species of Libellulidae, and one species of Petaluridae. The earliest records in the database were from 1879, and include two specimens of *Argia vivida* Hagen from the Santa Ana River in Southern California, and several records of *Hetaerina americana* (Fabricius) and *Libellula saturata* Uhler in Colton, San Bernardino County, California. These specimens are all held at INHS. The last year of record in the database was 2013.

The first peak in Odonata collections in California occurred in 1914–1915 with C.H. Kennedy's collections throughout the state (Kennedy 1917, Fig. 1). Subsequent peaks occurred in the mid-1950s, 1960s, and 1970s, with the largest collections from D. Paulson, R. Garrison, and S. Dunkle (Fig. 1). Most of the recent records come from CalOdes sightings and field surveys by J.E. Ball-Damerow over the period of 2010–2013.

The total number of species found throughout the state varied only slightly by decade, except for time periods when there were less than ~ 1,200 total records, e.g.

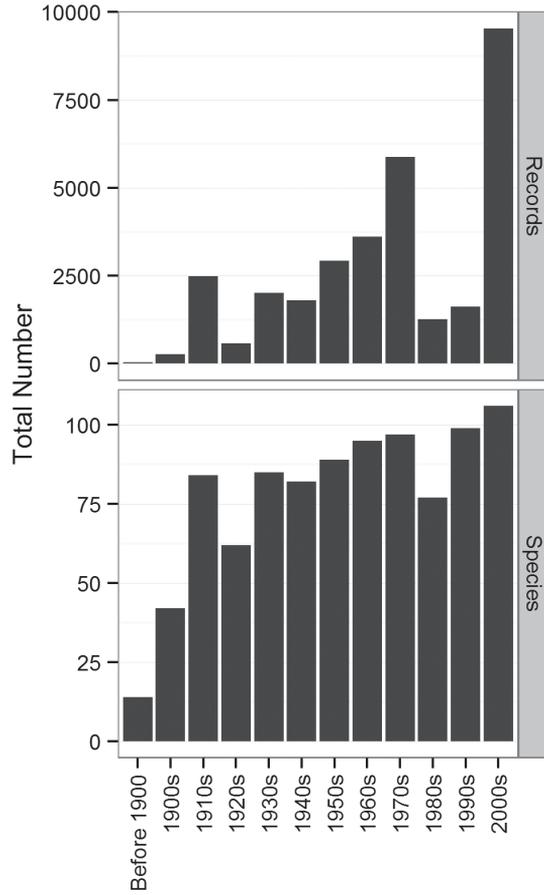
**Table 2.** Summary of total California Odonata records, and unique species records by year and either locality or county. Specimen database includes Calbug Institutions (California University and government-based collections), non-Calbug institutions, and private collections.

Data source	Total records	Unique locality records	Unique county records
Specimen database	21,648	11,149	8,716
C.H. Kennedy (1917)	1,190	527	404
J.E. B-D field collections	918	856	514
CalOdes	6,777	5,463	2,698
Odonata Central	1,492	1,005	923
Totals	32,025	19,000	13,255

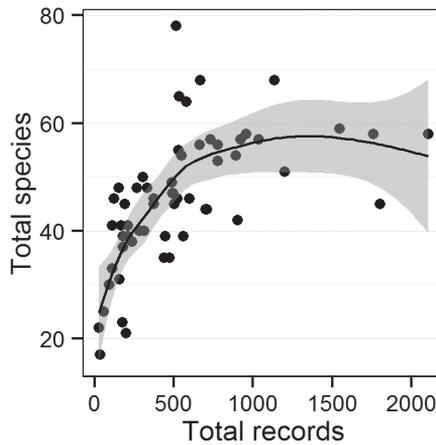


**Figure 1.** Total number of California Odonata records per year.

before 1900 and 1900–1910. The time period with the highest number of records and species was 2000–2013, with 9,535 records and 106 species, followed by the 1990s, with 99 species and only 1,623 total records (Fig. 2). The 1910s, which include C.H. Kennedy’s surveys, contribute 2,485 total records for 84 species (Fig. 2).



**Figure 2.** Total number of records and number of species by decade.



**Figure 3.** Relationship between species richness and total number of records by county, where each point represents a California county.

There was an exponential relationship between the total number of unique records from a given county and species richness observed (Fig. 3). The richness increased dramatically through ~ 600 total records, leveling off at ~ 58 species. Therefore, many counties with less than 600 records are likely to show higher species richness with increased sampling. The least-sampled county was Kings County, with only 28 records and 22 total species (Table 3). Riverside County was the most sampled with 2,108 unique records and 58 species observed (Table 3).

Most counties supported 40–60 species. Counties that were well above or below the confidence interval may be either relatively species-rich or species-poor (Fig. 3). Siskiyou, Shasta, Inyo, Placer, and Lake Counties were relatively rich in species, while some species-poor counties included Los Angeles, Stanislaus, Yolo, Kern, Colusa, and Ventura (Fig. 3).

A map of specimen localities for both time periods demonstrates some additional spatial bias and data gaps (Fig. 4). Dense clusters of records exist around urban centers, including the San Francisco Bay area, Sacramento, and major cities in southern California, such as Santa Barbara, Los Angeles, San Diego, and Riverside. The least sampled and/or occupied area is the desert region in the southeast of the state. While the number of total records was higher before 1976, the spatial distribution of records before 1976 and after 1979 is similar.

### Contribution of collection types to county records

Calbug institutions contributed the highest number of total records with 14,207 total records, followed by observation-based records with 8,269 total records (Table 1). Non-Calbug institutions and private collections provided 5,803 and 3,746 total records, respectively.

The observation-based records contributed the highest number of unique county records with 538 (by species and county only), followed by the Calbug institutions with 353 unique records (Fig. 5). Non-Calbug institutions and private collections contributed 87 and 83 unique county records, respectively. There were 705 county records originated from two of the four collection types, 594 records originated from three types, and 370 records originating from all four collection types (Fig. 5).

### Species occurrence records

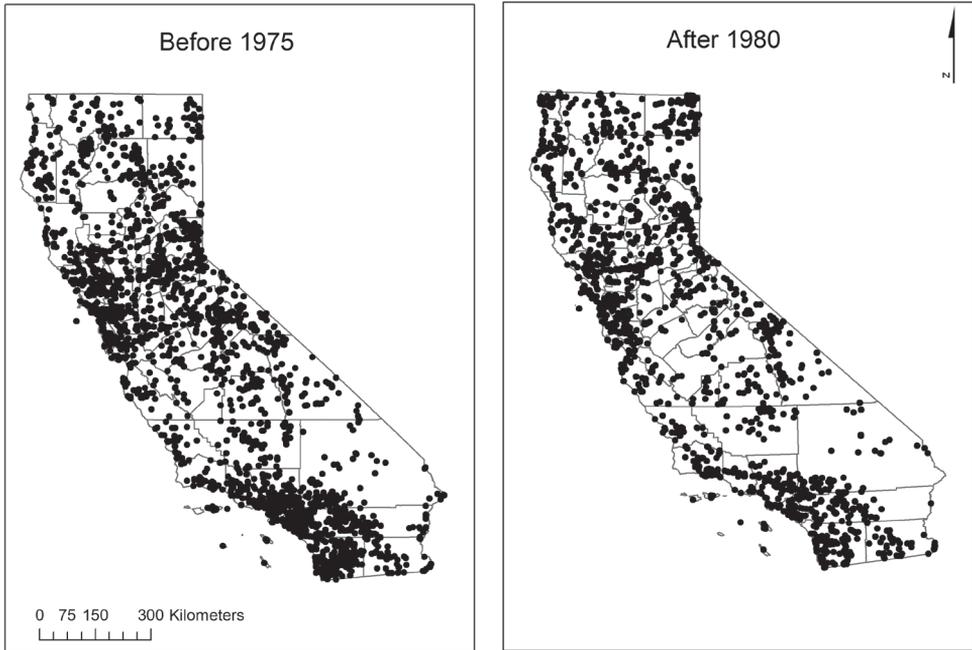
There were 8,642 unique species occurrence records (i.e. unique locality and date) before 1976, and 9,175 unique occurrence records after 1979. The most commonly sampled species before 1976 were *Argia vivida*, *Sympetrum corruptum* Hagen, *Libellula saturata*, *Enallagma carunculatum* Morse, and *Ischnura cervula* Selys. The most commonly sampled or observed species after 1979 were *Argia vivida*, *Sympetrum corruptum*, *Ischnura cervula*, *Libellula saturata*, and *Anax junius* (Drury) (Table 4). The least

**Table 3.** Total number of records and species for each county.

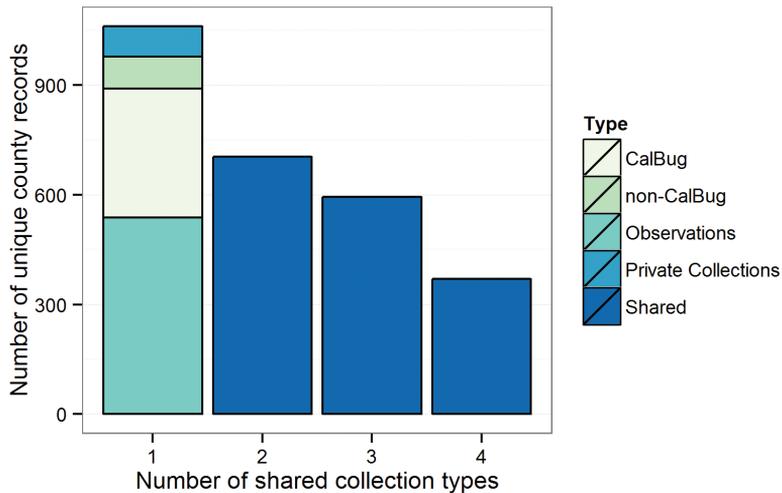
County	Total records	Species richness	County	Total records	Species richness
Kings	28	22	Napa	492	47
Sutter	33	17	Alameda	496	47
San Benito	56	25	San Mateo	504	45
Alpine	93	30	Shasta	514	78
Amador	109	41	Sacramento	524	46
Glenn	111	33	Plumas	530	55
Tehama	123	46	Placer	533	65
Lake	153	48	Fresno	547	54
San Joaquin	157	31	Imperial	562	39
Madera	169	41	Modoc	580	64
San Francisco	177	23	Mono	598	46
Calaveras	179	39	Butte	664	56
San Luis Obispo	180	37	Lassen	668	68
Santa Cruz	191	45	Santa Barbara	701	44
Merced	199	21	Yolo	710	44
Mariposa	209	39	Humboldt	731	57
Del Norte	211	41	Colusa	776	53
Solano	235	38	Nevada	777	56
Sierra	268	48	Mendocino	892	54
Yuba	283	40	Stanislaus	904	42
Trinity	306	50	El Dorado	924	57
Marin	314	40	Sonoma	956	58
Monterey	332	48	San Bernardino	1038	57
Tulare	372	46	Siskiyou	1136	68
Tuolumne	372	45	Santa Clara	1202	51
Orange	437	35	Inyo	1548	59
Contra Costa	445	39	San Diego	1759	58
Ventura	474	35	Los Angeles	1804	45
Kern	487	49	Riverside	2108	58

sampled species after 1979 were *Enallagma basidens* Calvert, *Somatochlora albicincta* (Burmeister), *Epithea spinigera* (Selys), *Stylurus intricatus* (Selys), and *Ophiogomphus severus* Hagen (Table 4). *Aeshna canadensis* Walker, *Tramea calverti* Muttkowski, and *Sympetrum vicinum* (Hagen) were not observed before 1998, 1988, and 1980, respectively. *Enallagma basidens*, *Sympetrum albicincta*, and *Nehalennia irene* (Hagen) were only observed one time prior to 1976 (Table 4).

Thirty-seven species decreased in relative occurrence in the two time periods examined, while 66 species increased (Table 4). Species with the highest increases in relative occurrence were *Anax junius*, *Tramea lacerata* Hagen, *Libellula forensis* Hagen, and *Libellula luctuosa* Burmeister. Species with the greatest declines in relative occur-



**Figure 4.** Spatial distribution of California records before 1976, and after 1979.



**Figure 5.** Number of unique county records for each collection type (Calbug collaborating institutions, non-Calbug institutions, observations - Cal Odes and Odonata Central, and private collections), and number of unique county records with two, three, and four shared data types.

rence were *Argia vivida*, *Sympetrum corruptum*, *Enallagma annexum* (Hagen), *Ischnura denticollis* (Burmeister), and *Enallagma carunculatum* (Table 4). Many of the species with the highest declines are likely the result of differences in sampling approaches

**Table 4.** Summary of species records, including earliest and latest observation or specimen collection date, unique occurrences (by site and year) before 1976 and after 1979, and the change in relative occurrence in unique records. Bolded records show the same relationship (i.e. increase or decrease in species prevalence) reported in Ball-Damerow et al. (2014). Records that are likely to be a result of taxonomic biases, such as failure to collect common species or species that are difficult to identify, and a focus on rare or charismatic species, are indicated by \*.

Family	Species	Earliest year	Latest year	Before 1975	After 1980	Change
Coenagrionidae	<i>Argia vivida</i> *	1879	2013	767	535	-232
Libellulidae	<i>Sympetrum corruptum</i> *	1892	2013	612	414	-198
Coenagrionidae	<i>Enallagma annexum</i> *	1900	2013	268	134	-134
Coenagrionidae	<i>Ischnura denticollis</i> *	1900	2013	256	126	-130
Coenagrionidae	<i>Enallagma carunculatum</i> *	1900	2013	329	218	-111
Coenagrionidae	<i>Amphiagrion abbreviatum</i>	1904	2013	168	70	-98
<b>Calopterygidae</b>	<b><i>Hetaerina americana</i></b>	<b>1879</b>	<b>2013</b>	<b>304</b>	<b>220</b>	<b>-84</b>
Coenagrionidae	<i>Argia nahuana</i> *	1894	2013	115	35	-80
<b>Libellulidae</b>	<b><i>Sympetrum illotum</i></b>	<b>1892</b>	<b>2013</b>	<b>270</b>	<b>205</b>	<b>-65</b>
Coenagrionidae	<i>Enallagma praevarum</i> *	1900	2013	103	67	-36
<b>Gomphidae</b>	<b><i>Octogomphus specularis</i></b>	<b>1900</b>	<b>2013</b>	<b>97</b>	<b>61</b>	<b>-36</b>
Coenagrionidae	<i>Enallagma civile</i> *	1926	2013	195	167	-28
Libellulidae	<i>Pantala hymenaea</i> *	1912	2013	141	114	-27
<b>Cordulegastridae</b>	<b><i>Cordulegaster dorsalis</i></b>	<b>1900</b>	<b>2013</b>	<b>139</b>	<b>118</b>	<b>-21</b>
Coenagrionidae	<i>Telebasis salva</i>	1900	2013	86	63	-23
Coenagrionidae	<i>Enallagma boreale</i> *	1903	2013	92	71	-21
Libellulidae	<i>Palaethemis lineatipes</i> *	1914	2013	103	84	-19
<b>Lestidae</b>	<b><i>Archilestes californicus</i></b>	<b>1900</b>	<b>2012</b>	<b>61</b>	<b>48</b>	<b>-13</b>
<b>Libellulidae</b>	<b><i>Libellula nodisticta</i></b>	<b>1894</b>	<b>2013</b>	<b>51</b>	<b>39</b>	<b>-12</b>
Libellulidae	<i>Libellula comanche</i>	1914	2013	50	38	-12
<b>Lestidae</b>	<b><i>Lestes congener</i></b>	<b>1900</b>	<b>2013</b>	<b>64</b>	<b>53</b>	<b>-11</b>
<b>Lestidae</b>	<b><i>Lestes dryas</i></b>	<b>1910</b>	<b>2013</b>	<b>89</b>	<b>80</b>	<b>-9</b>
<b>Libellulidae</b>	<b><i>Sympetrum pallipes</i></b>	<b>1894</b>	<b>2013</b>	<b>130</b>	<b>125</b>	<b>-5</b>
Libellulidae	<i>Leucorrhinia hudsonica</i>	1914	2013	42	32	-10
Coenagrionidae	<i>Enallagma anna</i> *	1915	2012	26	19	-7
Coenagrionidae	<i>Enallagma clausum</i> *	1938	2013	19	12	-7
Libellulidae	<i>Plathemis subornata</i>	1915	2013	34	28	-6
<b>Libellulidae</b>	<b><i>Sympetrum danae</i></b>	<b>1914</b>	<b>2013</b>	<b>33</b>	<b>27</b>	<b>-6</b>
Coenagrionidae	<i>Ischnura barberi</i>	1897	2013	59	55	-4
<b>Gomphidae</b>	<b><i>Ophiogomphus bison</i></b>	<b>1907</b>	<b>2013</b>	<b>58</b>	<b>55</b>	<b>-3</b>
<b>Libellulidae</b>	<b><i>Sympetrum obtrusum</i></b>	<b>1914</b>	<b>2013</b>	<b>39</b>	<b>36</b>	<b>-3</b>
Libellulidae	<i>Libellula croceipennis</i>	1914	2013	22	19	-3
Aeshnidae	<i>Aeshma walkeri</i>	1900	2013	41	40	-1
Lestidae	<i>Archilestes grandis</i>	1897	2012	25	24	-1
Libellulidae	<i>Erythemis collocata</i> *	1900	2013	216	227	11
<b>Libellulidae</b>	<b><i>Sympetrum semicinctum</i></b>	<b>1909</b>	<b>2013</b>	<b>61</b>	<b>63</b>	<b>2</b>
<b>Coenagrionidae</b>	<b><i>Coenagrion resolutum</i></b>	<b>1914</b>	<b>2011</b>	<b>13</b>	<b>13</b>	<b>0</b>
Aeshnidae	<i>Aeshma interrupta</i>	1914	2013	50	53	3

Family	Species	Earliest year	Latest year	Before 1975	After 1980	Change
Lestidae	<i>Lestes disjunctus</i>	1912	2013	62	66	4
Coenagrionidae	<i>Ischnura gemina</i> *	1900	2013	12	13	1
Gomphidae	<i>Stylurus intricatus</i>	1915	2012	6	7	1
Gomphidae	<i>Erpetogomphus compositus</i>	1914	2013	48	52	4
Lestidae	<i>Lestes unguiculatus</i>	1914	2013	10	13	3
Coenagrionidae	<i>Enallagma basidens</i>	1974	2012	1	4	3
Corduliidae	<i>Cordulia shurtleffi</i>	1914	2013	32	37	5
Coenagrionidae	<i>Argia hinei</i>	1915	2013	12	16	4
Gomphidae	<i>Stylurus plagiatus</i> *	1965	2013	4	8	4
Corduliidae	<i>Epitheca spinigera</i>	1914	2013	2	6	4
Corduliidae	<i>Somatochlora albicincta</i>	1952	2013	1	5	4
Coenagrionidae	<i>Argia moesta</i>	1938	2013	17	22	5
Libellulidae	<i>Orthemis ferruginea</i>	1935	2013	16	21	5
Gomphidae	<i>Ophiogomphus severus</i> *	1914	2013	3	8	5
<b>Gomphidae</b>	<b><i>Progomphus borealis</i></b>	<b>1900</b>	<b>2013</b>	<b>61</b>	<b>70</b>	<b>9</b>
Libellulidae	<i>Sympetrum internum</i> *	1914	2013	12	18	6
Coenagrionidae	<i>Argia alberta</i>	1915	2013	19	26	7
Coenagrionidae	<i>Nehalennia irene</i> *	1973	2013	1	9	8
<b>Lestidae</b>	<b><i>Lestes stultus</i></b>	<b>1903</b>	<b>2013</b>	<b>45</b>	<b>56</b>	<b>11</b>
Gomphidae	<i>Erpetogomphus lampropeltis</i>	1915	2013	10	19	9
Gomphidae	<i>Ophiogomphus morrisoni</i> *	1914	2013	23	33	10
<b>Libellulidae</b>	<b><i>Libellula saturata</i></b>	<b>1879</b>	<b>2013</b>	<b>354</b>	<b>385</b>	<b>31</b>
Libellulidae	<i>Sympetrum madidum</i> *	1897	2013	59	72	13
Corduliidae	<i>Somatochlora semicircularis</i>	1914	2013	21	32	11
Libellulidae	<i>Libellula quadrimaculata</i>	1914	2013	80	95	15
Coenagrionidae	<i>Argia sedula</i>	1945	2013	26	38	12
Coenagrionidae	<i>Zoniagrion exclamationis</i>	1911	2013	51	65	14
Libellulidae	<i>Libellula composita</i> *	1915	2013	11	23	12
Aeshnidae	<i>Aeshna canadensis</i>	1998	2012	0	12	12
Coenagrionidae	<i>Ischnura erratica</i>	1900	2013	15	29	14
Coenagrionidae	<i>Ischnura hastata</i>	1938	2013	4	18	14
Libellulidae	<i>Tramea calverti</i>	1988	2011	0	14	14
Gomphidae	<i>Stylurus olivaceus</i> *	1914	2012	5	21	16
Libellulidae	<i>Macrodiplox balteata</i>	1947	2013	2	19	17
Libellulidae	<i>Leucorrhinia glacialis</i> *	1914	2013	15	33	18
Libellulidae	<i>Sympetrum costiferum</i> *	1934	2013	11	29	18
Aeshnidae	<i>Aeshna palmata</i> *	1914	2013	34	54	20
Gomphidae	<i>Ophiogomphus occidentis</i> *	1914	2013	17	36	19
Libellulidae	<i>Sympetrum vicinum</i>	1980	2012	0	19	19
Calopterygidae	<i>Calopteryx equabilis</i>	1951	2013	7	27	20
Libellulidae	<i>Brachymesia furcata</i>	1930	2013	7	28	21
Libellulidae	<i>Ladona julia</i>	1953	2013	4	25	21
<b>Libellulidae</b>	<b><i>Pachydiplax longipennis</i></b>	<b>1900</b>	<b>2013</b>	<b>189</b>	<b>222</b>	<b>33</b>

Family	Species	Earliest year	Latest year	Before 1975	After 1980	Change
Aeshnidae	<i>Aeshna umbrosa</i>	1915	2012	16	40	24
Coenagrionidae	<i>Ischnura ramburii</i>	1930	2013	7	32	25
Libellulidae	<i>Leucorrhinia intacta</i>	1918	2013	15	44	29
Coenagrionidae	<i>Argia agrioides</i>	1907	2013	71	104	33
Libellulidae	<i>Perithemis intensa</i>	1934	2013	8	38	30
<b>Coenagrionidae</b>	<b><i>Ischnura perparva</i></b>	<b>1898</b>	<b>2013</b>	<b>247</b>	<b>292</b>	<b>45</b>
Gomphidae	<i>Gomphus kurilis</i>	1905	2013	68	104	36
Corduliidae	<i>Macromia magnifica</i> *	1900	2013	27	61	34
Libellulidae	<i>Pantala flavescens</i>	1915	2013	20	55	35
Coenagrionidae	<i>Argia lugens</i>	1901	2013	86	126	40
Aeshnidae	<i>Anax walsinghami</i> *	1915	2013	19	56	37
Libellulidae	<i>Brechmorhoga mendax</i>	1901	2013	31	69	38
Libellulidae	<i>Tramea omusta</i>	1907	2013	31	69	38
Petaluridae	<i>Tanypteryx hageni</i> *	1918	2013	22	61	39
Libellulidae	<i>Plathemis lydia</i>	1912	2013	157	208	51
<b>Coenagrionidae</b>	<b><i>Argia emma</i></b>	<b>1910</b>	<b>2013</b>	<b>72</b>	<b>119</b>	<b>47</b>
Aeshnidae	<i>Rhionaeschna californica</i>	1897	2013	92	144	52
<b>Coenagrionidae</b>	<b><i>Ischnura cervula</i></b>	<b>1902</b>	<b>2013</b>	<b>317</b>	<b>394</b>	<b>77</b>
Corduliidae	<i>Epitheca canis</i>	1914	2013	16	77	61
<b>Aeshnidae</b>	<b><i>Rhionaeschna multicolor</i></b>	<b>1898</b>	<b>2013</b>	<b>257</b>	<b>345</b>	<b>88</b>
Libellulidae	<i>Libellula pulchella</i>	1905	2013	84	166	82
<b>Libellulidae</b>	<b><i>Libellula luctuosa</i></b>	<b>1929</b>	<b>2013</b>	<b>54</b>	<b>143</b>	<b>89</b>
Libellulidae	<i>Libellula forensis</i>	1900	2013	85	220	135
<b>Libellulidae</b>	<b><i>Tramea lacerata</i></b>	<b>1900</b>	<b>2013</b>	<b>107</b>	<b>254</b>	<b>147</b>
<b>Aeshnidae</b>	<b><i>Anax junius</i></b>	<b>1900</b>	<b>2013</b>	<b>196</b>	<b>361</b>	<b>165</b>
Total number of unique occurrences:				8642	9175	

in the recent data, much of which were observation-based, as compared to the older specimen data, which was entirely collection-based. Species with the highest declines, that also match patterns of decline in a recent resurvey study by Ball-Damerow et al. (2014), include *Hetaerina americana*, *Sympetrum illotum* (Hagen), *Octogomphus specularis* (Hagen), and *Cordulegaster dorsalis* Hagen.

In comparing the average and range of latitude and elevation across individual species occurrence localities, we excluded all records with an error radius of greater than 4 km. The total number of unique records before 1976 available was then 5,142 and the total number of unique records after 1979 was 7,785. The median average latitude across all species increased by 0.7° ( $\pm 0.82$ ,  $p < 0.001$ ), indicating an average shift of around 78 km northwards (Table 5). Average minimum latitude declined slightly by 0.12° ( $\pm 1.1$ ,  $p = 0.01$ ), and average maximum latitude increased by 0.59° ( $\pm 1.3$ ,  $p < 0.001$ , Table 5). Neither average nor average maximum elevation across species changed significantly over the two time periods, but average minimum elevation declined by 108 m ( $\pm 360$  m,  $p = 0.003$ ; Table 5).

**Table 5.** Summaries of change in unique species latitude and elevation values before 1976 and after 1979. Unique records represent unique combinations of species, locality coordinates, and year. Records included in this assessment have an error radius  $\leq 4$  km.

	Average change	Standard deviation	Wilcoxon rank-sign test	P-Value
<b>Avg Latitude</b>	<b>0.70° (78 km)</b>	<b>0.82</b>	<b>V = 542</b>	<b>&lt;0.001</b>
<b>Min Latitude</b>	<b>-0.12° (-13 km)</b>	<b>1.12</b>	<b>V = 3429</b>	<b>0.01</b>
<b>Max Latitude</b>	<b>0.59° (65 km)</b>	<b>1.28</b>	<b>V = 643</b>	<b>&lt;0.001</b>
Avg Elevation (m)	-49	248	V = 2730	0.37
<b>Min Elevation (m)</b>	<b>-108</b>	<b>360</b>	<b>V = 3327</b>	<b>0.003</b>
Max Elevation (m)	49	613	V = 2099	0.19

## Discussion

The California Odonata database provides an overview of common patterns to be expected in the temporal distribution of museum records in California. For odonates, peaks in specimen acquisition occurred in 1914–15 as a result of C.H. Kennedy's work (Kennedy 1917), with subsequent peaks in the 1950s, 1960s and 1970s through the combined work of several collectors. After this mid-20<sup>th</sup> century time period, specimen acquisition was slower. The largest peak in the Odonata database has occurred since 2000, and represents mostly observation-based records obtained from odonate enthusiasts.

Previous work has noted a decline in specimen acquisition of natural history museums over the past 30–40 years that corresponds with declines in funding for many of these institutions (Pyke and Ehrlich 2010). However, observation-based records now provide a valuable complement to specimen records in documenting change in species prevalence and distribution, especially when such records are photo-vouchered and vetted (e.g. Breed et al. 2013, Pyke and Ehrlich 2010, Soberon et al. 2000).

The present study also identified spatial biases and data gaps, which should be addressed in any distributional analyses and in designing future sampling investigations of California odonates. As demonstrated in a previous spatial analysis of Odonata collection data in North America, collections are often located near more highly populated regions (e.g. Hassall and Thompson 2010). Sampling locations for California odonates are clustered around urban areas, such as the San Francisco Bay area, Sacramento, Los Angeles, and San Diego. The more sparsely populated desert region in the southeast has very few records, which may also be the result of a lack of freshwater habitat in the region (Fig. 4).

Species richness is not strongly associated with total number of records at the statewide scale (Fig 2), while it is at the county scale (Fig 3). During the 1980s and 1990s, there was a significant drop in the total number of records without a parallel drop in species richness. It seems that after 1,500 records species richness for the state levels off at around 100 species, which is close to the total number known resident species in the state (106 species). Even in 1980, with 1,265 total records, species richness dropped only to 77 species (Fig 2). There is a stronger exponential relationship between the total number of records and species richness observed in a given county

(Fig. 3). While species richness leveled off at around 58 species per county with at least 600 records, there were some obvious outliers that could represent relatively species rich or poor counties. In particular, Shasta County had 78 species recorded with only 514 records, which is likely because it is located in the warmest region with relatively high precipitation and aquatic habitat. In contrast, counties with below average species richness given the number of records were all dry regions in the Central Valley or southern California. Similarly, Hassall and Thompson (2010) found that collection effort, in addition to warm temperature and water availability, plays a major role in species richness of odonates observed in various regions of North America. Future sampling, particularly in under-sampled regions and in warm areas with higher freshwater habitat availability (e.g. Sutter County and Lake County), is therefore likely to yield additional species.

Each of the different collection types—Calbug (i.e. California) institutions, non-Calbug institutions, private collections, and observation-based records—contributed significantly to the total number of records and to county records for species. The Calbug institutions had the highest total number of records, followed by observation-based records, which had just over half the number of total records as Calbug. However, observations contributed significantly more county records for species. The goal of many enthusiasts is to find new county records, which likely explains this difference. We find that recent observation-based records have greatly contributed to our knowledge of the spatial distribution of odonate species in California.

Apparent changes in species prevalence according to occurrence records are sometimes the result of variation in taxonomic biases, particularly in comparing natural history specimens and observation-based records (Table 4). According to existing occurrence records, two species with the highest decline in prevalence over time were two of the most common species in the state, *Argia vivida* and *Sympetrum corruptum*. Many individuals reporting species observations to CalOdes or Odonata Central may have neglected these species in at least some of their lists, perhaps because these collectors considered less-common species to be more interesting or noteworthy. Another potential problem with observation-based data is the difficulty in identifying certain species in the field. In general, the most difficult group to identify is the genus *Enallagma* (particularly *E. boreale* and *E. annexum*), and many enthusiasts report them as *Enallagma* sp. or as “bluets”. Less experienced enthusiasts in particular may avoid reporting this group or other difficult to identify species, such as *Argia agrioides* and *Argia nahuana*. In contrast, Odonata taxonomists contributing to specimen records from the early and mid-20<sup>th</sup> century often focused on these groups, which were in need of taxonomic revision (e.g. Garrison 1984). As a result of this known discrepancy, such species should not be included in comparing specimen and observation-based data unless analysis methods address collecting biases, or only include results of certain collectors less likely to demonstrate this taxonomic bias. In general, charismatic, rare, and colorful species are often more likely to be present in both specimen collections and in observation-based lists (e.g. Dunn 2005).

Species that have increased in prevalence over time, however, often demonstrate more reliable results than those with apparent declines (Szabo et al. 2010). Many

of the species with the highest increases in relative occurrence also demonstrated increased prevalence in a recent resurvey study (Ball-Damerow et al. 2014, Table 4). Eight out of the ten species with the highest increases in prevalence were habitat generalists, nine species were widespread throughout the state, and all ten were found across a wide range of elevation from sea level to around 2,000 m. Similarly, previous studies have demonstrated that widespread, habitat generalist species have expanded considerably over time (Ball-Damerow et al. 2014, Dupont et al. 2011, Julliard et al. 2004, Korkeamaki and Suhonen 2002). The two most conspicuous migratory species, *Anax junius* and *Tramea lacerata*, demonstrated the highest increases in prevalence. In a related resurvey study, Ball-Damerow et al. (2014) found that four out of the five migratory species in the state were among those with the highest increases in prevalence, including *A. junius* and *T. lacerata*. The other two migratory species that increased in the resurvey study were *Sympetrum corruptum* and *Pantala hymenaea*, both of which are more drab-colored, less conspicuous, and may therefore be less reported in recent observation-based lists (Ball-Damerow et al. 2014).

Odonata species in California have expanded northwards by an average of around 78 km and demonstrated an average increase in northern range margins of 65 km. This shift is unlikely to be the result of location bias, considering that overall distribution of sampled sites was similar across the two time periods (Fig. 4), and favorite collecting sites are not likely to shift north in this way. Similarly, a study of 37 species of British Odonata showed a northward shift at the range margin of about 74 km when comparing records from 1960–70 and 1985–1995 (Hickling et al. 2005). Overall, a wide range of taxa are shifting northwards and to higher elevations as a result of increasing temperatures (e.g. Angert et al. 2011, Hickling et al. 2006, Parmesan 2006).

However, we also observed a decline in the average minimum elevation across species. This could be the result of increases in dry-season water habitats throughout low elevation areas of the Central Valley with increased irrigation for agriculture (Ball-Damerow et al. 2014). This region of the state was previously drier and may have supported fewer odonates in the early 20<sup>th</sup> century. In contrast, mountainous regions generally have higher rainfall and more natural aquatic habitat. The unexpected decline in elevation could also be a result of more recent spatial bias to collect near centers of human population, which also tend to occur at lower elevations.

## Conclusions

The California Odonata database is one of the largest state-level databases for this order of insects in North America. This database provides a valuable source of information to determine change in Odonata communities and species distribution in the region over time. The timespan of the collection, from the late 1800s through 2013, coincides with unprecedented human population growth, redistribution of water throughout an agriculture-intensive state, and large-scale land use change (Mount 1995). One of the most powerful applications of this database is its use as a data-exploration tool. For

example, researchers may identify particular species, regions, or even collectors that warrant further study or that may be amenable to analyses of change over time. Further investigation will undoubtedly yield discoveries concerning changes in Odonata biology and distribution over time. Moreover, comparisons of our California odonate data to that of other regions or groups of organisms may provide insight into the general use of Odonata as biological indicators of change over time and more general principles of global change biology.

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## Supplementary material I

### California Odonata database records after data processing, as described in methods.

Authors: Joan E. Ball-Damerow, Peter T. Oboyski, Vincent H. Resh

Data type: occurrence

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# Review of the genera *Anelaphinis* Kolbe, 1892 and *Atrichelaphinis* Kraatz, 1898 (Coleoptera, Scarabaeidae, Cetoniinae)

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## Abstract

New material collected recently throughout the Afrotropical region has led to a major reassessment of taxa within the genera *Anelaphinis* Kolbe, 1892, *Atrichelaphinis* Kraatz, 1898 and other closely related genera. As a result, the name *Megalleucosma* Antoine, 1989 is here synonymised with *Anelaphinis* and a lectotype is designated for the type species, *Cetonia dominula* Harold, 1879. The genus *Atrichelaphinis* is redefined and a new subgenus, *A. (Eugeaphinis)*, is proposed for *Elaphinis simillima* Ancey, 1883, *Elaphinis vermiculata* Fairmaire, 1894, *Niphetophora rhodesiana* Péringuey, 1907, *Atrichelaphinis deplanata* Moser, 1907 (with *Anelaphinis kwangensis* Burgeon, 1931 as junior synonym) and *Anelaphinis sternalis* Moser, 1914. Additionally, three new species and one new subspecies are recognised and described in this new subgenus: *A. (Eugeaphinis) bomboesbergica* **sp. n.** from South Africa; *A. (Eugeaphinis) bjornstadi* **sp. n.** from Tanzania; *A. (Eugeaphinis) garnieri* **sp. n.** from south-east Africa (Tanzania, Zimbabwe); and *A. (Eugeaphinis) deplanata minettii* **ssp. n.** from central Africa (Malawi, Mozambique, Congo-Kinshasa, Congo-Brazzaville, South Africa, Rwanda, Zambia, Zimbabwe). The genus *Atrichelaphinis* is compared to its closest relatives and two separate keys are proposed, one for *Atrichelaphinis* and one for the sub-Saharan genera exhibiting completely or partially fused parameres.

## Keywords

Africa, *Cetonia dominula*, *Anelaphinis*, *Atrichelaphinis*, *Heterelaphinis*, *Megalleucosma*, *Niphetophora*, synonymy, new taxa

## Introduction

A number of new taxa closely associated with the genus *Anelaphinis* Kolbe, 1892 have recently been reported through intensified work in a number of Afrotropical countries. An attempt to integrate these into existing generic groups has led to a fresh analysis of the type specimens of the species previously included in this genus. This has revealed a state of relative confusion and great uncertainty about the allocation of previously described species to a number of closely related genera that have proliferated during the past century. This, combined with the realization that both genera *Anelaphinis* and *Atrichelaphinis* Kraatz, 1898 have effectively not been subject to any substantial revision since their original description (cf. Holm and Marais 1992), has prompted a full investigation of their current state and taxonomic development.

The two genera *Atrichelaphinis* and *Anelaphinis* exhibit similesiomorphic similarities between each other and with a number of other closely related genera (Holm and Marais 1992). The key character between the two has generally been considered to be the number of protibial denticles, with *Atrichelaphinis* showing three denticles, with the anterior two extremely approximated, while *Anelaphinis* exhibits one to three denticles poorly approximated. The two genera, on the other hand, share a common aedeagal structure, exhibiting completely fused parameres. In the view of the complexity highlighted above, these characters are now insufficient to allow the unequivocal allocation of several species within either of the two genera. It is, therefore, necessary to revise the taxonomic structure of these and other related genera, by incorporating a new, expanded set of diagnostic characters that can assist with the fine-scale resolution of the species group in question.

## Methods

The description of morphological characters follows the terminology used in Holm and Marais (1992). The length of each specimen excludes head and pygidium, and was measured from the anterior margin of the pronotum to the apex of the elytra. Specimen width represents the maximum width of the elytra, at the level of the humeral callus. Photos of the specimens selected for illustrations were taken using a Nikon D3200 camera fitted with a Nikkor 105 mm objective and Kenko macro tubes. Alternatively, a Canon EOS 550D fitted with a Canon EF 100 mm 1/28 Macro USM lens and a Canon Power Shot S45, combined with a Leica MZ16 dissecting microscope, were used to obtain finer details. Photos were processed with photo stacking technique, using Combine ZP (free software by Alan Hadley, <http://www.hadleyweb.pwp.blueyonder.co.uk>).

Collection abbreviations used within the text are as follows:

<b>BMNH</b>	The Natural History Museum, London, UK
<b>CCEC</b>	Center for the Curation and Study of Collections, Lyon, France
<b>IRSN</b>	Belgian Royal Institute of Natural Sciences, Bruxelles, Belgium
<b>ISAM</b>	Iziko South African Museum, Cape Town, South Africa
<b>MNHN</b>	National Museum of Natural History, Paris, France

<b>MNHU</b>	Natural Sciences Museum of the Humboldt University, Berlin, Germany
<b>MRAC</b>	Royal Museum for Central Africa, Tervuren, Belgium
<b>NMKE</b>	National Museum of Kenya, Nairobi, Kenya
<b>PCAB</b>	Private Collection Anders Bjørnstad, Skien, Norway
<b>PCDC</b>	Private Collection Didier Camiade, Sallespisse, France
<b>PCJT</b>	Private Collection Julien Touroult, Soyaux, France
<b>PCPA</b>	Private Collection Philippe Antoine, Roubaix, France
<b>PCRM</b>	Private Collection Robert Minetti, La Ciotat, France
<b>PCRPR</b>	Private Collection R Perissinotto & L Clennell, Port Elizabeth, South Africa
<b>PCSR</b>	Private Collection Sébastien Rojkoff, Lyon, France
<b>PCTB</b>	Private collection Thierry Bouyer, Chênée, Belgium
<b>PCTG</b>	Private Collection Thierry Garnier, Montpellier, France
<b>TMSA</b>	Ditsong National Museum of Natural History (formerly Transvaal Museum), Pretoria, South Africa

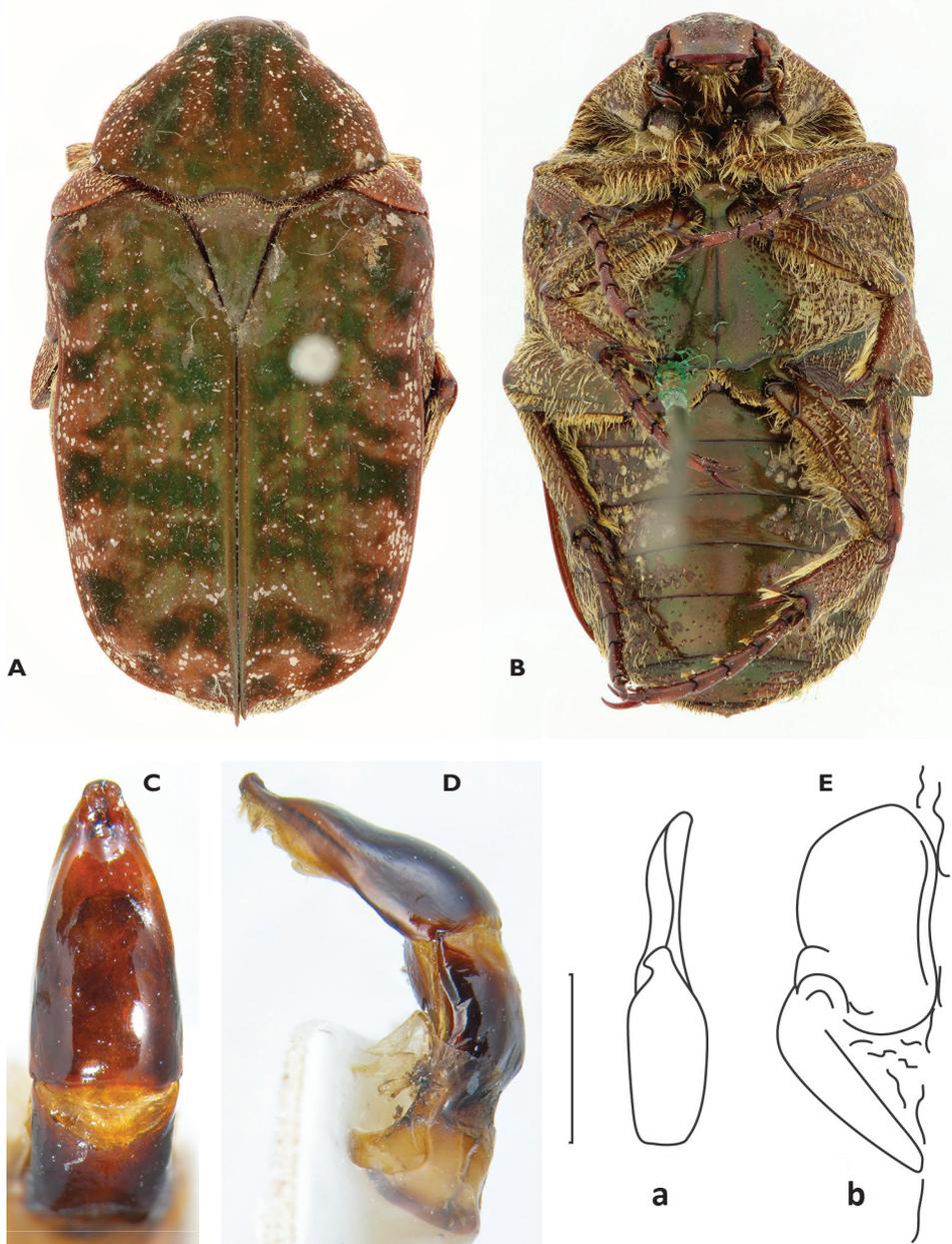
## Taxonomic account

### Genus *Anelaphinis* Kolbe, 1892

After clarifying an erroneous identification of *Cetonia dominula* Harold, 1879, contained in Kraatz (1880: 172–173; 1892: 415), Kolbe (1892a: 135–136) created the genus *Anelaphinis*, designating *C. dominula* as its type species. Upon a closer analysis of the four syntypes deposited at MNHU, a lectotype is here designated. This is a male specimen (Figure 1) carrying the following eight labels: 1) (blue-grey colour) "dominula Harold, Angola or."; 2) (red-orange colour) "type"; 3) (white colour) "60113"; 4) (white colour) "Anelaphinis dominula Harold type ♂"; 5) (yellow colour) "Zool. Mus. Berlin"; 6) (blue colour) "Hist. Coll. (Coleoptera)/Nr. 60113/Cetonia dominula Harold\*/Malange Homeyer & Schütt/ Zool. Mus. Berlin"; 7) (red colour) "Syntypus Anelaphinis dominula (Harold 1879) labelled by MNHUB 2012"; 8) (white colour with red margin) present designation "Lectotype *Anelaphinis dominula* (Harold, 1879) S. Rojkoff 2012". The other three syntypes are labelled as "Paralectotypes". All syntypes match perfectly the description of Harold (1879: 77). Kolbe (1892a) did not provide a detailed description of the genus, but briefly compared it to the genera *Macrelaphinis* Kraatz, 1880, *Niphobleta* Kraatz, 1880 and even to the Asian *Protaetia* Burmeister, 1842. Shortly after, he described *Eucosma breviceps* (Kolbe 1892b: 253).

A study of the type series of *A. dominula* reveals the presence of all characters used to define *Megalleucosma* Antoine, 1989 (type species: *Eucosma breviceps* Kolbe, 1892), especially in the structure of the aedeagus and the sclerite of the internal sac (Figures 1C–E). Consequently, *Megalleucosma* Antoine, 1989 is here considered as a junior synonym of *Anelaphinis* Kolbe, 1892 (syn. n.). *Anelaphinis dominula* is definitely not a synonym of any of the species considered by Antoine (1989), as clearly shown in his comparative aedeagal study.

It is not known what prompted Kolbe (1892b: 253) to describe *E. breviceps* from Barombi station, Cameroun, as belonging to another genus only a few months after the



**Figure 1.** *Anelaphinis dominula* (Harold, 1879), Holotype (MNHU). **A** Dorsal view **B** ventral view **C** parameres in dorsal view **D** parameres in lateral view **E** sclerite of internal sac (**a** dorsal view; **b** lateral view) (Scale bar = 1 mm).

description of the genus *Anelaphinis*, despite their obvious generic similarities. De Lisle (1947: 38-39) was among the few to have correctly used the genus *Anelaphinis* in his description of *A. vaillanti*. Schauer too, was able to assign members of the genus accurately, as evidenced by his determinations of the MNHU material. Ruter (1960: 437) recognised

the synonymy of *A. vaillanti* with *E. breviceps*, but regarded it as a member of *Alleucosma*. He acknowledged the complexity of this group of genera and the difficulty of placing species correctly within them, but did not subscribe to De Lisle's (1947) proposal.

Among the other species usually placed within *Anelaphinis* are: *Elaphinis simillima* Ancey, 1883; *E. vermiculata* Fairmaire, 1894; *Niphethophora rhodesiana* Péringuey, 1907; *Atrichelaphinis deplanata* Moser, 1907; *A. sternalis* Moser, 1914; and *A. kwangensis* Burgeon, 1931. All have in common an aedeagus with parameres completely fused and without sclerite in the internal sac. Eventually, this character has been regarded as key to the diagnosis of the genus *Anelaphinis* (e.g. Holm and Marais 1992). With the exception of Antoine (1989), there has been no attempt to take into account other characters of the aedeagus in the taxonomy of this and other closely related genera. This includes Moser (1914: 606), who described *A. simillima* on the basis of a male specimen only and then compared it to *C. dominula*; as well as Schenkling (1921: 306), who reported *C. dominula* from Angola and Ethiopia. Schenkling's position, probably taken on the basis of the work of Schoch (1896: 384), was promptly followed by Burgeon (1931: 219, 221) who described *A. collarti* and *A. kwangensis* with drawings of their aedeagus, and Burgeon (1934: 260) reporting "*Anelaphinis* apud *dominula*" from Elisabethville (Congo-Kinshasa) without any other specification (see also Ferreira 1965: 1207; Marais and Holm 1992: 7 and 47; Krajcik 1998: 50). The classification into different genera has largely relied on external morphological characters and on the colour pattern of the dorsal habitus. Only recently, Antoine (1987: 464; 1988: 48; 1989a: 31; 1989b: 245; 1991: 2) and Antoine and Holm (1993: 101–102) were able to clarify the taxonomic position of most of these closely related genera, namely: *Alleucosma* Schenkling, 1921; *Alleucosma* (*Eoalleucosma*) Antoine, 1989; *Analleucosma* Antoine, 1989; *Aphelinis* Antoine, 1987; *Heteralleucosma* Antoine, 1989; *Molynoptera* Kraatz, 1897; *Molinopteroides* Antoine, 1989; *Niphethophora* Kraatz, 1883; *Paralleucosma* Antoine, 1989; *Paranelaphinis* Antoine, 1988; *Phaneresthes* Kraatz, 1894 and *Pseudalleucosma* Antoine, 1989.

### Summary of the current taxonomic composition of the genus *Anelaphinis* Kolbe, 1892

*Anelaphinis* Kolbe, 1892

*Alleucosma* Schenkling, 1921, *partim*.

*Megalleucosma* Antoine, 1989: 248, 265, **syn. n.**

Type species: *Cetonia dominula* Harold, 1879

*Anelaphinis allardi* (Ruter, 1978)

*Eucosma allardi* Ruter, 1978

*Megalleucosma allardi* (Ruter) Antoine, 1989: 269

*Anelaphinis bourgoini* (Burgeon, 1932)

*Alleucosma bourgoini* Burgeon, 1932

*Megalleucosma bourgoini* (Burgeon) Antoine, 1989: 271

*Anelaphinis breviceps* (Kolbe, 1892)

*Eucosma breviceps* Kolbe, 1892: 253

*Alleucosma breviceps* (Kolbe, 1892)

*Anelaphinis vaillanti* De Lisle, 1947: 38

- Megalleucosma breviceps* (Kolbe) Antoine, 1989: 271  
*Anelaphinis dominula* (Harold, 1879)  
*Cetonia dominula* Harold, 1879  
*Anelaphinis maritima* (Moser, 1914)  
*Eucosma maritima* Moser, 1914  
*Alleucosma maritima* Moser, 1914  
*Alleucosma maritimi* Schein, 1956: 194  
*Anelaphinis pauliani* (Antoine, 1989)  
*Megalleucosma pauliani* Antoine, 1989: 268  
*Anelaphinis similis* (Antoine, 1989)  
*Megalleucosma similis* Antoine, 1989: 270

### Genus *Atrichelaphinis* Kraatz, 1898

This genus was erected by Kraatz (1898: 220), in order to accommodate species close to, but different from those included in *Elaphinis* by Burmeister (1842). Without designating a type species, Kraatz (1898) included in *Atrichelaphinis* three species, *Cetonia irrorata* Fabricius, 1798, *Cetonia tigrina* Olivier, 1789 and *Elaphinis vermiculata* Fairmaire, 1894, mainly on the basis of their sharing a bilobed "ligula" and the shape of the metatibial spur. Kraatz was familiar with the genus *Micrelaphinis* Schoch, 1896, having described in 1896 varieties of *Micrelaphinis mutabilis* Schoch, 1895, but failed to recognise *Cetonia irrorata* as part of this genus, despite the diagnostic shape of its clypeus. This was only rectified later by Péringuey (1907: 339). Marais and Holm (1989) redefined the taxonomic position of the genus *Elaphinis* Burmeister, 1842 and its relationships with *Micrelaphinis* Schoch, 1894. They (re-)transferred *E. vermiculata* Fairmaire, 1894 to *Atrichelaphinis s. l.*, on the basis of the fused aedeagal parameres and, while highlighting the need to undertake a revision of the genus, they ignored the original work of Kraatz (1898), who had already placed *E. vermiculata* in *Atrichelaphinis*. In their catalogue (Marais and Holm 1992: 11), *Cetonia tigrina* Olivier, 1789 was designated as type species for the genus, which at that stage comprised four species: *A. deplanata* Moser, 1907 (synonym: *Anelaphinis kwangensis* Burgeon, 1931; Antoine 1988: 48); *C. nigropunctulata* Péringuey, 1896; *E. quadripunctata* Lansberge, 1882; and *C. tigrina* Olivier, 1789 (synonym: *C. furvata* Fabricius, 1798). No further elaboration on the genus was provided in Holm and Marais (1992: 195), where only the two South African species were considered, *A. nigropunctulata* and *A. tigrina*.

Following this, Antoine (2002: 182–186) redefined *Atrichelaphinis s. s.* as composed of two species, *A. tigrina* and *A. nigropunctulata*. He created the new sub-genus *Heterelaphinis*, with *Cetonia quadripunctata* Lansberge, 1882 as type species and including *Leptothyrea sexualis* Schein, 1956, as well as the newly described *A. (H.) nigra* Antoine, 2002. Simultaneously, he transferred *A. deplanata* and *Elaphinis vermiculata* Fairmaire, 1894 to the genus *Anelaphinis* on the basis of their pronotal shape.

The consequences of the confusion created with the genus *Atrichelaphinis* and with the species previously included in *Anelaphinis* are that currently their taxonomic posi-

tion remains unclear (with the exception of *A. dominula*) and badly in need of revision. Only two options appear to be viable at the moment: 1) including them in an existing genus; or 2) erecting a new taxonomic entity especially for them. Upon completing an extensive analysis of many specimens for each species, the following key diagnostic characters are here selected for the new taxonomic order proposed in the section below.

### Diagnostic characters:

- a) ventral surface, with extensive scale-type hair cover;
- b) clypeus, ratio of length/width;
- c) anterior clypeal margin, with inflexions and/or ridges;
- d) antennal club, longer in male (sexual dimorphism);
- e) pronotal shape, of octogonal type;
- f) pronotal structure, surface more or less bulbous/tectiform, tuberculate or without any modification at middle of the frontal margin, posterior margin more or less emarginate in front of the scutellum;
- g) mesosternal apophysis, transverse;
- h) elytra, tricostate;
- i) protibiae, bi- or tridentate with variable denticle positions;
- j) meso- and metatibiae, exhibiting external carina;
- k) terminal spurs of metatibiae showing sexual dimorphism;
- l) parameres, completely fused and showing apical expansions, apex more or less curved downwards, usually with small median incision/sinuosity;
- m) female genitalia.

As suggested by Ruter (1960), the main diagnostic character for the separation of the "*Elaphinis*-type" genera is the aedeagus. As all the above mentioned species exhibit completely fused parameres, with internal sac lacking the sclerite, and most features generally associated with *Atrichelaphis*, this is the only suitable genus for this species group. No other genus matches these characteristics closely enough to warrant consideration. A minor problem is that not all the characteristics mentioned above are perfectly suitable for the incorporation of both subgenera, as defined by Antoine (2002). Nevertheless, the work of Antoine is here confirmed through new diagnostic characters and supported, as it provides a valuable proposal for the way forward. Some important remarks are, however, necessary at this stage.

Firstly, Antoine (2002) defined *Atrichelaphinis* mainly through a pronotal character, describing its posterior border straight or slightly concave in front of the scutellum. This is not a clear-cut character and could potentially generate misunderstandings. The study of several hundred specimens of the two species belonging to *Atrichelaphinis s. s.* shows a posterior pronotal border with a straight or slightly concave median part, while on both sides the border is largely curved down to the rounded posterior angles. The edge of the posterior angles is in front of the straight median part of the posterior border (in front of the scutellum). This contradicts Antoine's (2002) statement that

"*marge postérieure du pronotum non étirée obliquement en arrière*" and qualifies the posterior border as consisting of three different parts, or bisinuate in shape.

Secondly, Antoine also separated the nominal subgenus from *Heterelaphinis* through the shape of the aedeagal parameres, with apical median protrusion incised or not, the protibiae bi- or tridentate and the antennal club, either equal in the two sexes of *Atrichelaphinis s. s.* or longer in the male of *Heterelaphinis*. However, observations undertaken during this study show that the antennal club is always longer in males than in females, in both subgenera, with maximum difference observed in *Heterelaphinis*. To appreciate correctly this character, it is necessary to compare specimens of the same size. This observation is also valid for the four species previously included in *Anelaphinis* mentioned above.

Antoine (2002) separated the species of *Anelaphinis* and *Atrichelaphinis* using as key characters protibiae bi- or tridentate and apex of the parameres reployed or not. However, he omitted another important character: the clypeus, which is transverse and without sexual dimorphism in *Atrichelaphinis* while it is longer than wide in the three species of *Heterelaphinis*.

The ex-*Anelaphinis* species exhibit the main characteristics of the genus *Atrichelaphinis s.l.*, which should be enough not to erect a new genus. There are, however, two features that do not allow a similar, full placement of some species within this genus. These are a transverse clypeus with sexual dimorphism, protibiae bidentate with wide separation between the teeth, in association with completely fused parameres without apical modification and just curved downwards, rather than reployed. To include species exhibiting such characters, we consider as necessary to erect a new subgenus, *A. (Eugeaphinis)* subgen. n. The implication of this is that the genus *Atrichelaphinis* and the two recognized subgenera must be redefined. Thus, the classification of Antoine (2002) is completed and modified here below.

### **Summary of the current taxonomic composition of the genus *Atrichelaphinis* Kraatz, 1898**

*Atrichelaphinis (Atrichelaphinis)* Kraatz, 1898

*Elaphinis* Péringuey, 1907.

Type species: *Cetonia tigrina* Olivier, 1789

*Atrichelaphinis (Atrichelaphinis) tigrina* (Olivier, 1789)

*Cetonia tigrina* Olivier, 1789

*Cetoninus (Cetonia) tigrina* (Olivier) MacLeay, 1838

*Elaphinis tigrina* (Olivier)

*Cetonia fuvvata* Fabricius, 1798

*Atrichelaphinis fuvvata* (Fabricius)

*Euryomia fuvvata* (Fabricius)

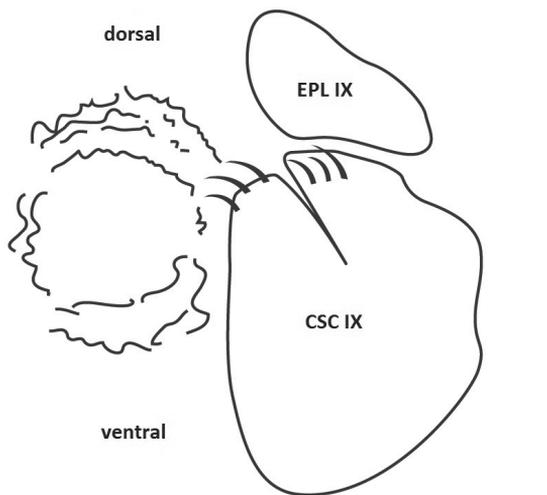
*Atrichelaphinis (Atrichelaphinis) nigropunctulata* (Péringuey, 1896)

*Cetonia nigropunctulata* Péringuey, 1896

- Elaphinis nigropunctulata* (Péringuey)  
*Elaphinis nigropunctata* (Péringuey)  
*Atrichelaphinis* (*Heterelaphinis*) Antoine, 2002  
 Type species: *Elaphinis quadripunctata* Lansberge, 1882  
*Atrichelaphinis* (*Heterelaphinis*) *quadripunctata* (Lansberge, 1882)  
     *Elaphinis quadripunctata* Lansberge, 1882  
     *Atrichelaphinis quadripunctata* (Lansberge)  
     *Cetonia quadripunctata* (Lansberge)  
*Atrichelaphinis* (*Heterelaphinis*) *sexualis* (Schein, 1956)  
     *Leptothyrea sexualis* Schein, 1956  
     *Atrichelaphinis* (*Heterelaphinis*) *nigra* Antoine, 2002  
*Atrichelaphinis* (*Eugeaphinis*) **subgen. n.**  
     *Pseudanelaphinis* Antoine (*in litteris*)  
 Type species: *Atrichelaphinis deplanata* Moser, 1907  
*Atrichelaphinis* (*Eugeaphinis*) *deplanata deplanata* (Moser, 1907)  
     *Atrichelaphinis deplanata* Moser, 1907  
     *Atrichelaphinis deplanate* (Moser)  
     *Anelaphinis deplanata* Moser  
     *Anelaphinis kwangensis* Burgeon, 1931  
     *Atrichelaphinis kwangensis* (Burgeon)  
*Atrichelaphinis* (*Eugeaphinis*) *deplanata minettii* **subsp. n.**  
*Atrichelaphinis* (*Eugeaphinis*) *rhodesiana* (Péringuey, 1907)  
     *Niphetophora rhodesiana* Péringuey, 1907  
     *Anelaphinis rhodesiana* (Péringuey)  
*Atrichelaphinis* (*Eugeaphinis*) *bomboesbergica* **sp. n.**  
*Atrichelaphinis* (*Eugeaphinis*) *garnieri* **sp. n.**  
*Atrichelaphinis* (*Eugeaphinis*) *simillima* (Ancey, 1883)  
     *Elaphinis simillima* Ancey, 1883  
     *Anelaphinis simillima* (Ancey)  
     *Atrichelaphinis simillima* Müller, 1939  
*Atrichelaphinis* (*Eugeaphinis*) *sternalis* (Moser, 1914)  
     *Anelaphinis sternalis* Moser, 1914  
*Atrichelaphinis* (*Eugeaphinis*) *vermiculata* (Fairmaire, 1894)  
     *Elaphinis vermiculata* Fairmaire, 1894  
     *Anelaphinis vermiculata* (Fairmaire)  
     *Atrichelaphinis vermiculata* (Fairmaire)  
*Atrichelaphinis* (*Eugeaphinis*) *bjornstadi* **sp. n.**

### *Atrichelaphinis* s. l. Kraatz, 1898

**Generic characters.** Clypeus rectangular; antennal club longer in male than in female; pronotum sub-octagonal, anterior border convex with or without projection, posterior



**Figure 2.** *Atrichelaphinis (Eugeaphinis) deplanata* (Moser, 1907). Female genitalia (EPL IX: epipleurite IX; CSC IX: coxosubcoxite IX) (Scale bar = 1 mm).

border largely convex, more or less bisinuate, posterior angles not acute; scutellum longer than wide, apex from more or less acute to slightly dull; elytra tricostate; mesosternal apophysis transverse; male abdomen concave with a median depression; protibia bi- or tridentate, meso- and metatibias with transverse carina on external side, metatibia widened and thickened at apex; aedeagus with parameres fused, except at apex, internal sac without sclerite; female genitalia (Figure 2) exhibiting regression of tergite and retention of epipleurite IX as dorsopleurite, showing articulation on simplified gonopod, with gonopod composed of coxosubcoxite IX made of partial fusion of coxite and subcoxite.

### *Atrichelaphinis (Atrichelaphinis) Kraatz, 1898*

*Atrichelaphinis* Kraatz, 1898; Distant 1911: 266; Schenkling 1921: 304; Marais and Holm 1992: 11.

*Elaphinis* Péringuey, 1907; Schenkling 1921: 304; Schein 1960: 98.

**Type species.** *Cetonia tigrina* Olivier, 1789.

**Subgeneric characters.** Clypeus transverse (almost as long as wide) without sexual dimorphism, bilobed; median part of pronotal posterior border either straight or slightly concave in front of scutellum; protibia tridentate, with two distal denticles very close to each other, proximal tooth sometimes very reduced or as slight sinuosity; metatibial apical spurs not enlarged in female; aedeagus with parameres fused and apically reployed downwards, except sometimes with small incision in downturning apical part (or situation when such incision is absent). Two species are currently included in the nominal subgenus.

***Atrichelaphinis* (*Atrichelaphinis*) *tigrina* (Olivier, 1789)**

Figure 3

*Cetonia tigrina* Olivier, 1789: 91; Gory and Percheron 1833: 272; MacLeay 1838: 46; Boheman 1857: 27; Schenkling 1921: 304; Antoine 1991: 2; Marais and Holm 1992: 11; Holm and Marais 1992: 197; Antoine 2002: 185.

*Cetoniinus* (*Cetonia*) *tigrina* (Olivier) MacLeay, 1838: 46.

*Elaphinis tigrina* (Olivier) Blanchard, 1850: 12; Ancey 1883: 95; Kraatz 1883: 384; Gerstaecker 1884: 46; Fairmaire 1893: 10; Schoch 1895: 108; Kraatz 1895a: 382; Distant 1897: 576; Péringuey 1907: 449; Schenkling 1921: 304; Holm and Marais 1992: 197; Antoine 2002: 185.

*Atrichelaphinis tigrina* (Olivier) Moser, 1907: 321; Péringuey 1908: 684; Distant 1911: 266; Schenkling 1921: 304; Marais and Holm 1992: 11; Holm and Marais 1992: 197; Antoine 2002: 185.

*Atrichelaphinis fuvata* (Fabricius) Marais & Holm, 1992: 11.

*Cetonia fuvata* Fabricius, 1798: 130; Thunberg 1818: 420; Boheman 1857: 27; Schenkling 1921: 304; Antoine 1991: 2; Marais and Holm 1992: 11; Holm and Marais 1992: 197; Antoine 2002: 185.

*Elaphinis fuvata* (Fabricius) Burmeister, 1842: 597; Blanchard 1850: 12; Boheman 1857: 27; Harold 1878: 213; Fairmaire 1887: 129; Schenkling 1921: 304; Holm and Marais 1992: 197; Antoine 2002: 185.

*Euryomia fuvata* (Fabricius) Redtenbacher, 1868: 81; Schenkling 1921: 304; Antoine 2002: 185.

**Type specimen.** Holotype unknown.

**Redescription (n > 100).** Size: length ♂, 8.6–15.2 mm; ♀, 9.6–15.0 mm; width ♂, 5.0–8.8 mm; ♀, 5.3–9.1 mm.

**Body.** Dorsum orange-brown, matt with black marks well defined and more or less developed, especially on head and pronotum; often with white tomentose spots on pronotum, scutellum and exceptionally on elytra; setae short on vertex, pronotum (mainly on lateral side) and elytral base, extremely short and barely visible on clypeus, elytra and pronotal disc.

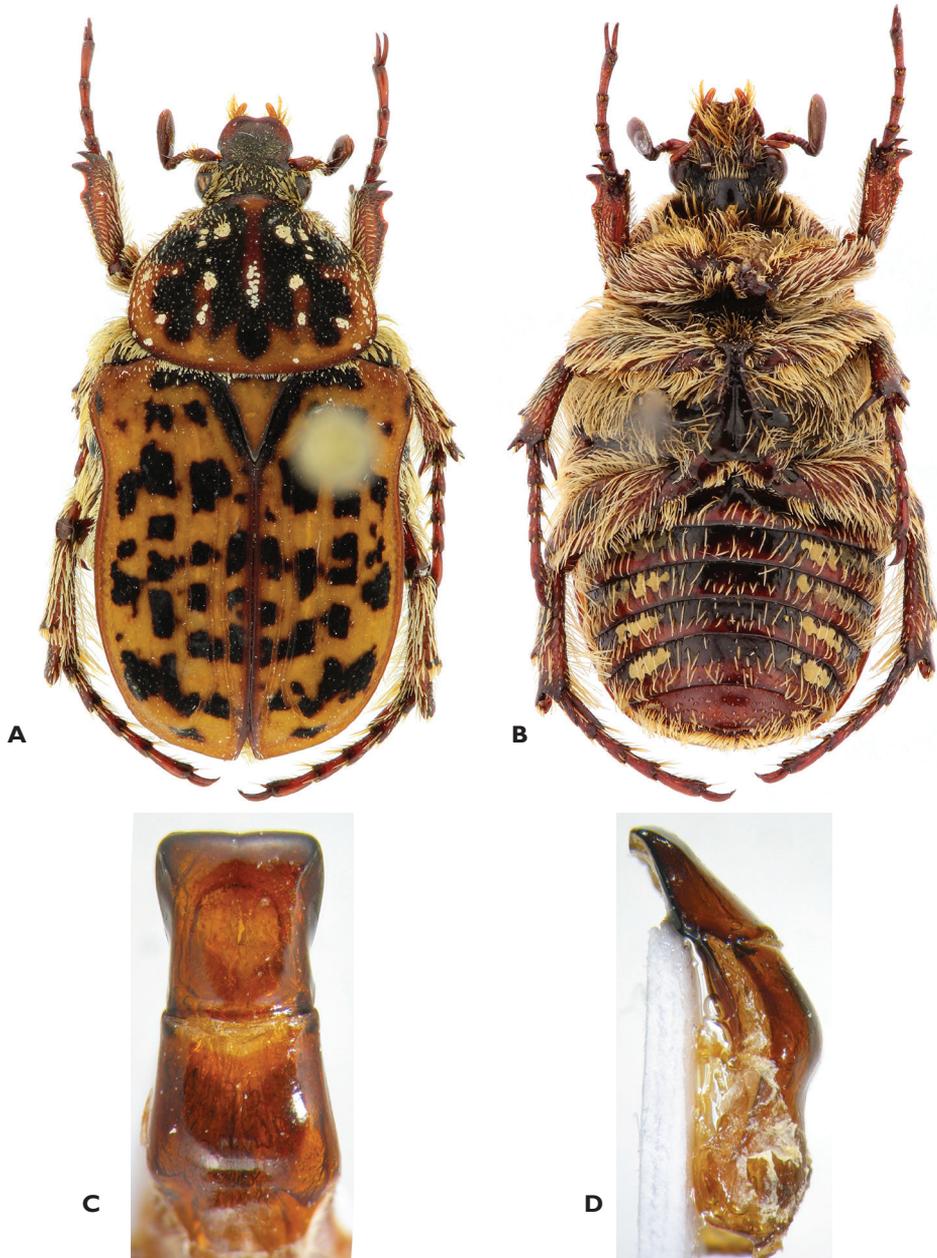
**Head.** Clypeus almost as long as wide, bilobed and upturned on anterior margin, punctures deep, with setigerous punctures becoming confluent laterally and in front.

**Pronotum.** Angles round, postero-lateral ones sometimes vanishing; posterior margin straight to concave in front of scutellum; with reborded lateral margins.

**Scutellum.** Variably marked with black markings and white tomentose spots; setae barely noticeable, mainly at margins.

**Elytra.** Disc exhibiting three pairs of single to double geminate striae, with first two usually complete, third more or less complete; odd costae convex; sutural apex from blunt to protruding.

**Pygidium.** Black with some light to dark brown areas; lunulate setigerous punctures, sometimes forming a complete ring on the surface but near apex forming more or less horizontal and confluent lines; apex marginated.



**Figure 3.** *Atrichelaphinis (Atrichelaphinis) tigrina* (Olivier, 1789), male, South Africa, Western Cape (PCSR). **A** Dorsal view **B** ventral view **C** parameres in dorsal view **D** parameres in lateral view.

*Underside.* Shiny, black with more or less developed brown areas and white tomentose spots on metasternum and abdomen; setae long, scattered and shorter on mesepimera and abdominal sternites; mesosternal apophysis transverse, sometimes very

large, compressed between mesocoxae, usually flat, sometimes showing relief, covered with setae, but not protruding in front of them; metasternum laterally strongly sculptured with wrinkles, median part glabrous and smooth, with longitudinal median line; abdomen more densely sculptured laterally with horseshoe punctures; concave in males, sometimes with slight groove, convex in females.

*Legs.* Long setae particularly dense on femora and tibiae; metatibiae and metafemora thickened, without tomentum; metatibial spur thin and pointed in male, slightly enlarged and blunt in female.

*Aedeagus.* Parameres subparallel in their apical half, then enlarged; lateral apical angle showing more or less developed hook-like protrusion; downturned part of apex showing incision at middle.

**Remarks.** One female from the MNHU (Coll. L.W. Schaufuss, labeled "Cap b. Sp.") exhibits protibiae bidentate, with teeth widely separated. Other female specimens have been observed with the same feature, but no males. This seems to be exceptional and possibly due to wearing during the fossorial action required to lay eggs underground. The species is mainly distributed in the eastern part of South Africa, reaching the Western Cape Province along the southern coastline. There are also occasional reports from Zimbabwe and southern Mozambique (Holm and Marais 1992). This is a typical flower and fruit feeder that has been observed on a large variety of plants, from grasses to large trees.

### *Atrichelaphinis (Atrichelaphinis) nigropunctulata* (Péringuey, 1896)

Figure 4

*Cetonia nigropunctulata* Péringuey, 1896: 163; Schenkling 1921: 304; Antoine 1991: 2;

Marais and Holm 1992: 11; Holm and Marais 1992: 196; Antoine 2002: 185.

*Elaphinis nigropunctulata* (Péringuey) Péringuey, 1907: 448; Antoine 2002: 185.

*Elaphinis nigropunctata* (Péringuey) Distant, 1897: 576; Schenkling 1921: 304.

*Atrichelaphinis nigropunctulata* (Péringuey) Moser, 1907: 321; Distant 1911: 266;

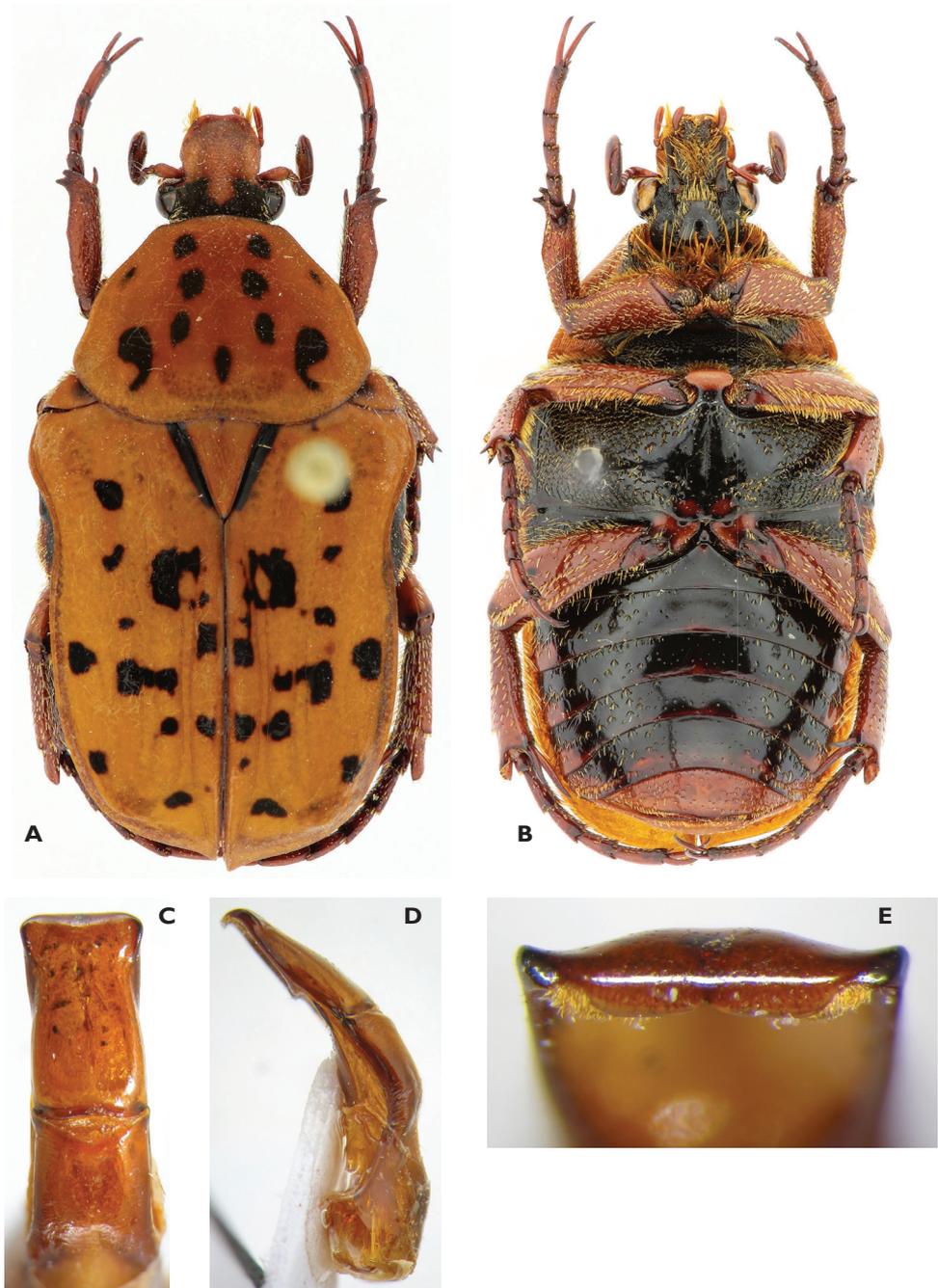
Schenkling 1921: 304; Schein 1960: 98; Marais and Holm 1992: 11; Holm and Marais 1992: 196; Krajcik 1998: 50; Antoine 2002: 185.

**Type specimen.** Holotype in ISAM.

**Redescription (n > 30).** Size: length ♂, 12.8–15.2 mm; ♀, 13.1–14.8 mm; width ♂, 7.7–8.8 mm; ♀, 7.7–8.8 mm.

*Body.* Orange with black markings on pronotum, scutellum and elytra, sometimes very reduced; occasionally showing some isolated small spots of white tomentum on pronotum, pygidium and venter; pilosity occasional and restricted to head.

*Head.* With vertex and lateral part of the frons black, clypeus slightly transverse, bilobed at apex, with anterior margin reborded and lobes slightly upturned. Sculpture deep, simple, becoming confluent in front, laterally and on frons; antennae darker.



**Figure 4.** *Atrichelaphinis (Atrichelaphinis) nigropunctulata* (Péringuey, 1896) male, South Africa, Barberton (PCSR). **A** Dorsal view **B** ventral view **C** parameres in dorsal view **D** parameres in lateral view **E** apex of the parameres.

*Pronotum.* With angles rounded, lateral margins almost entirely reborded except near posterior angles, lateral angles always marked, posterior part of lateral margin concave; posterior margin concave in front of scutellum, then laterally very convex; sculpture usually weak on disc, generally denser and deeper laterally.

*Scutellum.* Acute, grooved laterally; punctuation limited to anterior angles.

*Elytra.* Sculpture very scattered, disc with two pairs of geminate striae, usually consisting of virtually complete single lines, sometimes merged with horseshoe sculpture, lateral sculpture present or not, series of deep and large points along lateral margin always present; sutural apex from blunt to slightly protruding.

*Pygidium.* Sculpture usually of small points or lines, sometimes of wrinkles and/or horseshoe setigerous punctures; posterior margin slightly reborded; occasionally covered with short setae, particularly around margins.

*Underside.* Black except metepisternum, lateral parts of metacoxae, metasternum and sternites; mesepimeron black or orange; mesosternal apophysis orange with black sides, transverse, compressed between mesocoxae and not protruding; moderately covered with setae, except on abdominal sternites; metasternum with wrinkles and long pilosity laterally, grooved in the middle and poorly sculpted to smooth; abdomen poorly sculpted with setigerous horseshoe punctures, setae short; concave to grooved in males, convex in female.

*Legs.* Metafemora and metatibia enlarged apically, spurs not dilated in either sex; moderately covered with setae, particularly around base; metatibial spur thin and pointed in male, thin and less acute to slightly blunt in female.

*Aedeagus.* Parameres almost twice as long as wide; basal half converging in front, apical divergent; lateral apical angles showing fairly developed hook.

**Remarks.** The distribution of this species is restricted to the mountainous northeast part of South Africa. Some specimens could be confused superficially with some forms of *A. tigrina*, however they can be separated through analysis of the dorsal sculpture, shape of the pygidium and aedeagus. The species is most frequently found feeding on *Protea* spp. flowers.

### *Atrichelaphinis* (*Heterelaphinis*) Antoine, 2002

**Type species.** *Elaphinis quadripunctata* Lansberge, 1882

**Subgeneric characters.** Clypeus longer than wide with the apex slightly sinuous; anterior pronotal border tuberculate or tectiform, but minimally so in female; protibiae bidentate, with teeth normally separated; metatibial apical spurs strongly enlarged (spatuliform) in female; parameres of aedeagus fused with apex modified (in dorsal view), with protrusion in the middle deeply incised or not, apex laterally modified or not. Three species are currently included in this subgenus.

***Atrichelaphinis (Heterelaphinis) quadripunctata* (Lansberge, 1882)**

Figures 5 and 6

*Elaphinis quadripunctata* Lansberge, 1882: 24; Ritsema 1888: 225; Kolbe 1897: 180; Antoine 1991: 2; Marais and Holm 1992: 11.

*Atrichelaphinis quadripunctata* (Lansberge) Marais & Holm, 1989: 30; Marais and Holm 1992: 11; Krajcik 1998: 50.

*Cetonia quadripunctata* (Lansberge) Antoine, 2002: 185.

**Type specimen.** Marais and Holm (1992) mentioned two paralectotypes: one in the BMNH collections and one in the MNHN. The male specimen housed in the MNHN shows the following labels: "Somali, Ouarsangueli, Revoil 1881, Museum Paris/1598 81"; and "Lectotype, *Elaphinis quadripunctata* van Lansberge, Ph. Antoine det 88". There is, however no reference to this designation in the publications of Antoine (1991, 2002), apart from a mention of the lectotype in the legend to Figure 21 of Antoine (2002). Consequently, in order to settle the status of the species, the male illustrated in Figure 5 is here designated as Lectotype and a new label is added to the two described above, reading: "Lectotype, *Elaphinis quadripunctata* van Lansberge, Rojkoff & Perissinotto 2014". Four other specimens, identified as *Elaphinis quadripunctata* by Antoine in 1994, were found in the MNHN collections. Two females have the same label as the lectotype and are here designated as paralectotypes. The last specimens, one male missing pronotum and head and a female are only labelled "Ex-Musaeo Van Lansberge" and "Museum Paris, ex. Coll. R. Oberthur". It is possible that these specimens belong to the type series, but as this could not be confirmed during this study, they cannot be designated as paralectotypes here.

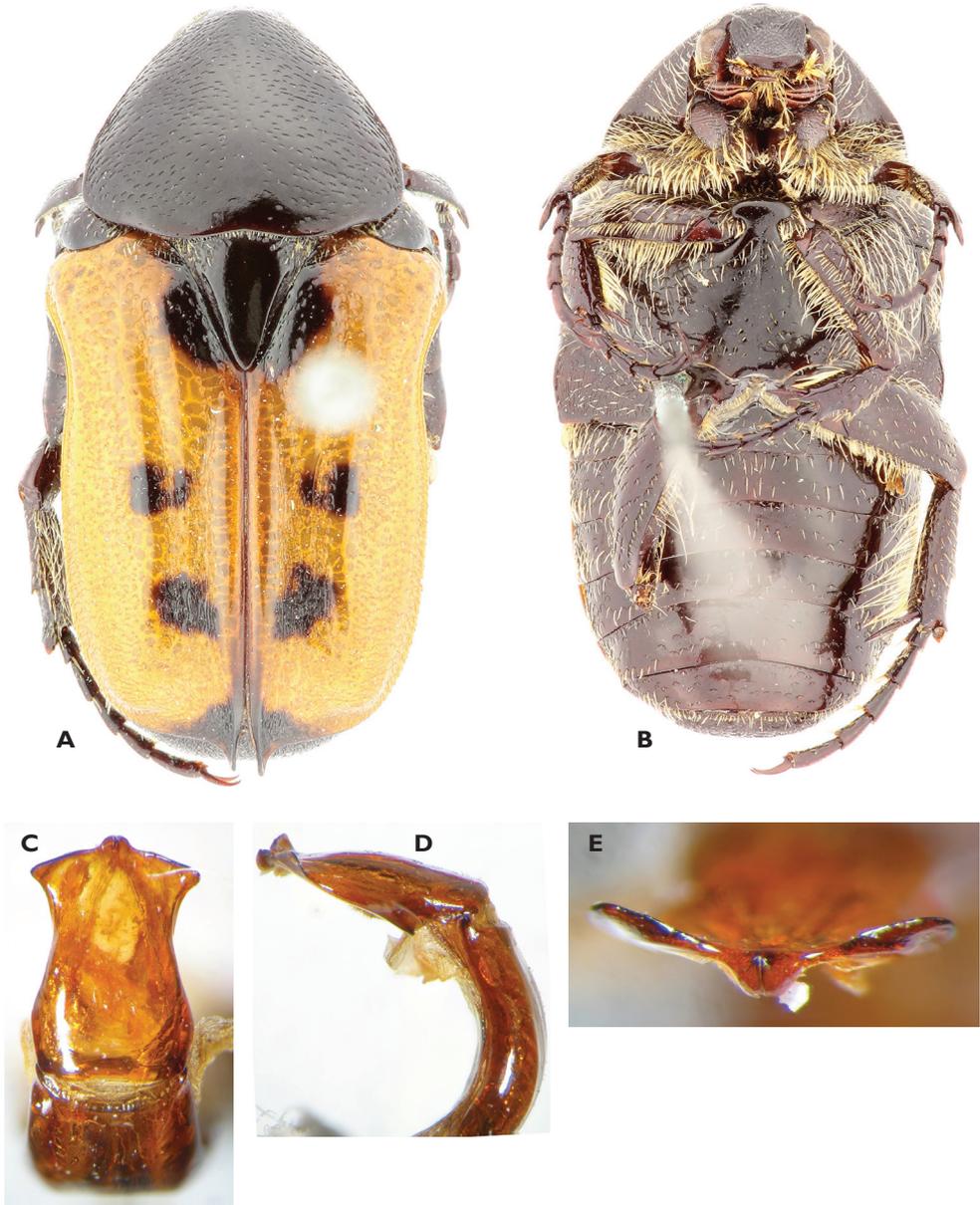
**Redescription (n = 7).** Size: length LT ♂, 11 mm; width 5.5 mm.

**Head.** Dark brown with blackish areas, strongly sculpted, converging points forming deep striae; clypeus longer than wide, lateral and anterior margins strongly reborded, anterior slightly upturned and very slightly bilobed, lateral margins almost carinate in the basal part, then curved downwards, depressed in the middle and reborded in the apical part as the anterior margin, clypeal disc convex; frons with large striated protuberance between eyes, vertex with few smooth jointed areas between striae in apical part, posterior part only punctate; antennae brown with long clubs (as long as the flagellum in male).

**Pronotum.** Transverse, dark brown with transverse points of sculpture, disc poorly punctate, sculpture becoming more dense and confluent to striae in front and laterally; anterior margin slightly wider than head, medially slightly tuberculate; lateral margins reborded with very smooth lateral angles in posterior third; posterior margin bisinuate (concave in front of scutellum), posterior angles rounded.

**Scutellum.** Dark brown, longer than wide, apex acute, smooth, only a few setigerous points on lateral angles (scale pilosity); laterally grooved.

**Elytra.** Orange with four black markings, one on side of scutellum, one at middle split on each costa (discal and humeral), one on apical quarter near the suture and last



**Figure 5.** *Atrichelaphinis* (*Heterelaphinis*) *quadripunctata* (Lansberge, 1882), lectotype male, Somalia (MNHN). **A** Dorsal view **B** ventral view **C** parameres in dorsal view **D** parameres in lateral view **E** apex of parameres.

on spiny apex; costae convex, smooth with only few points, discal costa incomplete, humeral costa concave to suture with concavity reaching elytral disc; sculpture of small longitudinal lines (near scutellum) and of horseshoe points in anterior half, becoming

confluent posteriorly and leading to two formations: 1) laterally (i.e. between humeral costa and lateral margin) transverse lines becoming longer and denser toward apex; 2) longitudinal lines between sutural and humeral costae becoming more numerous and strigillate towards apex; few minute and very short setae near apex.

*Pygidium.* Transverse, chestnut brown; sculpture horseshoe-like to annulate points drawing large irregular circles towards apex, some transverse striae along apex; few minute and very short setae.

*Underside.* From dark brown to chestnut brown, sculpture setigerous with long whitish pilosity, not dense except on femora and laterally on sternites 2–5; sculpture sparse, crescent on metasternum, denser to confluent laterally, disc poorly sculpted; abdomen with horseshoe sculpture, median part almost smooth, denser laterally near the margin; posterior coxae reborded laterally, setigerous sculpture made of transversal to backward-curved striae; mesosternal apophysis glabrous, transverse with minute points, strongly compressed between mesocoxae but not protruding; male abdomen concave with visible groove on sternites 2–5.

*Legs.* From dark brown to chestnut brown, with whitish pilosity; protibiae bidentate, meso- and metatibiae with median carina; profemora strigillate, mesofemora with crescent punctures or small striae, long setigerous stria along internal margin; metafemora slightly dilated with crescent punctures or small striae; all tarsal segments longer than first, metatarsi spiny, claws normal.

*Aedeagus.* Parameres fused and short, with two carinated lateral spines at apex, apical centre with short protrusion.

**Remarks.** Only the MNHN type specimens are known. No recent material was found in the collections examined. Unfortunately, Lansberge (1882) did not specify the number of specimens used for his description. The specimen length indicated in his work does not match the measurements reported above. This difference cannot be explained at this stage, but it is possible that Lansberge (1882) may have only provided a coarse estimate, without accurate measurement. The female is larger than the male; its abdomen does not exhibit a deep groove but there are occasional slight depressions on sternites III and IV, otherwise it varies from flat to slightly convex. The main difference between the two sexes lies in the metatibial spurs, which are strongly enlarged in the female (especially the upper one, spatuliform when thin), but acute and curved at the apex in the male. Nothing is known about the biology of this species, but the adult is probably a flower visitor.

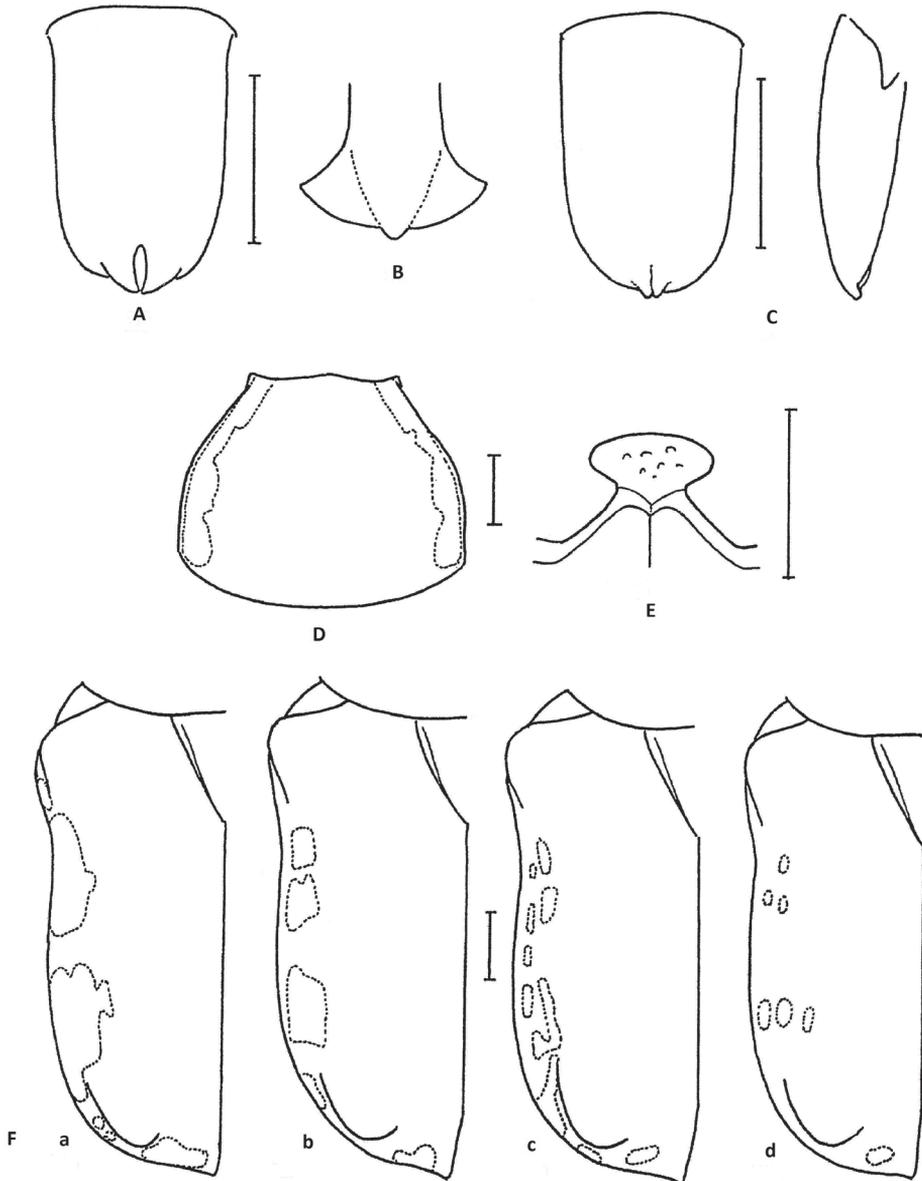
### *Attrichelaphinis (Heterelaphinis) sexualis* (Schein, 1956)

Figure 6

*Leptothyrea sexualis* Schein, 1956: 196; Marais and Holm 1992: 42; Krajcik 1998: 52.

**Type specimen.** Holotype in NMKE: "Somaliland, Wardere, V.19 (THE Jackson)".

**Translation of original description (n = unknown).** After Schein (1956: 196–197). Size: length 10–11 mm; width 5–6 mm. Shiny and black species.



**Figure 6.** *Atrichelaphinis* (*Heterelaphinis*) *sexualis*: **A** parameres. *Atrichelaphinis* (*Heterelaphinis*) *quadripunctata*: **B** apex of the parameres of the the lectotype. *Atrichelaphinis* (*Heterelaphinis*) *nigra*: **C** parameres **D** male pronotum **E** mesosternal lobe **F** left elytron (**a** male; **b–d** female). Scale bar = 1 mm (From Antoine 2002: 187; permission obtained: 13 Feb 2014).

*Head.* Clypeus longer than wide; lateral and anterior margins reborded and up-turned, anterior margin flat and bilobed; deeply punctured; antennal club slightly longer than basal antennomeres, antennae orange/red.

*Pronotum.* Black or red, with white stripe along the lateral margin and two deep and round white maculae at base in male, red and without white maculae in female; almost as long as wide, posterior margin almost straight in front of scutellum, only slightly concave; posterior angles very blunt; lateral margin parallel in distal part, then strongly convergent in front.

*Scutellum.* Longer than wide, with lateral margins slightly concave, apex not acute.

*Elytra.* Black, with white macula at umbone (reaching the suture); 4–6 irregular stripes of broken white maculae and two white longitudinal stripes on disc, parallel to suture, made of irregular and interrupted spots in male; female without white maculae or only reduced marks in place of male stripes; white macula at sutural apex most often present; lateral margins subparallel, narrowing slightly towards apex; lateral costa forked and raised near the shoulder, reaching the humeral callus; sutural costa raised; third costa between sutural and lateral equally raised, joining the lateral costa near apical callus; suture and costae smooth, intervals exhibiting two thin geminate striae usually dissipating near lateral declivity.

*Pygidium.* Orange/red, covered by annular and ovoid sculpture; with two elongate and interrupted white maculae (separated in 4 parts) in male, absent in female.

*Underside.* Black, with last and penultimate segments orange/red in female; white maculae on epimeres, lateral parts of sternum and laterally on abdominal sternites 2–5 in male; female immaculate; fore coxae and sides of sternum with whitish pilosity; metasternal apophysis constricted between metacoxae, anterior part flat in shape of hammer; metasternum smooth at middle towards median sulcus, sides striated; abdominal segments widely punctated, with thin setae on sides; male without mid abdominal depression.

*Legs.* Protibiae widened towards apex, second tooth rounded in male, acute in female; metatibial spurs uneven and acute (longer one slightly curved) in male, enlarged with blunt apex in female; tarsi slender, metatarsus as long as as metatibia in male, shorter in female, first tarsal segment not spiny in either sexes.

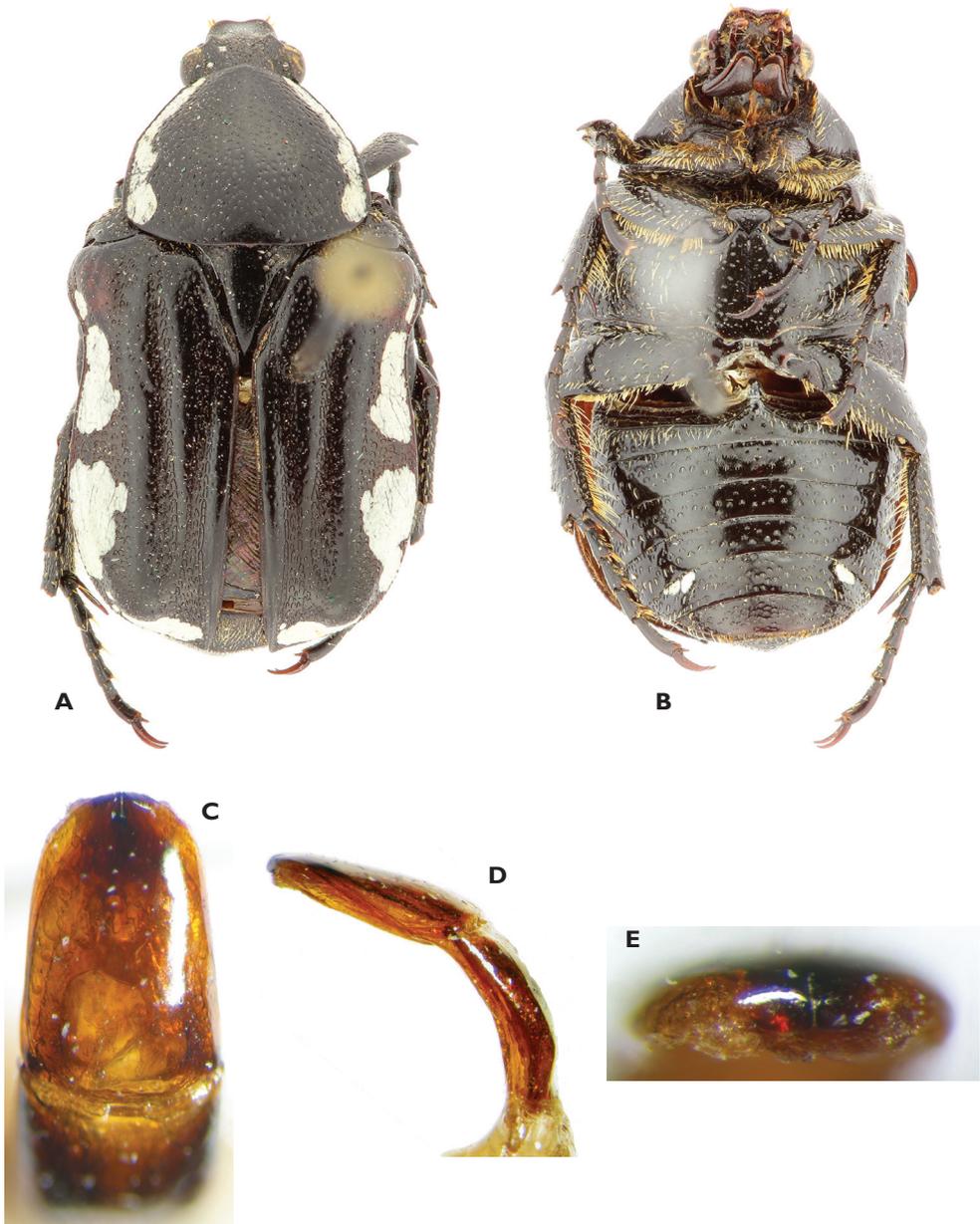
*Aedeagus.* Apex of parameres round with two very small and short median protrusions, without space between them.

**Remarks.** Described from Somaliland with no specification on number of type specimens. The description is based on the work of Schein (1956: 196–197) but no further information could be obtained on the types studied by Schein. Also, no newly collected specimens were obtained during this study. The species seems to be restricted to the Ogaden region along the south-eastern Ethiopian border with Somalia. The biogeographic characteristics of the area suggest that the species may be present in both countries. Like the other species, it is probably a flower visitor.

### *Atrichelaphinis (Heterelaphinis) nigra* Antoine, 2002: 185

Figures 6 and 7

**Type specimens.** Holotype male in MNHN: "Somalie, Berbera Check, ex. Coll. Argod 1931". Two female paratypes in MNHN with the same label.



**Figure 7.** *Atrichelaphinis* (*Heterelaphinis*) *nigra* Antoine, 2002. Holotype male, Somalia (MNHN). **A** Dorsal view **B** ventral view **C** parameres in dorsal view **D** parameres in lateral view **E** apex of the parameres.

**Redescription (n = 3).** Size: length 8.8–10.3 mm; width 5.2–6.0 mm.

*Body.* Appearance stocky, black to dark-brown, from dull to slightly shiny, with white tomentose spots; lateral and irregular band on pronotal margin in male, narrower

in female, occasionally reduced to line on lateral angle; three main spots on lateral margins of elytra in male, reduced and fragmented in female.

*Head.* Longer than wide, rectangular, with slightly sinuate anterior margin, slightly upturned and markedly thickened; disc convex; sculpture of large and deep punctures forming laterally some striae; lateral margin almost carinate at base, curving downwards and depressed at middle and reborded in apical part, as anterior margin; vertex and frons without protuberance, with same sculpture as clypeus; antennae dark-brown with club as long as flagellum in male, shorter in female.

*Pronotum.* Slightly transverse, larger at posterior angles; sculpture of transverse punctures with circular distribution centered at middle of posterior margin, middle unsculpted longitudinal line on disc, posterior margin in front of scutellum also unsculpted; anterior margin slightly wider than head, slightly tectiform, lateral margins reborded with very smooth lateral angles at middle; posterior margin convex, straight to convex in front of scutellum.

*Scutellum.* Black to dark-brown, longer than wide, apex acute, smooth, with few punctures only on lateral angles and along lateral parts of basal third; grooved laterally.

*Elytra.* Dull, except costae and callus which are slightly shiny; strongly sculpted with two different punctures, fine on costae and horseshoe with central point (semi-annular) on remaining surface; sculpture of first two interstriae becoming confluent in apical half; costae strongly elevated, discal one almost complete to apical callus and strongly developed; apex angular but not produced; lateral margin reborded on basal half.

*Pygidium.* Transverse with horseshoe setigerous sculpture, setae thin and separate; medial line strongly convex, wide and smooth area just before apex reborded and depressed, depression exhibiting striae; two small depressions near anterior angles and one spot of white tomentum on each side.

*Underside.* With scattered lunulate setigerous sculpture, setae longer on sternum than on abdomen; wide crescent punctures on metasternum, disc poorly sculpted (few fine punctures), denser to confluent laterally; abdomen with horseshoe sculpture regularly distributed; posterior coxae reborded laterally, latero-posterior angles well marked, setigerous sculpture of transversal to backward-curved striae; mesosternal apophysis transverse with few setigerous punctures, compressed between the mesocoxae and not protruding; male abdomen concave with visible groove on the sternites 3–5; two small lateral spots on sternite 6 in male, absent in female.

*Legs.* Exhibiting whitish double setae, one long and simple, second scale-type; protibiae bidentate, meso- and metatibiae with carina in apical third; profemora strigillate, mesofemora with crescent punctures to small striae, long setigerous stria along internal margin; metafemora slightly dilated, with crescent punctures to small striae; first tarsal segment shorter than others, metatarsi not spiny; claws normal.

*Aedeagus.* Simple, with sides converging in front; apex rounded and slightly protruding at center, very short longitudinal incision just in front of protrusion.

**Remarks.** This species is only known from the type series (male holotype and two female paratypes) and is apparently restricted to Somalia. Females exhibit a convex abdomen and enlarged to spatuliform metatibial spurs, while male spurs are slender and acute.

***Atrichelaphinis* (*Eugeaphinis*) subgen. n.**

**Type species.** *Atrichelaphinis deplanata* Moser, 1907

**Subgeneric characters.** Clypeus transverse, more or less upturned (this represents a very strong sexual dimorphic character in some species), with anterior angles at the level of the antennal insertion; anterior pronotal border from slightly tectiform (minimally in male) to tuberculate; protibiae bidentate, with denticles normally separated; metatibial apical spurs enlarged or not in female; parameres of aedeagus fused, with apex sometimes sinuate or projecting laterally into hook-like expansion, but without frontal protrusion at middle and never repleyed on ventral side, only curved downwards at apex.

The type of *Atrichelaphinis deplanata* was labelled by Antoine (1988) as "*Pseudanelaphinis deplanata*". Specimens of the same species and of *Anelaphinis kwangensis* Burgeon, 1931 were also labelled as "*Pseudanelaphinis*". However, no publication relating to this genus (*in litteris*) could be traced during this study. Eight species and one subspecies are currently included.

***Atrichelaphinis* (*Eugeaphinis*) *deplanata deplanata* (Moser, 1907)**

Figures 8 and 9

*Atrichelaphinis deplanata* Moser, 1907: 316–317; Schenkling 1921: 304; Girard 1993: 165; Marais and Holm 1992: 11; Joly 1993: 9.

*Atrichelaphinis deplanata* (Moser, 1908) Touroult & Le Gall, 2001: 34.

*Atrichelaphinis deplanate* (Moser) Antoine, 1988: 48.

*Atrichelaphinis kwangensis* (Burgeon) Marais & Holm, 1992: 11.

*Anelaphinis deplanata* (Moser) Antoine, 1991: 2; Antoine 2002: 186.

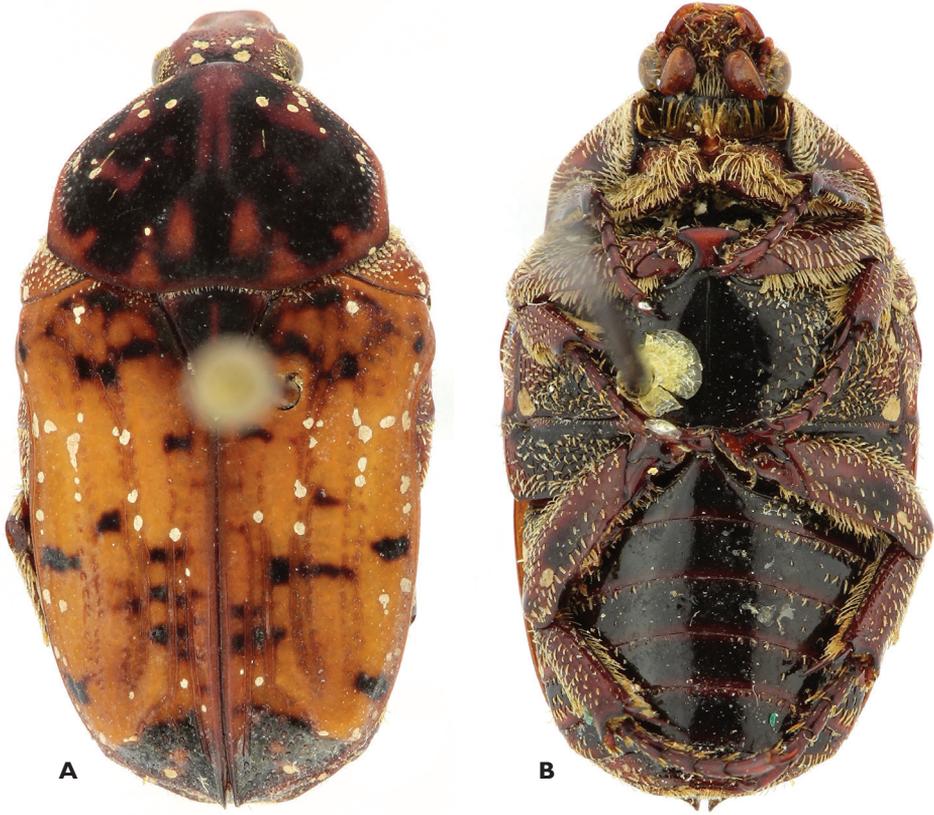
*Anelaphinis kwangensis* Burgeon, 1931: 221–222; Burgeon 1932: 95; Burgeon 1935: 470; Basilevsky 1955: 114; Antoine 1988: 48; Antoine 1991: 2.

**Type specimens.** *A. deplanata*, holotype in MNHU: "Dahomey"; *A. kwangensis*, holotype in MRAC: "Musée du Congo, Kwango V-1927, (D? Zoballo), Don R. Mayné".

**Redescription (n > 30).** Size: length ♂, 9.6–13.3 mm; ♀, 9.8–12.4 mm; width ♂, 5.6–6.9 mm; ♀, 6.2–7.0 mm.

**Body.** Dorsally velutinous, background colour from light-yellow to light-brown, with many black/dark brown markings and small white maculae; scale pilosity mainly on ventral surface, more extensive in male than in female, particularly dense on antero-lateral borders of pronotum, on mesepimerons and legs.

**Head.** Clypeus transverse, almost bilobed in front, anterior margin reborded, anterior angles rounded, lateral angle visible from above, large and dense simple punctures on disc, laterally wrinkled; small white maculae scattered throughout dorsal surface, scale pilosity laterally behind eyes; antennae concolor, with clubs slightly longer in male than in female.



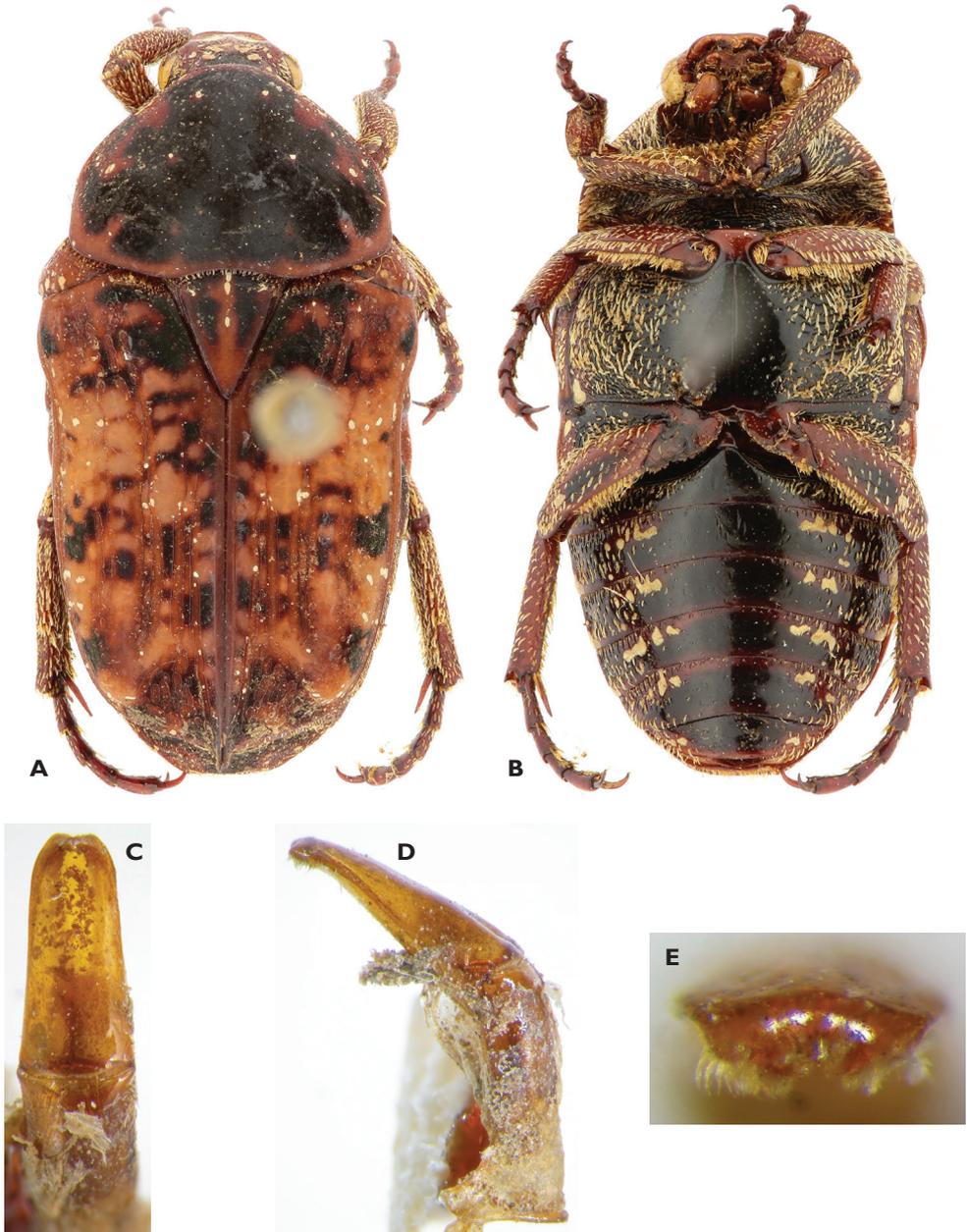
**Figure 8.** *Atrichelaphinis (Eugeaphinis) deplanata deplanata* (Moser, 1907), holotype (MNHU). **A** Dorsal view **B** ventral view.

*Pronotum.* Exhibiting strong development of black markings, reducing the background colour to margins in some specimens; octagonal, anterior margin from straight to slightly tectiform, disc bulbous in front and without punctures; lateral margin almost completely reborded, with posterior half straight from subparallel to convergent, lateral angles rounded but visible, posterior angles rounded; posterior margin straight to weakly convex laterally, medial part strongly emarginate in front of scutellum.

*Scutellum.* With apex from weakly rounded to acute, lateral margins from straight to weakly concave and with lateral grooves.

*Elytra.* Usually showing transverse area lighter than base and apical parts, which exhibit more black marks; tricostate, with the second costa raised only in basal half; three pairs of geminate striae, sculpture of horseshoe-like punctures diverging at basal part of each stria, becoming confluent and geminate on upper half; apico-sutural angle acute, longer in male than in female.

*Pygidium.* Light brown with black markings, with horseshoe punctures and dense scale pilosity; exhibiting many depressed areas.



**Figure 9.** *Anelaphinis kwangensis* Burgeon, 1931, holotype (MRAC). **A** Dorsal view **B** ventral view **C** parameres in dorsal view **D** parameres in lateral view **E** apex of parameres.

*Underside.* Brown and black with white maculae; scale pilosity dense on lateral parts of sternum which are striated; abdominal pilosity thinner and reduced to lateral sides where punctuation consists of few horseshoe setigerous puncture; middle of ster-

num and abdomen without punctuation, only longitudinal line visible on metasternum, abdomen weakly concave in male, convex in female; mesosternal apophysis transverse, compressed and not protruding between mesocoxae, metasternal declivity with scale pilosity.

*Legs.* Light brown, with scale pilosity, metafemora widened, metatibia short, thickened at apex, tarsi unmodified and normal; latero-posterior angle of metacoxae rounded; metatibial spurs thin and acute in male, slightly thickened and acute in female.

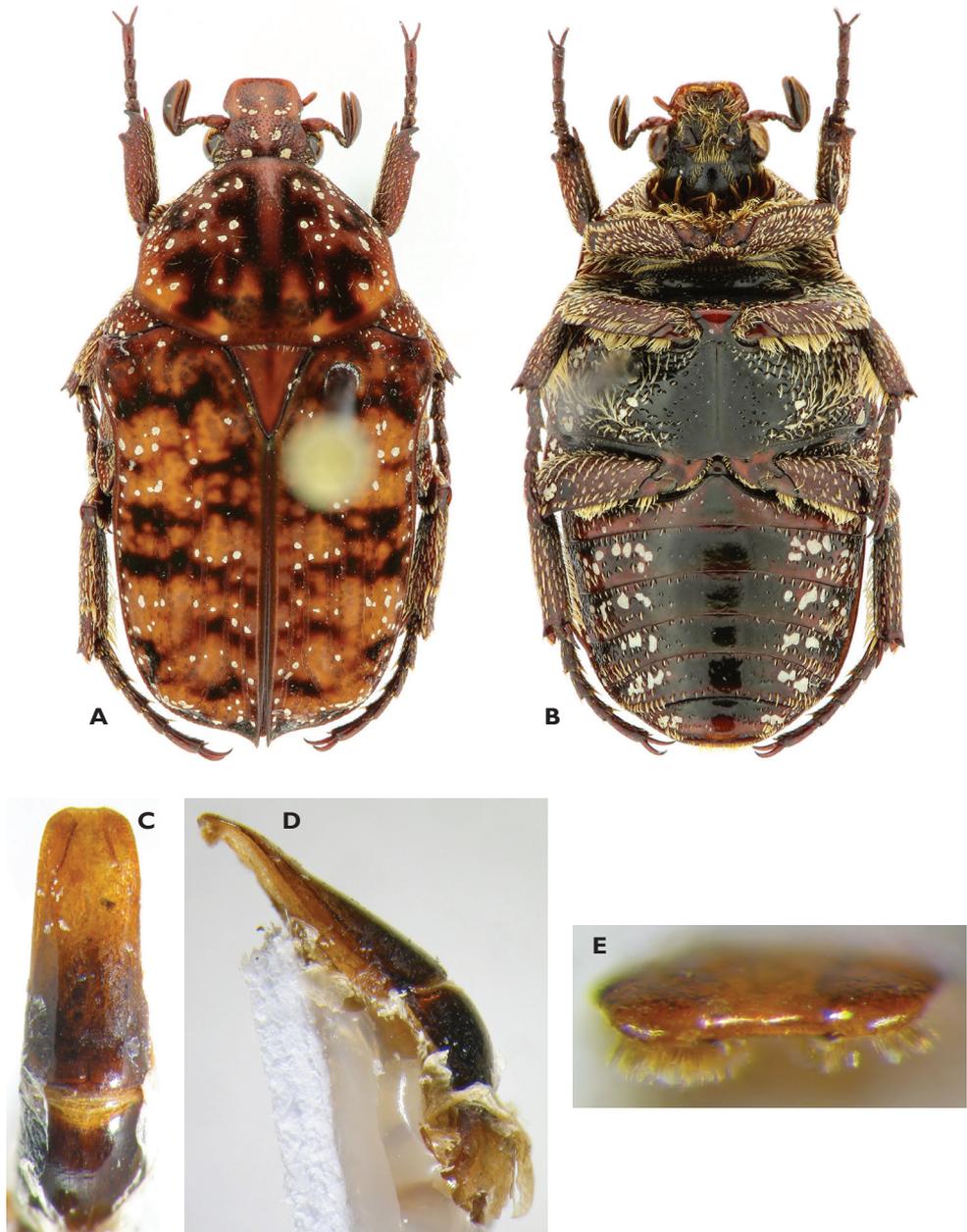
*Aedeagus.* Parameres narrowing gently towards apex, more abruptly close to apex; apex truncate and curved downwards, apical curved part from bilobed to incised (in frontal view).

**Remarks.** Through courtesy of the MNHU and the MRAC, an opportunity was provided to study both types of *A. deplanata* (Figure 7) and *A. kwangensis* (Figure 8). As already indicated by Antoine (1988: 48), the synonymy between these two taxa can now be conclusively confirmed. Many specimens from several countries were analysed, including Cameroon, Guinea, Ivory Coast, Togo, Congo-Brazzaville, Congo-Kinshasa, Central African Republic and Kenya. The species seems to be a flower visitor.

***Atrichelaphinis (Eugeaphinis) deplanata minettii* subsp. n.**

Figure 10

**Type specimens.** Holotype male, **Zambia:** Central Province, Mfwanta, S13°07'247", E30°19'345", 1429 m, R. Minetti leg., XI-2010 (MNHN). Paratypes, **Angola:** Huila Prov., 2 km S Negola, S14°08'53", E14°28'16", à vue S. Rojkoff rec., 9-XII-2012, 1♀ (PCSR). **Congo-Brazzaville:** Pool, Mabaya, Bruno Le Rü leg, III-1989, 1♂ (PCDC). **Congo-Kinshasa:** Katanga, Manika, Ch. Seydel leg, C 19101, X-1931, 1♀ (MRAC); Kafakumba, F.G. Overlaet, IV-1932, 1♂ (MRAC); Lualaba, Zilo, Dr. V. Allard leg., XI-1974, 1♂ (MNHN Coll. Ruter); Lulua, Kapanga, F.G. Overlaet, IX-1933, 1♀ (MRAC); Katanga, exploration du PNU, riv. Kapelo, Miss. Hasson & Bouyer, Projet ICCN-NA-SEA, PNU082A, 10/16-XI-2002, 1♂ (CPTB); Katanga, exploration du PNU, env. Lusinga, Miss. Hasson & Bouyer, Projet ICCN-NA-SEA, PNU063, 25-X/5-XI-2002, 1♀ (CPTB). **Malawi:** West, Dzelanyama Fst., 4200 ft, 25-II-1985, 1♂ (PCTG); Mzuzu, Nhorongoro, S11°29' E33°59', 1375 m, R.J. Murphy leg, 26-XII-1996, 1♀ (PCTG); same locality, 4500 ft, R.J. Murphy leg, 30-XII-1996, 1♂ (PCTG). **Mozambique:** Sierra de Choa, D. Camiade leg, XI/XII-2012, 1♀ (PCDC). **Rwanda:** Rinkwavu, J. Roggeman leg, VI-1970, 1♂ (MRAC); Rwinkwavu, Montfort leg, IV-1976, 2♂ (IRSN, Coll. Alexis I.G. 30 374); Mayaga, J. Roggeman leg, VI-1972, 3♀ (MRAC); Kigali, Dr. V. Allard leg, II-1971, 1♂, 1♀ (MNHN, Coll. Ruter); Nyarubuye (Kibinga), Dr. V. Allard leg, 5-XII-1972, 1♂? (abdomen absent), 2♀ (MNHN, Coll. Ruter). **South Africa:** Afriq. Austr., Linokana, Dr. E. Holubi, 1894 (170–357), 1♀ (MNHN); Transvaal, ex. Coll. Oberthür, 2♂ (MNHN); Pretoria N., Van Son G., II-1936, Transvaal Mus. don, 1♀ (MRAC). **Zambia:** same data as holotype, 1♀ (PCSR); Central Province, 50 km E Serenje, S. Rojkoff & K. Werner



**Figure 10.** *Atrichelaphinis* (*Eugeaphinis*) *deplanata minettii* subsp. n., holotype (PCSR). **A** Dorsal view **B** ventral view **C** parameres in dorsal view **D** parameres in lateral view **E** apex of parameres.

leg, 7/8-XII-2005, 1♂ (PCSR); SE Lusaka, S15°33'662", E28°30'646", 1281 m, in fruit-baited trap, J. Touroult leg, 22-XI-2006, 1♀ (PCJT). **Zimbabwe:** Rhodésie du Sud, Selukwe, A. Ellenberger 1915, 1♂ (MNHN), 1♀ (PCSR).

**Description (n = 31).** Size: length ♂, 9.1–11.5 mm; ♀, 10.2–11.5 mm; width ♂, 5.2–6.4 mm; ♀, 5.7–6.5 mm. This new subspecies differs from the nominal form by exhibiting the following characters: smaller size; black/brown markings more regularly disposed and reduced; background colour more reddish; anterior pronotal elevation more enhanced; lateral pronotal angles less round and hind part of lateral border slightly longer; antescutellar concavity weak; pilosity of sternum thinner, especially in male; parameres with lateral sides subparallel, apex with dull lateral angles, shape more squared.

**Derivatio nominis.** This subspecies is named after the French collector Robert Minetti, who brought to the authors' attention the holotype specimen from Zambia.

**Remarks.** There was initially some reservation in erecting this new subspecies, despite the morphological differences with the other forms mentioned above. Only the study of a large series of *A. (E.) deplanata* from various localities made it possible to isolate the new subspecies, considering also its broad geographic distribution. It is here given subspecies status because some of the specimens from Rwanda and Kenya actually represent a transition between the two forms, exhibiting intermediate characteristics such as coloration, shapes of pronotum and aedeagus. However, no potential intermediate forms were available from Congo-Brazzaville, where both subspecies are known to occur, but in separate parts of the country. Despite the Rwanda-Kenya transition zone, the new subspecies has a separate geographical distribution area from the nominal subspecies, which is restricted to western and central Africa. The new subspecies is distributed from central to east Africa and throughout the eastern half of southern Africa.

### *Atrichelaphinis (Eugeaphinis) rhodesiana* (Péringuey, 1907)

Figure 11

*Niphetophora rhodesiana* Péringuey, 1907: 451; Schenkling 1921: 352; Antoine 1991: 2; Holm and Marais 1992: 53.

*Anelaphinis rhodesiana* (Péringuey) Antoine & Holm, 1993: 102.

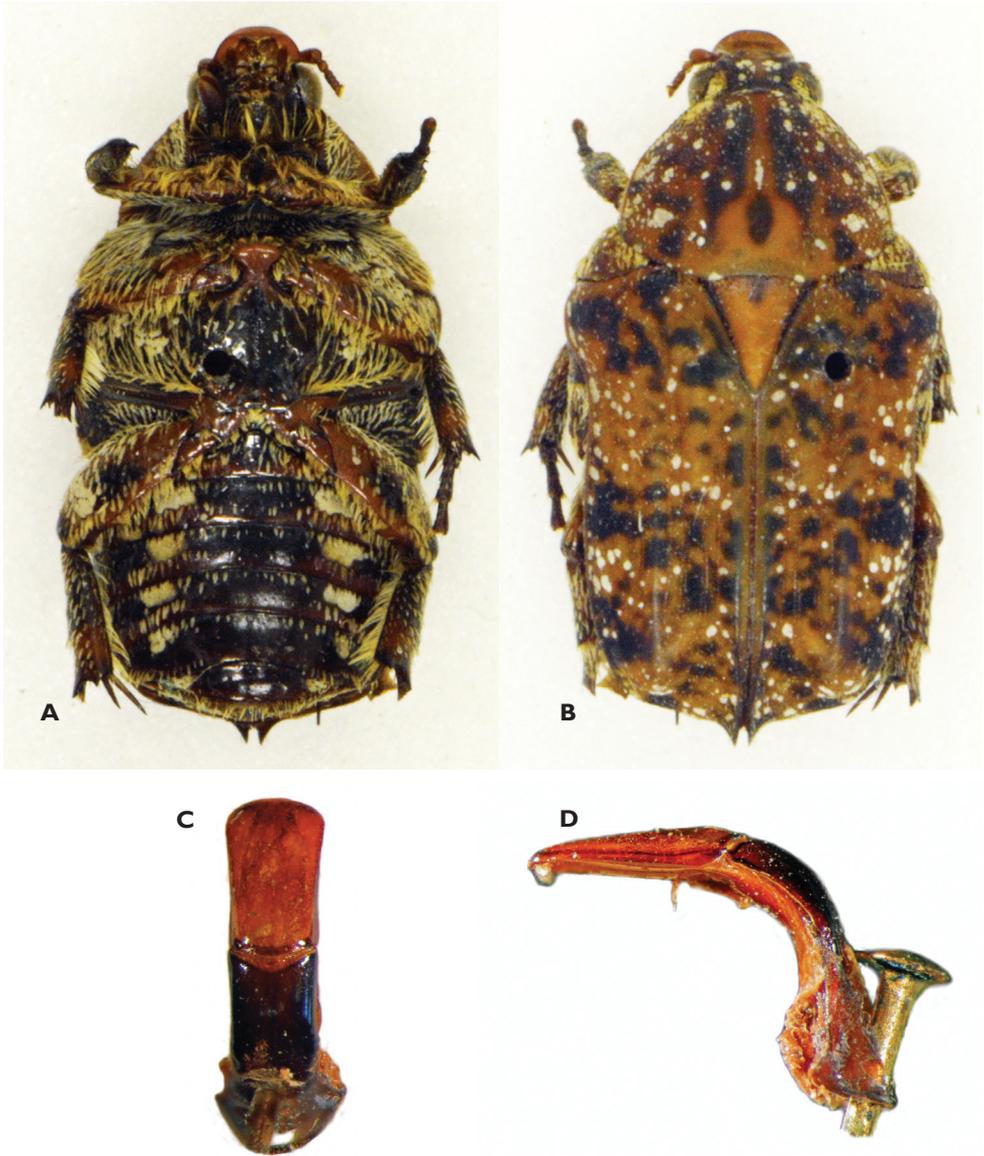
**Type specimen.** Holotype male: "S. Rhodesia, Umtali " (ISAM).

**Redescription (n = 42).** Size: length ♂, 10.2–12.6 mm; ♀, 10.4–12.2 mm; width ♂, 5.7–6.9 mm; ♀, 5.7–7.0 mm.

**Body.** Light brown mottle with dark marks from green to brown, dark color at times covering virtually entire surface; matt to shiny, white spots of tomentum scattered throughout; light pilosity distributed on vertex, along lateral margins of pronotum, on mesepimeron, on elytra (mainly on sides and apex) and pygidium.

**Head.** Clypeus slightly transverse, anterior margin strongly upturned in male, reborded and slightly bilobed in female; disc convex; punctures scattered and superficial, striolated laterally and in front.

**Pronotum.** Transverse, lateral angles strongly rounded almost imperceptible to slightly discernible; lateral margin completely reborded; posterior margin concave in front of scutellum, laterally convex; anterior margin bluntly tuberculate at middle; punctuation sparse on disc, becoming denser and stronger laterally and in front.



**Figure 11.** *Atrichelaphinis* (*Eugeaphinis*) *rhodesiana* (Péringuey, 1907), holotype (ISAM). **A** Dorsal view **B** ventral view **C** parameres in dorsal view **D** parameres in lateral view.

*Scutellum.* With short setae and occasional round punctures at base; apex acute.

*Elytra.* With two pairs of striae between sutural costae; discolateral costae with lunulate punctures more or less complete and confluent, horseshoe sculpture also on lateral margins; apicosutural angle acute and more or less developed.

*Pygidium.* Parabolic with upturned posterior margin.

*Underside.* Shiny, generally with spots of white tomentum on abdomen and metasternum, sometimes also on metafemora; mesosternal apophysis transverse,

compressed between the mesocoxae, anterior margin slightly convex; median part of metasternum and abdomen without pilosity and less sculpted.

*Legs.* Protibiae tri- to unidentate; meso and metatibiae with transverse carina under middle of external side slightly enlarged; metalegs more robust in female; second metatarsomere longer than third and fourth; with setae longer than in any other area; metatibial spurs thin and acute in male, slightly enlarged and blunt in female.

*Aedeagus.* Parameres (Figure 9D) about twice as long as wide (sometimes even longer), wider at apex than at base; laterally concave and not modified, apex convex with round angles; downturned part of apex from straight/convex to sinuate and slightly incised at middle.

**Remarks.** A large number of specimens from Zimbabwe and South Africa was analysed for this study (in IRSN, MNHN, MNHU, PCR, PCSR). The South African distribution of the species is restricted to the eastern, wetter part of the country (Holm and Marais 1992). Although no supporting records were found, the species is likely to occur also in neighbouring Mozambique and Botswana. It is normally found on a variety of flowers, fermenting fruit and sap flows.

***Atrichelaphinis (Eugeaphinis) bomboesbergica* sp. n.**

<http://zoobank.org/CE128E12-51B9-4143-8AA3-72E301FBFCB0>

Figure 12

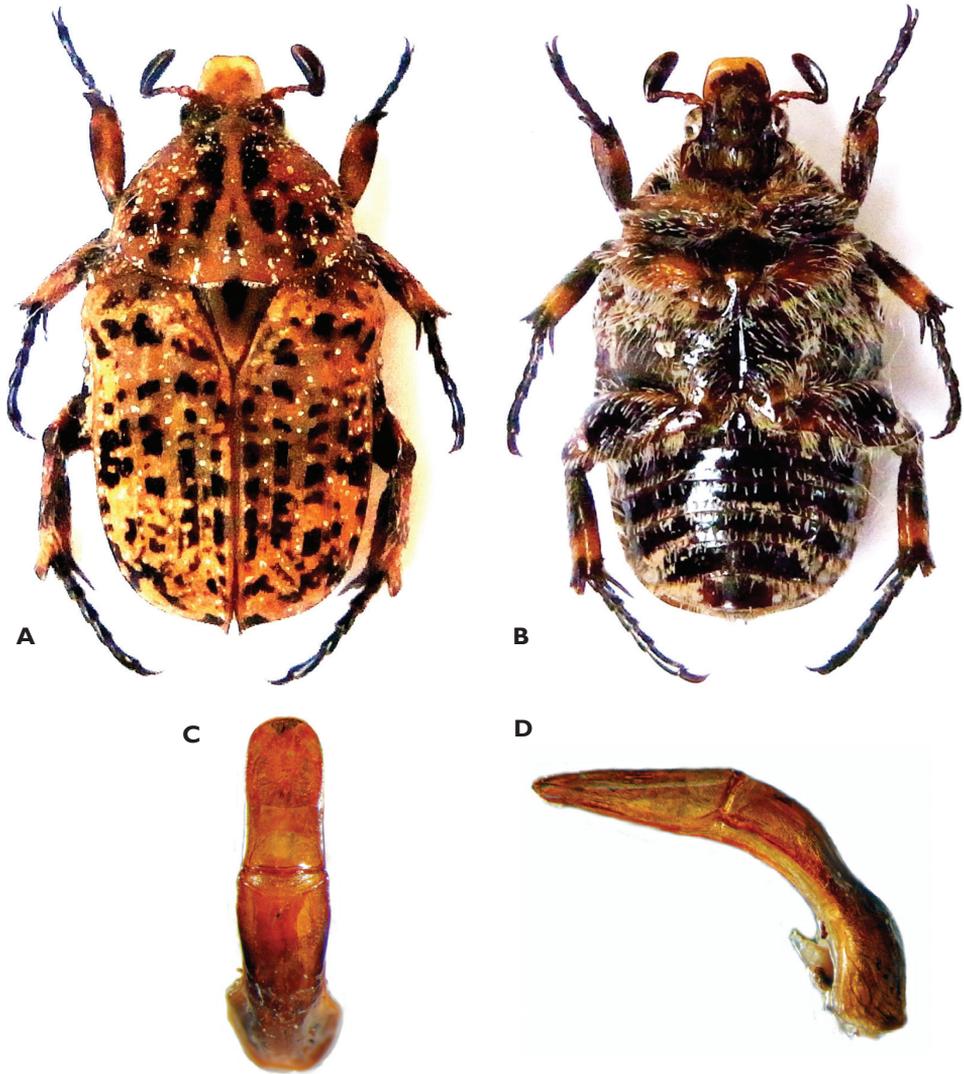
**Type specimens.** Holotype male: **South Africa** EC, Hofmeyr, 28-XI-2011, R. Perissinotto & L. Clennell leg (ISAM). Paratypes: 1♂, same data as holotype (ISAM, PCR); 1♂, same data as holotype, but 10-XII-2011 (PCR); 8♂ 3♀, same data as holotype, but 24-XII-2011 (TMSA, PCSR); 2♂ 1♀, same data as holotype, but 26-XII-2011 (PCR); 8♀, same data as holotype, but 18-XII-2010 (PCR, PCSR).

**Description (n = 25).** Size: length ♂, 9.4–11.7 mm; ♀, 10.1–12.8 mm; width ♂, 5.8–6.7 mm; ♀, 6.2 to 7.8 mm.

*Body.* Dorsal surface slightly shiny, ground colour from ochraceous to light-brown, with many black/dark brown markings and small white maculae; scale-like setae present and particularly well developed on pronotum, more extensive in male than in female.

*Head.* Anterior margin of clypeus sharply upturned, particularly in male, slightly bilobed apically, anterior angles weakly rounded, lateral declivity visible from above; large crescent to horseshoe punctures, particularly dense on frons and vertex; scale-type setae particularly long and dense from frons to vertex; antennae with pedicel and flagellum reddish-brown, but clubs dark brown to black, club notably longer in male than in female.

*Pronotum.* With black markings not covering more than half of total area and particularly developed on anterior part of disc, on both sides of medial line; anterior margin tectiform; disc moderately tuberculate in front; with scale-like setae and round punctures diffuse but widespread throughout surface, setae more dense and longer on lateral margins; lateral margins and angles smoothly rounded with ante-scutellar arch relatively straight.



**Figure 12.** *Atrichelaphinis* (*Eugeaphinis*) *bomboesbergica* sp. n., holotype male (ISAM). **A** Dorsal view **B** ventral view **C** parameres in dorsal view **D** parameres in lateral view.

*Scutellum.* With apex from weakly rounded to acute; lateral margins from straight to weakly concave, with shallow and narrow lateral grooves; prominent oblong medial black mark extending from base to middle of disc; exhibiting few fine punctures on apical half but no scale-like setae.

*Elytra.* Weakly tricostate, with costae barely visible in apical part; sutural costa bulging out towards middle of elytral length; striae partly geminate and with coarse horseshoe sculpture; black marking most developed around humeral and apical calluses and in mid area of lateral half; apical sutural end virtually straight in male but curving outwards in female.

*Pygidium*. Brown to reddish at centre, becoming dark brown to black towards lateral and lower margins; fine sculpture and dense cover of scale-like setae throughout surface; exhibiting 2–3 pairs of depressed areas close to lateral margins.

*Underside*. Dark brown to black with white scattered maculae, particularly on metasternum and lateral margins of abdominal sternites; densely covered with long white setae, replaced in mid area of metasternum and abdominal sternites by few scattered scale-like setae; coarse and scattered horseshoe sculpture throughout, except on central areas of sternum and abdominal sternites; abdominal sternites weakly concave at middle in male, slightly convex in female; mesosternal apophysis ochraceous, small and rounded, with no projections extending between mesocoxae.

*Legs*. Tibia and femora light brown, with dark brown to black tips and joints; scattered white maculae present on both dorsal and ventral sides; tarsi dark brown to black; protibia unidentate but broadening remarkably towards apex, forming spade-like structure; numerous long setae throughout surface and scale-like setae at joints; metatibial spurs thin and acute in male, slightly enlarged and blunt in female.

*Aedeagus*. Parameres virtually straight from base to apical convergence, forming then a perfectly round apex, with slight indent at centre (dorsal view); apical margin curving downwards, but no ventral folding or projections visible in lateral view.

**Derivatio nominis.** The species is named after the Bamboesberg mountain range of the Eastern Cape Province of South Africa, where it was discovered on its south-western slopes.

**Remarks.** This new species represents the southernmost extension of the genus distribution range in the Afrotropical Region. *Atrichelaphinis bamboesbergica* appears to be restricted to a small area of the eastern Karoo semiarid region, where its larval stages develop exclusively in the dung middens of the antbear, *Orycteropus afer* (Pallas, 1766). Adults have a relatively short life span (2–3 weeks) and appear to be unable to feed, as none has yet been observed either on fruits, flowers or sap flows.

***Atrichelaphinis (Eugeaphinis) garnieri* sp. n.**

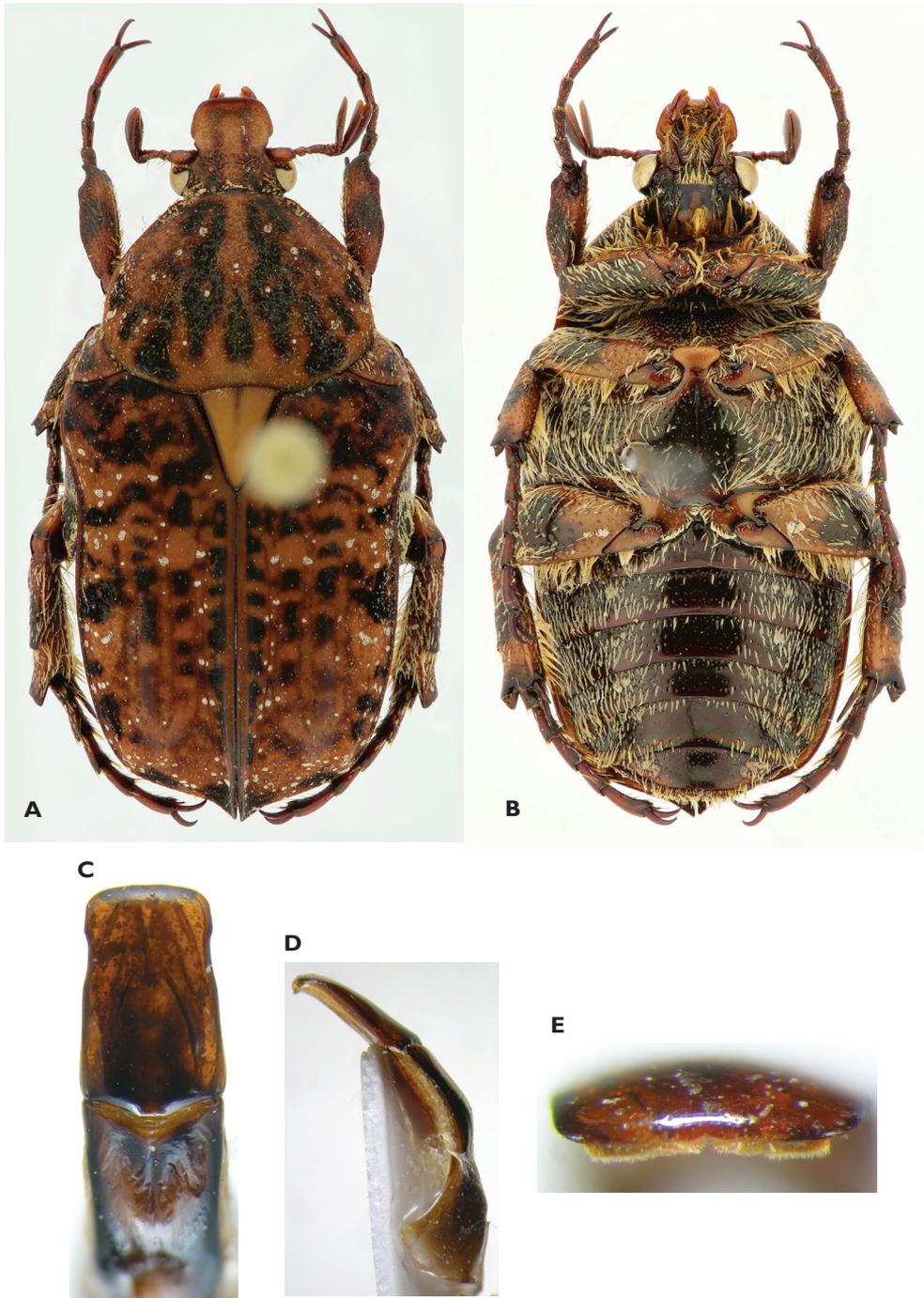
<http://zoobank.org/8023917C-2959-465D-8EDC-A40BF9D631EC>

Figures 13 and 14

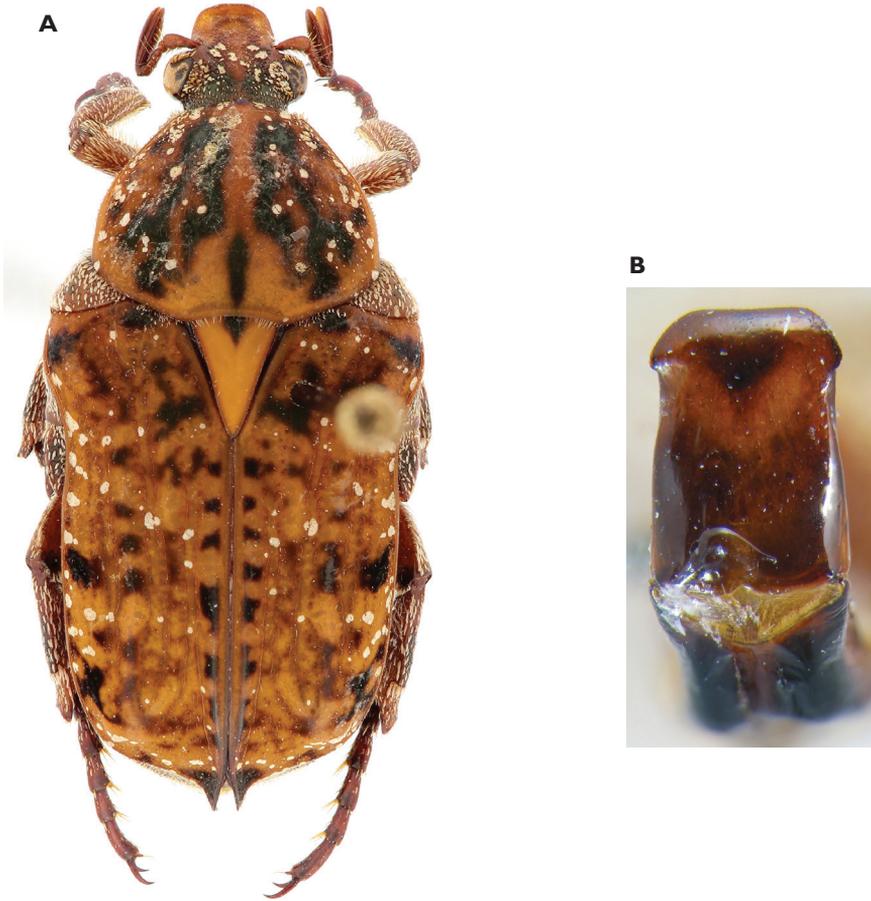
**Type specimens.** Holotype male: **Tanzania**, Mtandi Masasi reg., 19-III-2008 (IRSN). Paratypes: **Tanzania**, 2♂ 2♀, same data as HT (PCTG, PCSR, PCRP); 1♂ 1♀, same locality, but I-2006 (PCTG); 2♀, Morogoro reg., Uluguru Mts, M. Coache leg, IV-2006 (PCSR); **Zimbabwe**, 1♂, Rhod., Christon Bank, Dr. V. Allard don, 25-XI-1974 (MNHN).

**Description (n = 10).** Size: length ♂, 10.7–13.6 mm; ♀, 10.7–12.9 mm; width ♂, 6.1–7.4 mm; ♀, 6.2–7.4 mm.

*Body*. Light brown mottle with dark marks from green to brown, dark color at times covering virtually entire surface; matt to shiny, white spots of tomentum scattered throughout; light pilosity distributed on vertex, along lateral margins of pronotum, on mesepimeron, on elytra (mainly lateral margins and apex) and pygidium.



**Figure 13.** *Atrichelaphinis* (*Eugeaphinis*) *garnieri* sp. n., holotype male (PCSR). **A** Dorsal view **B** ventral view **C** parameres in dorsal view **D** parameres in lateral view **E** apex of parameres.



**Figure 14.** *Atrichelaphinis (Eugeaphinis) garnieri* sp. n., paratype male, Zimbabwe (MNHN). **A** Dorsal view **B** parameres in dorsal view.

*Head.* Clypeus slightly transverse, anterior margin strongly upturned in male, reborded and slightly bilobed and upturned in female; disc convex; sculpture scattered and superficial becoming striolated laterally and in front, few setae on frons and vertex.

*Pronotum.* Transverse, lateral angles strongly rounded and from almost imperceptible to slightly discernible; lateral margin completely reborded; posterior margin concave in front of scutellum, laterally convex; anterior margin tuberculate at middle; punctuation sparse on disc, becoming denser and stronger laterally and in front; pilosity present on lateral and frontal margins.

*Scutellum.* With very thin and short pilosity, occasional round punctures at base; apex acute.

*Elytra.* With two pairs of striae between sutural costae; discolateral costae with horseshoe sculpture more or less complete and confluent, horseshoe sculpture also on lateral margins; apicosutural angle acute and moderately developed.

*Pygidium*. Parabolic, with upturned posterior margin.

*Underside*. Shiny, generally with spots of white tomentum on abdomen and metasternum, sometimes also on metafemora; mesosternal apophysis transverse, compressed between the mesocoxae and with anterior margin slightly convex; median part of metasternum and abdomen without pilosity and poorly sculpted.

*Legs*. Protibiae from bi- to tridentate (third tooth sometimes drastically reduced); meso and metatibae with transverse carina under middle of external side; metafemora and metatibiae strongly enlarged in both sexes; second meta-tarsomere longer than third and fourth; male metatibial spurs large and acute, especially upper one; protarsi (excluding claws) longer than protibiae (from joint to apex of apical tooth); metatarsi robust, especially in female; metatibial spurs slightly enlarged and blunt in male, strongly enlarged to spatuliform and blunt in female.

*Aedeagus*. Less than twice as long as wide; width at base larger or equal to width at apex; lateral sides of parameres parallel to convergent, with apical margins showing sinuosity and/or hook-like projections.

**Derivatio nominis.** The species is dedicated to the renowned French collector Thierry Garnier, who continues to contribute greatly to the knowledge of African entomofauna and brought to our attention several specimens of the type series.

**Remarks.** *A. (E.) garnieri* is very similar to *A. (E.) rhodesiana*, from which it can be separated by the shape of the aedeagus and some external differences. Its body is slightly larger and the dorsal black marking is also usually darker and more developed than in *A. (E.) rhodesiana* (except where forms of *A. (E.) rhodesiana* do not exhibit the typical colour pattern). The pilosity of *A. (E.) garnieri* is thinner and longer than that of *A. (E.) rhodesiana*, especially on the underside but more difficult to appreciate on the upperside due to wear. The pronotal tubercle is also more pronounced and larger in *A. (E.) garnieri* than in *A. (E.) rhodesiana*. The male metatibial spurs are larger and blunt in *A. (E.) garnieri*, especially the upper one, while in the female they are spatuliform. Finally, apart from exhibiting sinuosity and/or hook-like projections, the mean ratio of length to width of the aedeagus of *A. (E.) garnieri* is 1.59 versus the 1.88 of *A. (E.) rhodesiana*. The two species appear to be cryptic and are sympatric in Zimbabwe, which represents the northernmost geographic limit of *A. (E.) rhodesiana* and the southernmost for *A. (E.) garnieri*. The two females from the Uluguru Mountains show less enlarged metatibial spurs and very slight differences in the formation of subcoxite IX. However, it is likely that these constitute simple population variations.

### *Atrichelaphinis (Eugeaphinis) simillima* (Ancy, 1883)

Figure 15

*Elaphinis simillima* Ancy, 1883: 94–95; Kraatz 1892: 415; Kolbe 1892a: 136; Schenkling 1921: 306; Bourgoin 1930: 15; Müller 1939: 298; Antoine 1991: 2; Marais and Holm 1992: 7.

*Anelaphinis simillima* (Ancy) Schenkling, 1921: 306; Burgeon 1931: 219; Kolbe 1892a: 136; Müller 1939: 298; Arrow 1940: 4, 6; Marais and Holm 1992: 7.

*Atrichelaphinis simillima* Müller, 1939: 299.

**Type specimen.** Holotype not traced; described from "Abyssinie" (collected by Raffray, with no date but probably ca 1881).

**Redescription (n > 350).** Size: length ♂, 9.4–13.4 mm; ♀, 10.3–14.8 mm; width ♂, 5.5–7.8 mm ♀, 6.1–8.7 mm.

*Body.* Light brown, velutinous to shiny with dark markings never covering whole surface, always lighter areas present; mesepimeron with setigerous sculpture in both sexes.

*Head.* With metallic sheen; vertex velutinous and hairy, sometimes reaching clypeal disc; clypeus transverse, reborded and slightly bilobed in front, sometimes weakly upturned; sculpture dense and deep, simple on disc and more or less confluent in front and laterally; vertex with smooth area and tomentum, large and smooth longitudinal carina extending from vertex to clypeal disc which is convex.

*Pronotum.* Exhibiting metallic sheen and setae on lateral margins; with lateral angles usually broadly rounded, sometimes almost undistinguished; lateral margin completely reborded, posterior margin weakly concave in front of scutellum, laterally convex towards posterior angles; diffuse tomentose lines along lateral margins, sometimes very reduced, two radial lines on each side of midline usually made of three groups of spots more or less developed; sculpture marked, not dense on disc, more or less confluent laterally; dark green marks sometimes very reduced.

*Scutellum.* Longitudinal with apex from acute to blunt, without sculpture except near angles, without tomentum; with lateral grooves and sides almost straight or weakly curved inwards.

*Elytra.* With weak posthumeral emargination, reborded laterally; dark green marks sometimes very reduced or absent, but never covering whole surface; disc without tomentum; sculpture variable in size and intensity, usually vertical series of horseshoe punctures, sometimes confluent; short setae on lateral declivity and apex; apex acute but not protruding backwards.

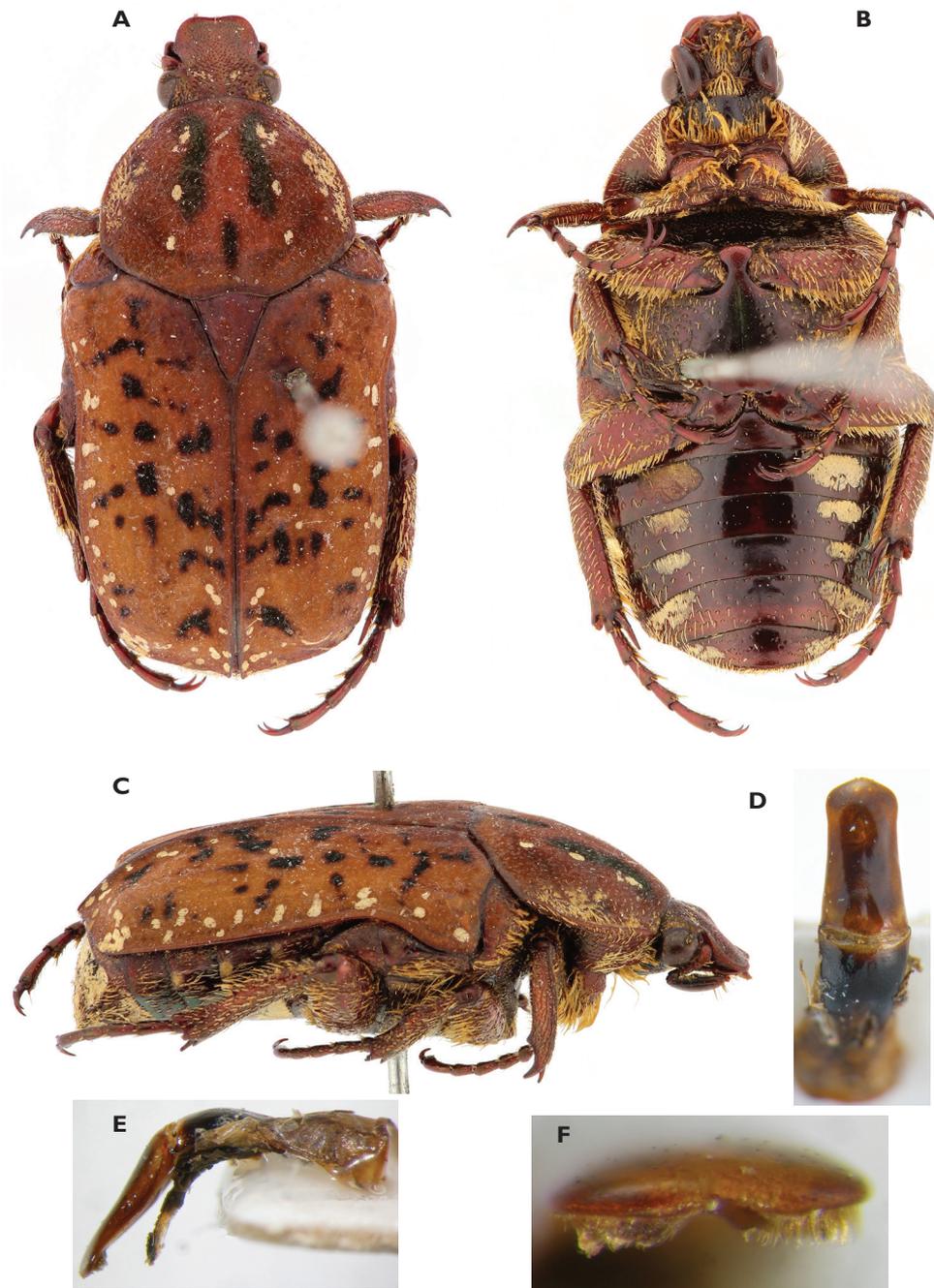
*Pygidium.* With short setae occasionally throughout surface.

*Underside.* Shiny, with metallic sheen; with dense pilosity; mesosternal apophysis transverse, finely punctate and glabrous, not or slightly protruding in front of mesocoxae, not clearly oriented in lateral view; metasternum and abdomen sculpted laterally (horseshoe to striolate punctures) and showing white tomentum usually more developed in male; abdomen concave in male, flat or slightly convex in female.

*Legs.* Meso- and metatibiae with carina on external side just under middle; metatarsomeres shorter and more robust in female; protibiae enlarged, metatibiae slightly broader and hind spurs enlarged in female; metatibial spurs thin and acute in male, slightly enlarged and less acute but not blunt in female.

*Aedeagus.* Parameres about twice as long as wide, side from parallel to slightly convergent in front, apex truncate with lateral angles rounded, sometimes weakly bulbous laterally, emarginated at middle of downturning apical part.

**Remarks.** All specimens examined originated from Ethiopia. Some are labeled "Shoa-Somali" but without precise locality and were collected during the expedition of V. Erlanger. They were probably also collected within the current borders of



**Figure 15.** *Atrichelaphinis* (*Eugeaphinis*) *simillima* (Ancey, 1883), "compared to type" by Bourgoin (IRSN). **A** Dorsal view **B** ventral view **C** lateral view **D** parameres in dorsal view **E** parameres in lateral view **F** apex of parameres.

Ethiopia. The type of Ancey (1883) could not be traced. Three specimens from the Oberthür Collection, collected in "Abyssinie" by Raffray and identified as *A. similima* by Antoine (1992), were found at the MNHN. Two of them are "ex-Museo D. Sharp 1890" and "ex-Museo Van Lansberge", respectively. They are both bigger than the size given by Ancey in his description. The third one, labelled "Abyssinie Raffray Voy. 1881" match the description and the sizes indicated by Ancey. It is not known if this specimen is the holotype or a cotype, but a red label indicating this possibility has now been attached to it by Rojkoff (2014). Because both collections of Ancey and Raffray were scattered through different collections, it is virtually impossible to establish the precise status of this specimen. The identification of *A. (E.) simillima* was based on specimens (4♂, 4♀) held in the IRSN and carrying the following labels "Comp. par Bourgoin au type" / "Harrar Abyssinie / Juin Juill. 1911 / G. Kristensen", and identified as "Elaphinis simillima Ancey / 1913 Det. A. Bourgoin". Horn et al. (1990: 18) reported that Ancey's Cetoniinae were in the JM Bédoc/Paris Collection, but they have not been traced since. Some specimens kept in the MNHN collections are labelled "Abyssinie/Raffray", but they cannot be regarded as type material. In the same publication where *A. (E.) simillima* was described, Ancey (1883) also included *Gnathocera costata* Ancey, 1883, the type material of which is housed in the MNHU, according to Marais and Holm (1992: 33).

### *Atrichelaphinis (Eugeaphinis) sternalis* (Moser, 1914)

Figure 16

*Anelaphinis sternalis* Moser, 1914: 606–607; Schenkling 1921: 306; Antoine 1991: 2; Marais and Holm 1992: 7.

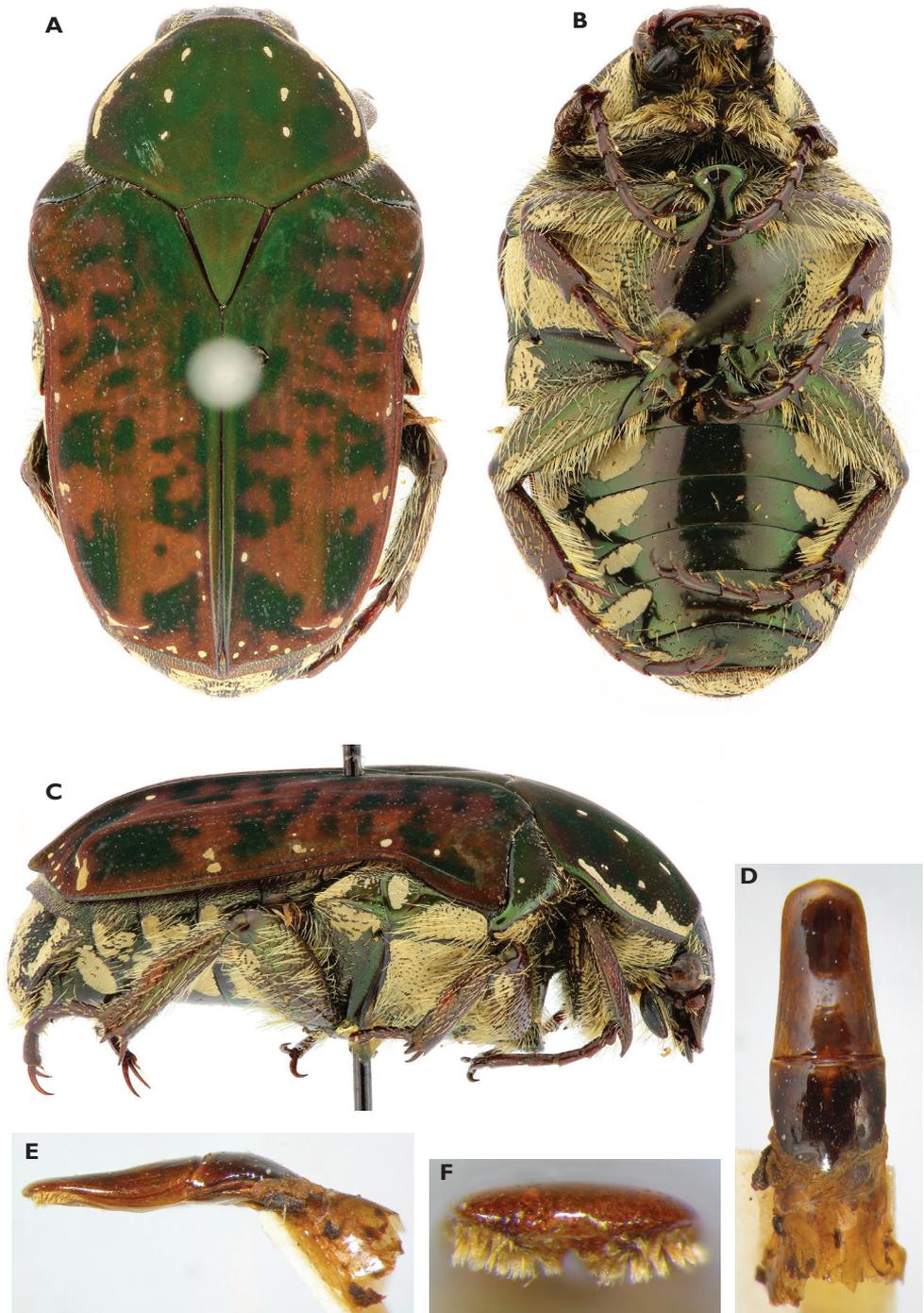
**Type specimen.** Holotype male: "Abessinien" (MNHU).

**Redescription (n = 24).** Size: length ♂, 12.1–13.7 mm; ♀, 12.9–13.5 mm; width ♂, 7.1–8.2 mm; ♀, 7.5–7.8 mm.

**Body.** Ground color from brown orange to brown red, with green marks more or less developed, at times covering whole dorsal surface with exception of few areas of ground color; velutinous, with metallic reflections as in *A. (E.) simillima*; tomentum and pilosity well developed and with almost same distribution as in *A. (E.) simillima*; mesepimeron mainly glabrous and without sculpture in male (sometimes with tomentum), with setigerous sculpture in female.

**Head.** Vertex velvety sometimes reaching clypeal disc; clypeus transverse, reborded and slightly bilobed in front; sculpture dense and strong, simple on disc and more or less confluent in front and laterally; vertex with smooth area and tomentum; large and very smooth vertical carina extending from vertex to clypeal disc, which is convex.

**Pronotum.** Transverse; lateral margins with very rounded lateral angles and regularly curved from posterior to anterior angles, reborded except in front of posterior angles; posterior margin strongly concave in front of scutellum, then bisinuate on



**Figure 16.** *Atrichelaphinis (Eugeaphinis) sternalis* (Moser, 1914), holotype (MNHU). **A** Dorsal view **B** ventral view **C** lateral view **D** parameres in dorsal view **E** parameres in lateral view **F** apex of parameres.

each side; sculpture very light, sometimes undiscernible, scattered on disc but slightly denser near the anterior angles, punctuation stronger in female; tomentose line along outer margins and two radial lines of three spots each at side of midline, sometimes extra spots between these and outer ones.

*Scutellum*. Longitudinal, acute to blunt, usually smooth but with few punctures in some specimens; grooved laterally, sides almost straight.

*Elytra*. With weak posthumeral emargination, reborded laterally; disc without tomentum and with sculpture consisting of simple to crescent small punctures forming simple striae and interstriae; dense horseshoe sculpture laterally, near humeral callus and apically; sutural apex acute, slightly protruding backwards in male but not in female.

*Pygidium*. With large tomentose spots and bands.

*Underside*. Shiny, with large tomentose areas on prosternum, procoxae, mesepimeron, metepimeron, metepisternum, sides of metasternum and abdomen; mesosternal apophysis finely punctate, not transverse, almost as wide as long, protruding in front of mesocoxae and orientated downwards; abdomen slightly concave in male and convex in female.

*Legs*. Shiny; meso- and metatibiae with carina on external side just below middle; female with protibiae and metatibial spurs enlarged, metatibiae stronger, metatarsomeres shorter and more robust than in male; metatibial spurs very thin and acute in male, very slightly enlarged and less acute but not blunt in female.

*Aedeagus*. Length of parameres less than twice their width, sides converging in front, apex rounded, not truncate and not bulbous laterally, incised in the mid downturning part of apex.

**Remarks.** This species is currently only known from Ethiopia. It is very close to *A. (E.) simillima* from which it can be separated through the sculpture of the dorsal side, the shape of the mesosternal apophysis and, to a lesser extent, the aedeagus. The *A. (Eugeaphinis)* species from Ethiopia are sometimes difficult to identify. For example, the Alexis Collection (IRSN) holds specimens from Lake Tana that exhibit a color pattern typical of *A. (E.) sternalis*; however upon close scrutiny they were found by the authors to resemble most closely *A. (E.) simillima*. However, the general body shape, the laterally bulbous apex of the parameres, the slightly more upturned anterior margin of the clypeus and the very weakly protruding mesosternal apophysis in front of the mesocoxae without downturning could cast some doubt over this identification. All the other characters are similar to those found in *A. (E.) simillima*. It is also possible that these specimens could represent either a new species, subspecies or just an hybrid between the two species. Another possibility is that of marked intraspecific variation. It may be necessary to study extensive series of specimens from more localities in order to resolve this issue conclusively.

### *Atrichelaphinis (Eugeaphinis) vermiculata* (Fairmaire, 1894)

Figure 17

*Elaphinis vermiculata* Fairmaire, 1894: 653–654; Kraatz 1895a: 381; Kraatz 1895b: 384; Preiss 1902: 99; Schenklng 1921: 304; Antoine 1991: 2; Antoine 2002: 186.

*Anelaphinis vermiculata* (Fairmaire) Antoine, 2002: 186.

*Atrichelaphinis vermiculata* (Fairmaire) Kraatz, 1898: 220; Schenklng 1921: 304; Antoine 2002: 186.

**Type specimen.** Holotype not traced.

**Redescription (n = 11).** Size: length ♂, 12.1–13 mm; ♀, 10.7–13.9 mm; width ♂, 6.7–7.6 mm ♀, 6.1–7.9 mm.

*Body.* Velutinous, from light brown with dark marks to dark green with dark brown areas, white small irregular spots scattered throughout, sometimes becoming confluent on lateral declivity of elytra, pronotum and pygidium; light pilosity usually present on vertex and lateral margins of pronotum, mesepimeron, elytral apex and pygidium; mesepimeron with sculpture and pilosity limited to anterior half, posterior half smooth.

*Head.* With median vertical smooth carina extending from vertex to clypeal disc; clypeus clearly transverse, anterior margin reborded in both sexes but not strongly raised, slightly incised in the middle, more strongly punctate laterally and in front, where punctuation becomes confluent; disc exhibiting smooth areas.

*Pronotum.* Octagonal; not tuberculate on anterior margin; lateral angles well marked but rounded; lateral margins completely reborded, with posterior half parallel; posterior angles rounded; sculpture of setigerous crescents, usually sparse and poorly pronounced on disc, but stronger in front and on lateral margins; posterior margin from straight to slightly concave in front of scutellum, lateral edges convex.

*Scutellum.* Not uniformly sculpted, laterally grooved, and with white tomentum.

*Elytra.* With lateral margins almost straight and parallel, posthumeral emargination weak; sculpture of strong and well marked horseshoe punctures sometimes confluent, especially in apical half; space between vertical lines of punctuation of same width, appearing not geminate; sutural apex blunt.

*Pygidium.* With white, small spots becoming confluent; light pilosity throughout.

*Underside.* Shiny, with small white spots on postero-lateral angles of sternites and metasternum, sometimes on the mesepimeron and metepimeron, some apical spots also on femora; pilosity long and thin, extending throughout surface except middle of metasternum and abdomen; mesosternal apophysis transverse, anterior margin straight, strongly compressed between mesocoxae and not protruding in front in lateral view; abdomen concave in male, convex in female, last sternite less sculpted at middle in male.

*Legs.* Metafemora sometimes with white spot of tomentum on underside close to joint; protibiae enlarged in female, meso- and metatibiae with transverse carina just after middle; metatibial spurs slender and more acute in male, larger and blunt in female.

*Aedeagus.* Parameres converging regularly at apex, without lateral expansions or modifications; apex with marked incision at middle of downturning margin.

**Remarks.** Most of the specimens analysed in this study originated from Erythrea (PCDC, PCSR, MNHN, MNHU). Although the type was not traced, all specimens match Fairmaire's (1894) original description. The species has also been reported from



**Figure 17.** *Atrichelaphinis (Eugeaphinis) vermiculata* (Fairmaire, 1894), male, Erythrea (PCSR). **A** Dorsal view **B** ventral view **C** parameres in dorsal view **D** parameres in lateral view **E** apex of parameres.

Ethiopia, locality confirmed through the study of one female labelled "Abyssinie, Tigray, Alitiena" (close to the Erythrean border) and one couple labelled "Abyssinien" in the MNHN collections.

***Atrichelaphinis (Eugeaphinis) bjornstadi* sp. n.**

<http://zoobank.org/ACCEC445-F973-4AED-A334-875219242983>

Figure 18

**Type specimens.** Holotype male: **Tanzania**, Mbulu, Mamamisara, 2000 m, J. Kielland leg, (Bjørnstad 34728), 6-III-1981 (IRSN). Paratypes: **Tanzania**, 1♂, same data as HT (Bjørnstad 34727) (PCSR); 4♂ 1♀, Babati D., Mt. Kwaraha, 1850 m, J. Kielland leg, 30-IV-1987 (Bjørnstad 35080, PCTG; Bjørnstad 35077-35079 and 35081, PCSR, PCRP and IRSNB); 1♀, Ngorongoro Crater, 2200 m, J. Kielland leg, 14-II-1980, (Bjørnstad 35052, PCSR); 1♀ same data as above but 2300 m (Bjørnstad 41980, PCAB).

**Description (n = 9).** Size: length ♂, 13.6–14.6 mm; ♀, 12–15 mm; width ♂, 7.9–8.5 mm; ♀, 7.1–8.7 mm.

*Body.* Velutinous, brown with green to dark green marks, with small white spots scattered throughout, sometimes becoming confluent on lateral declivity of elytra, pronotum and pygidium; light pilosity distributed on vertex, lateral margins of pronotum, apical part of elytra and pygidium; mesepimeron with sculpture and pilosity on whole surface.

*Head.* Clypeus slightly transverse, almost as long as wide, anterior margin reborded and slightly incised at middle; disc convex, regularly punctated on entire surface, except few small smooth areas, punctures denser and confluent laterally and in front.

*Pronotum.* Not tuberculate in front, with round and slightly detectable lateral angles; posterior half of lateral margins not parallel but convergent in front; posterior angles blunt; posterior margin strongly concave in front of scutellum, with lateral edges almost straight; sculpture of setigerous crescent punctures, almost absent on disc, denser in front and laterally.

*Scutellum.* Unsculpted, laterally grooved, with white tomentum.

*Elytra.* With lateral margins almost straight and parallel, posthumeral emargination weak; sculpture of thin and incomplete horseshoe punctures more developed laterally and at apex, sometimes confluent resulting in broken lines; lines of punctuation geminate; sutural apex acute.

*Pygidium.* With small white spots scattered throughout, becoming confluent.

*Underside.* Shiny, with white confluent tomentum laterally on anterior margin of sternites and on lateral sides of metasternum; pilosity long and thin; mesosternal apophysis transverse, anterior border slightly convex, strongly compressed between mesocoxae and not protruding in front in lateral view; abdomen concave in male, convex in female; last sternite less sculpted at middle in male.



**Figure 18.** *Atrichelaphinis (Eugeaphinis) bjornstadi* sp. n., holotype (PCSR). **A** Dorsal view **B** ventral view **C** parameres in dorsal view **D** parameres in lateral view **E** apex of parameres.

*Legs.* Metafemora sometimes with white spots of tomentum on underside close to joint; meso- and metatibiae with transverse carina just after middle; metatibial spurs thinner and more acute in male, larger and blunt in female.

*Aedeagus.* Parameres forming slight concavity at middle of lateral margins; without projections at apex, but with marked incision at middle of downturned frontal margin.

**Derivatio nominis.** This species is named after the Norwegian entomologist Anders Bjørnstad, who provided the type series for study.

**Remarks.** This species is most closely related to *A. (E.) vermiculata*, from which it can be separated mainly by the shape of the clypeus. It has also a distinct pronotum, with lateral margins strongly diverging in a posterior direction and the lateral angles obliterated, which also allow easy separation from *A. (E.) vermiculata*. Its elytra exhibit visible but relatively shallow sculpture. The species has so far only been recorded from northern Tanzania.

**Updated key to the species of the genus *Atrichelaphinis* Kraatz, 1898**

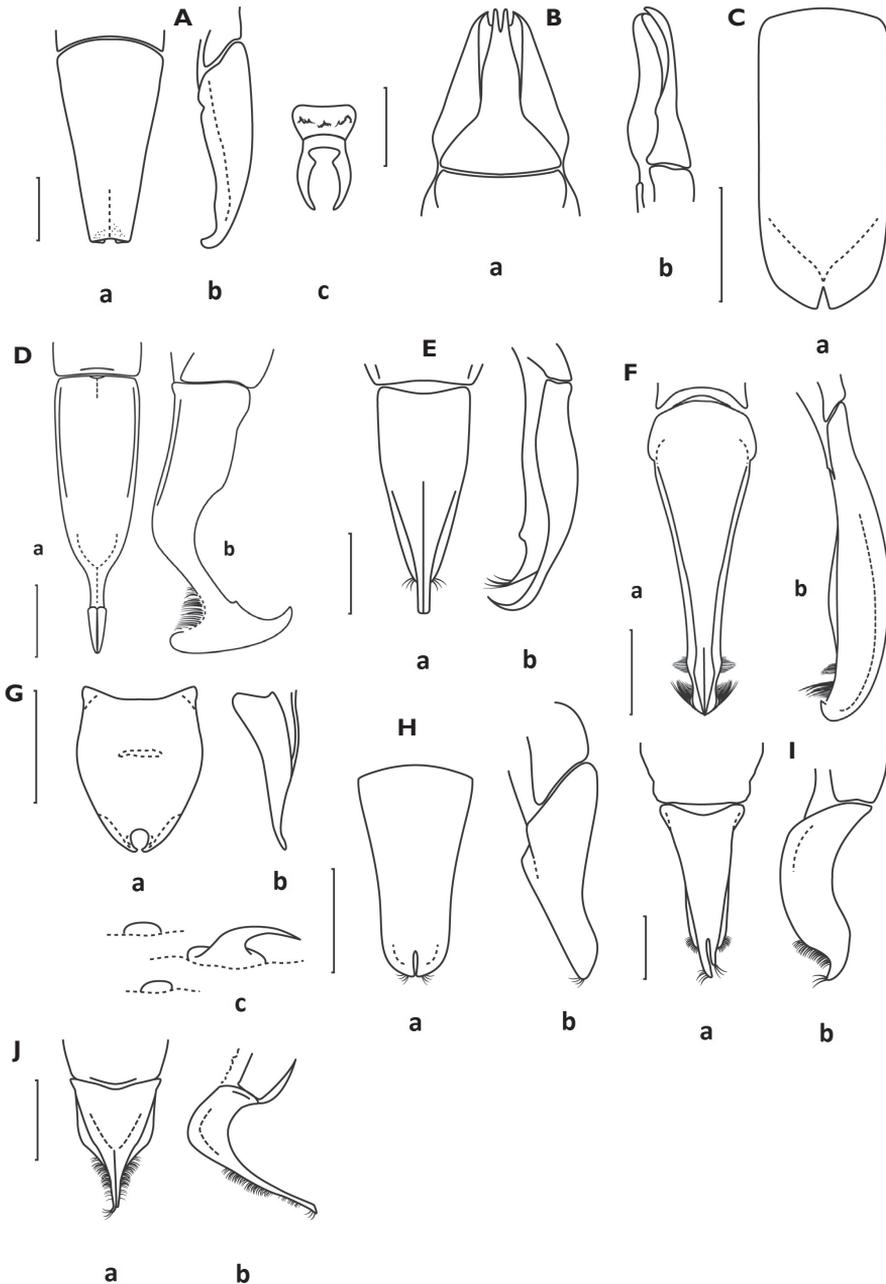
- Protibiae tridentate, with two apical teeth close to each other .....2
- Protibiae bi- or tridentate, with two apical teeth normally separated .....3
- 2 Pygidium with setae and small round sculpture; first two elytral striae consisting of double grooves (Figure 3) .....*A. (A.) tigrina* (Olivier, 1789)
- Pygidium with scattered crescent sculpture, asetose; first two elytral striae consisting of single grooves (Figure 4).....*A. (A.) nigropunctulata* (Péringuey, 1896)
- 3 Dorsum black, sometimes with red parts or with yellowish elytra; clypeus longer than wide; aedeagus with protrusion at middle of apex in dorsal view..... 4
- Dorsum never black, usually ground color light brown or green; clypeus transverse; aedeagus simple at apex, occasionally with lateral projections.....6
- 4 Elytra yellowish; parameres medially and laterally protruding (Figure 5, Figure 6B) ..... *A. (H.) quadripunctata* (Lansberge, 1882)
- Elytra black to dark brown; parameres protruding only medially ..... 5
- 5 Dorsum entirely black without red areas, mesosternal apophysis large; medial protrusion of parameres incised but without meatus (Figure 6C–F, Figure 7).....*A. (H.) nigra* Antoine, 2002
- Dorsum with red areas (pronotum, scutellum, pygidium and last sternites); medial protrusion of parameres more developed, deeply incised and with large meatus (Figure 6A)..... *A. (H.) sexualis* (Schein, 1956)
- 6 Pronotum tuberculate at middle of anterior margin.....7
- Pronotum not tuberculate.....9
- 7 Clypeus upturned in both sexes (less in female), apical half of scutellum punctate to striolate (Figure 12).....*A. (E.) bambooesbergica* sp. n.
- Clypeus upturned only in male, simply reborded in female, scutellum without sculpture on apical half..... 8
- 8 Protarsi longer than protibiae; metafemora and metatibiae strongly enlarged (Figure 13), metatibial spurs enlarged and blunt in both sex, spatuliform in female .....*A. (E.) garnieri* sp. n.
- Protarsi shorter than protibiae; metafemora and metatibiae slightly enlarged (Figure 11), metatibial spurs thin and acute in male, slightly enlarged and blunt in female .....*A. (E.) rhodesiana* (Péringuey, 1907)

- 9 Mesosternal apophysis prominent between mesocoxae and projecting downwards (in lateral view), lateral margins of pronotum incompletely reborded near posterior angles (Figure 16).....*A. (E.) sternalis* (Moser, 1914) 10
- Mesosternal apophysis not prominent between mesocoxae ..... 10
- 10 Apicosutural angle of elytra acute and projecting backward; species of small size (9–12 mm)..... 11
- Apicosutural angle of elytra not projecting backward; species of larger size (12 to 15 mm) ..... 12
- 11 Pronotum predominantly dark-brown, with light colour and white tomentum restricted to margins; with posterior border clearly concave in front of scutellum; elytra with two large lateral light brown areas adjacent to metacoxae, basal and apical parts dark; parameres converging towards apex, then more abruptly near apex, apex truncate in front (Figures 8, 9) . *A. (E.) deplanata deplanata* (Moser, 1907)
- Pronotum light in colour, dark markings reduced but white tomentose spots more widespread; posterior margin weakly concave in front of scutellum; elytra light brown with dark markings regularly distributed; parameres almost parallel towards apex, truncate in front forming blunt angles (Figure 10)..... *A. (E.) deplanata minettii* subsp. n.
- 12 Elytral sculpture well developed, showing series of regularly-spaced horseshoe punctures (Figure 17) ..... *A. (E.) vermiculata* (Lansberge, 1882)
- Elytral sculpture faint and incomplete, with intervals between punctures irregular..... 13
- 13 Posterolateral angles of metacoxae from subacute to blunt; medium size species usually with metallic sheen, elytra light brown with few, small dark marks; tomentum mainly restricted laterally on pronotum and elytra (Figure 15).....*A. (E.) simillima* (Ancy, 1883)
- Posterolateral angles of metacoxae widely rounded; larger species without metallic sheen on dorsum; ground colour brown with large green patches and white tomentum scattered on entire surface (Figure 18) .....*A. (E.) bjornstadi* sp. n.

**Key to the African genera of Cetoniini close to *Atrichelaphinis*, with completely or partially fused parameres.**

- 1 Parameres completely fused, except for occasional presence of small sinuosity or incision on downturning apical margin (frontal view); parameres with or without projections..... 2
- Parameres partially fused, with apex incised or modified (dorsal view) ..... 5
- 2 Internal sac of aedeagus with sclerites (Figure 19A).....*Heteralleucosma* Antoine, 1989
- Internal sac without sclerites ..... 3
- 3 Protibia tridentate, with two apical teeth close to each other (Figures 3, 4)...  
..... *Atrichelaphinis (Atrichelaphinis)* Kraatz, 1898

- Protibia bi- or tridentate, with two apical teeth widely separated; mesosternal apophysis transverse and flat ..... 4
- 4 Aedeagus with protrusion at middle of apex (dorsal view) (Figure 5) .....  
..... *Atrichelaphinis* (*Heterelaphinis*) **Antoine, 2002**
- Aedeagus simple at apex, but often exhibiting lateral projections (Figures 6–16)..... *Atrichelaphinis* (*Eugeaphinis*) **subgen. n.**
- 5 Internal sac of aedeagus without sclerites ..... 6
- Internal sac with sclerites ..... 11
- 6 Parameres flat and composed of two weakly sclerotized lateral lobes, with median azygous sclerotized lamina (Figure 19B) ..... *Niphetophora* **Kraatz, 1883**
- Parameres not as above ..... 7
- 7 Parameres flat ..... 8
- Parameres visibly convex in lateral view ..... 9
- 8 Parameres with small incised protrusion at middle of apex (Figure 5) .....  
..... *Atrichelaphinis* (*Heterelaphinis*) **Antoine, 2002**
- Parameres with apical incision exhibiting two lateral, slightly sclerotized triangular parts; anterior border of clypeus separated from disc by deep groove (Figure 19C)..... *Paranelaphinis* **Antoine, 1988**
- 9 Apex of parameres with expansion visible in lateral view (Figure 19D) .....  
..... *Molynoptera* **Kraatz, 1897**
- Apex of parameres not expanded..... 10
- 10 Apical end of parameres with sharp but thin hook visible in lateral view and protruding on ventral side (Figure 19E).... *Pseudalleucosma* **Antoine, 1989**
- Apical end of parameres without modifications visible in lateral view, round with setae on ventral side (Figure 19F)..... *Molynopteroides* **Antoine, 1989**
- 11 Internal aedeagal sac with three sclerites; parameres flat, incised at middle of apex and slightly sclerified laterally at apex (Figure 19G) .....  
..... *Phaneresthes* **Kraatz, 1894**
- Internal aedeagal sac with one or two sclerites..... 12
- 12 Sclerites composed of two bands; parameres almost flat, slightly thickened and curved in apical third from lateral view, with apex rounded and exhibiting small median incision (Figure 19H)..... *Paralleucosma* **Antoine, 1989**
- Only one sclerite present..... 13
- 13 Sclerite consisting of thin, ovoid, longitudinal and erect band; parameres usually with cavity on upper side just before apex, apex more or less modified at extremity, setae on ventral side virtually sclerified (Figure 1).....  
..... *Anelaphinis* **Kolbe, 1892**
- Sclerite not as above..... 14
- 14 Parameres subparallel, sharply narrowing before apex, sclerite with complex shape (Figure 19I)..... *Alleucosma* (*Alleucosma*) **Schenkling, 1921**
- Parameres triangular, regularly narrowing from base to upturned apex; sclerite small, oval or flat but not with complex shape (Figure 19J).....  
..... *Alleucosma* (*Eoalleucosma*) **Antoine, 1989**



**Figure 19.** Schematic outlines of parameres (**a** frontal; **b** lateral; **c** chitinous appendage). **A** *Heteralleucosma insignis* Antoine, 1989 **B** *Niphetophora hildebrandti hildebrandti* (Harold, 1878) **C** *Paranelaphinis signata* Antoine, 1988 **D** *Molynoptera multiguttata* Kraatz, 1897 **E** *Pseudalleucosma machatschkei* (Ruter, 1960) **F** *Molynopteroides guttiventris* (Moser, 1914) **G** *Phaneresthes flavovariegata* Kraatz, 1894 **H** *Paralleucosma glycyphanoides glycyphanoides* (Moser, 1908) **I** *Alleucosma (Alleucosma) viridula* (Kraatz, 1880) **J** *Alleucosma (Eoalleucosma) duvivieri* (van der Poll, 1890) (Figure **C** after Antoine 1988; Figures **G** after Antoine 1989). Scale bar = 1 mm.

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# Review of the genus *Apotrechus* in China (Orthoptera, Gryllacrididae, Gryllacridinae)

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## Abstract

In the present paper, the genus *Apotrechus* Brunner-Wattenwyl, 1888 is revised. Two new species from China are described and illustrated: *Apotrechus quadratus* **sp. n.** and *Apotrechus truncatolobus* **sp. n.**. A new key and the distributional data are given.

## Keywords

Gryllacrididae, Gryllacridinae, *Apotrechus*, new species, China

## Introduction

The genus *Apotrechus* was proposed by Brunner-Wattenwyl (1888), with the type species *Apotrechus unicolor* Brunner-Wattenwyl, 1888. This genus resembles the genus *Eremus* Brunner-Wattenwyl, 1888, but differs from the latter in: smooth frons, spineless hind tibia and absence of male styli. Liu and Yin (2002) first studied *Apotrechus* in China, described one new species *A. nigrigeniculatus*. Liu and Bi (2008) gave a key of *Apotrechus* from China containing three species, and two new species *A. digitatus* and *A. fallax* were illustrated. Besides, Liu et al. (2010) also reported one new species

*A. transversus* from Zhejiang. Subsequently, Guo and Shi (2012) reviewed this genus of China and also provided a key containing six species in China which included one new species *A. bilobus*, and one new combination *A. parvospinus*.

Bian et al. (2014) provided a key to the species with one new species *A. trilobus* and the morphological photographs for five Chinese known species in this paper.

So far, the genus *Apotrechus* includes nine species in the world, among them, *A. unicolor* Brunner-Wattenwyl, 1888, *A. swinhoei* (Griffini, 1909), and *A. illawarra* Rentz, 1990 are recorded in Australia; *A. insolitus* (Walker, 1869) is distributed in Vietnam and others are recorded in China. In this paper, two new species of *Apotrechus* are identified and described, namely *Apotrechus quadratus* sp. n. and *A. truncatolobus* sp. n., which are distributed in Guangxi.

## Material and methods

All specimens of the genus were collected by light-trapping and net-catching from China. Adult specimens were preserved in 70% ethanol in the field, then removed and dried in the lab. The specimens were observed with the help of a Leica MZ 12.5 dissecting microscope and illustrated with the aid of a drawing tube attached to the microscope. Line drawings were made with Adobe Illustrator CS 6 graphic software. The length of the body was measured mesally by the distance between apex of fastigium verticis and posterior margin of tenth abdominal tergite, ovipositor by distance between base of subgenital plate and apex of ovipositor; pronotum, tegmina and hind femora by distance between summit of base and apex. All lengths are presented in millimeters. The venation nomenclature used in this paper is based on the interpretation of Karny (1937). All type specimens recorded here are deposited in the Shanghai Entomology Museum, the Chinese Academy of Sciences.

## Taxonomy

### Genus *Apotrechus* Brunner-Wattenwyl, 1888

urn:lsid:orthoptera.speciesfile.org:TaxonName:21786

*Apotrechus*: Brunner-Wattenwyl 1888: 383; Tepper 1892: 167; Kirby 1906: 152; Ramme 1933: 416; Karny 1937: 82; Rentz and John 1990: 1083; Liu and Bi 2008: 11, figs 1–5; Liu et al. 2010: 64; Guo and Shi 2012: 52.

**Type species.** *Apotrechus unicolor* Brunner-Wattenwyl, 1888.

**Generic diagnosis.** Body small, wings absent. Fastigium of vertex rather wide than scape, without lateral carinae; frons smooth, ocelli inconspicuous. Fore and mid tibiae with 4–5 pairs of spurs on ventral surface, mid tibia without inner upper apical spur on dorsal surface. Hind tibia armless or with rather small spine on ventral surface. Subgenital plate of male without styli. Ovipositor rather short, upcurved.

**Key to the Chinese species of the genus *Apotrechus***

- 1 Fore and mid femora with black apical part ..... 2
- Fore and mid femora without black apical part ..... 5
- 2 External margin of hind femur without spine; lobes of male subgenital plate with acute apex ..... ***A. trilobus* Bian & Shi, 2014**
- External margin of hind femur with spines ..... 3
- 3 Body smaller, about 14–18 mm long ..... 4
- Body larger, about 23 mm long; hind margin of female subgenital plate slightly concave ..... ***A. quadratus* sp. n.**
- 4 Male 9<sup>th</sup> abdominal tergite deeply excised; hind margin of female subgenital plate truncated ..... ***A. nigrigeniculatus* Liu & Yin, 2002**
- Male 9<sup>th</sup> abdominal tergite shallowly excised; hind margin of female subgenital plate rounded ..... ***A. fallax* Liu & Bi, 2008**
- 5 Frons without blackish longitudinal stripe; lobes of male 9<sup>th</sup> abdominal tergite with roundly truncate apex ..... ***A. truncatolobus* sp. n.**
- Frons with 2–3 blackish longitudinal stripes; lobes of male 9<sup>th</sup> abdominal tergite with acute apex ..... 6
- 6 Frons smooth ..... 7
- Frons sunken; dorsal side of hind tibia armed with 3 external and 2 internal spines ..... ***A. parvospinus* (Liu & Yin, 2002)**
- 7 Frons with 2 blackish longitudinal stripes; male subgenital plate with incurved lobes; female subgenital plate a bit broader than long ..... 8
- Frons with 3 blackish longitudinal stripes; male subgenital plate with straight lobes; female subgenital plate transverse, ovipositor with lateral lobes at base ..  
..... ***A. transversus* Liu et al., 2010**
- 8 Lobes of male subgenital plate with finger-shaped apex; ovipositor without lateral lobes at base ..... ***A. digitatus* Liu & Bi, 2008**
- Lobes of male subgenital plate with broadly rounded apex; ovipositor with lateral lobes at base ..... ***A. bilobus* Guo & Shi, 2012**

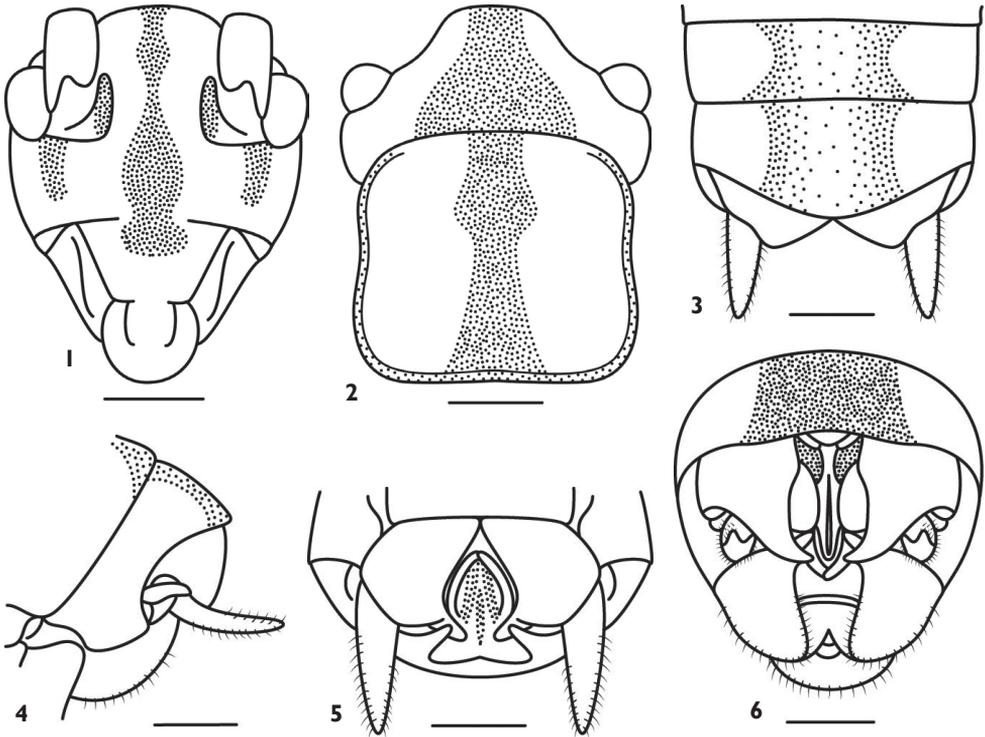
**1. *Apotrechus trilobus* Bian & Shi, 2014**

<http://zoobank.org/4DA1028E-49F8-4F99-A0ED-F632A4BFC4C3>

Figs 1–6

*Apotrechus trilobus*: Bian et al. 2014: 384–386.

**Description.** Male. Body medium sized. Wings absent. Fastigium of vertex rounded, about 2 times as wide as scape; eyes reniform, prominent; ocelli inconspicuous. Pronotum almost hexagon, paranota lower. Fore coxa with a spine, fore tibia on ventral surface with 5 pairs of spurs (included 1 pair of apical spurs); mid tibia without inner upper apical spur but with 4 pairs of spurs (included 1 pair of apical spurs) on ventral surface. Ventral



**Figures 1–6.** *Apotrechus trilobus* Bian & Shi, 2014. **1** head in frontal view **2** head and pronotum in dorsal view **3** end of male abdomen in dorsal view **4** end of male abdomen in lateral view **5** end of male abdomen in ventral view **6** end of male abdomen in caudal view. Scale: 1 mm.

surface of hind femur with 10–11 internal spines, but without external spine, hind tibia unarmed or with 1–2 minute spines on dorsal surface, bearing 3 pairs of apical spurs. 9<sup>th</sup> abdominal tergite divided into two lobes, which bearing spine-like apex pointing downwards, epiproct medially furrowed (Fig. 5). Cerci shorter, conical; subgenital plate broad, hind margin split into two lobes, apex of lobes spine-like, curved inside (Fig. 6).

Female. Unknown.

**Coloration.** Body infusate. Fastigium of vertex with darkish black longitudinal band; frons with 3 blackish longitudinal stripes, middle stripe broad, not connected with the longitudinal band of fastigium of vertex (Figs 1–2); inner margin of antenna foveolae and first segment with blackish spots. Pronotum with a darkish black longitudinal band in the middle and all margins black. Apex of fore and middle femora black, hind femur with a blackish longitudinal stripe on external surface, all tibiae darkish black on the base and apex.

**Measurements.** (length in mm)

	Body	Pronotum	Hind femur	Ovipositor
♂	16.0	3.8	10.0	–

**Material.** 1♂, Yunnan, Pingbian, Yuping, 2000m, 20.V.2009, Xian-Wei Liu et al. leg.

**Distribution.** China: Yunnan.

**2. *Apotrechus quadratus* Li & Liu, sp. n.**

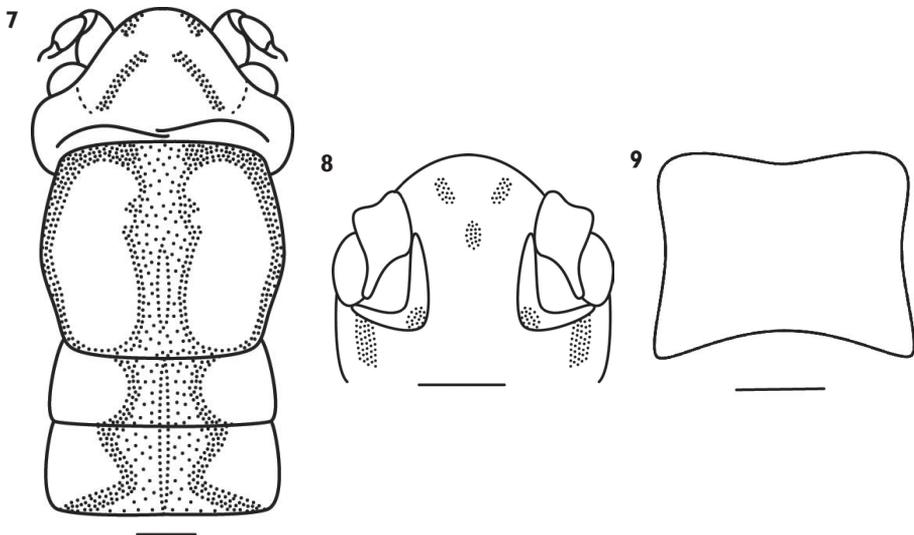
<http://zoobank.org/F5255058-CCB5-4734-9157-89E36EB98A9E>

Figs 7–9

**Description.** Female. Body large. Wings apterous. Fastigium of vertex roundly projected, about 2 times as wide as scape; eyes reniform, produced; ocelli faintly. Pronotum almost hexagon, lateral lobes longer than high. Fore coxa with a spine, fore tibia on ventral surface with 5 pairs of spurs (included 1 pair of apical spurs) but without inner upper apical spur; mid tibia on ventral surface with 4 pairs of spurs (included 1 pair of apical spurs). Hind femur on ventral surface armed 8 internal spines and 1–3 external spines; hind tibia on dorsal surface bearing 6 pairs of rather small spines and 2 pairs of apical spurs. Cerci shorter, conical; subgenital plate broad, square, and hind margin slightly concave (Fig. 9). Ovipositor short, curved upwards, apex blunt.

Male. Unknown.

**Coloration.** Body yellowish brown. Fastigium of vertex with 2 pairs of darkish black longitudinal bands; frons with 3 blackish longitudinal spots; inner margin of basal antenna and first segment with blackish spots. Lateral and fore margin of pronotum black, in the middle with a darkish black vertical stripe. Mesonotum and metanotum also with a black spot at middle parts (Figs 7–8). Hind femur with a blackish longitudinal stripe on external surface, all tibiae on base and apex darkish black.



**Figures 7–9.** *Apotrechus quadratus* sp. n. **7** head and pronotum in dorsal view **8** frons in front view **9** subgenital plate of female in ventral view. Scale: 1 mm.

**Measurements.** (length in mm)

	Body	Pronotum	Hind femur	Ovipositor
♀	23.0	4.8	10.5	5.5

**Material.** Holotype ♀, Guangxi, Xing'an, Maoer Mountain, 1700–2100m, 30.VII–6.VIII. 2013, Xian-Wei Liu et al. leg.

**Distribution.** China: Guangxi.

**Diagnosis.** This new species is closely related to *A. nigrigeniculatus* Liu & Yin, 2002, but differs mainly in the the latter in body larger and subgenital plate of female with hind margin slightly concave.

**Etymology.** The specific epithet refers to shape of female subgenital plate.

**3. *Apotrechus nigrigeniculatus* Liu & Yin, 2002**

urn:lsid:orthoptera.speciesfile.org:TaxonName:21789

Figs 10–11

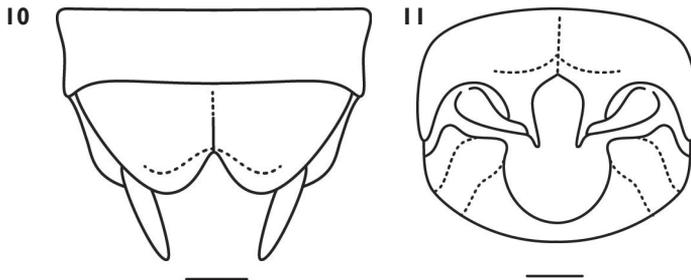
*Apotrechus nigrigeniculatus*: Liu and Yin 2002: 418; Guo and Shi 2012: 53; Bian et al. 2014: 383.

**Measurements.** (length in mm)

	Body	Pronotum	Hind femur	Ovipositor
♂	15.0–16.5	3.5	9.0–10.0	–
♀	14.0	3.7	7.5	5.0

**Material.** 2♂♂, Sichuan, Emei Mountain, 1840m, 16.VIII.1985, Gen-Tao Jin leg..

**Distribution.** China: Sichuan.



**Figures 10–11.** *Apotrechus nigrigeniculatus* Liu & Yin, 2002. **10** end of male abdomen in dorsal view **11** end of male abdomen in caudal view. Scale: 1 mm.

**4. *Apotrechus fallax* Liu & Bi, 2008**

urn:lsid:orthoptera.speciesfile.org:TaxonName:21787

Figs 12–16

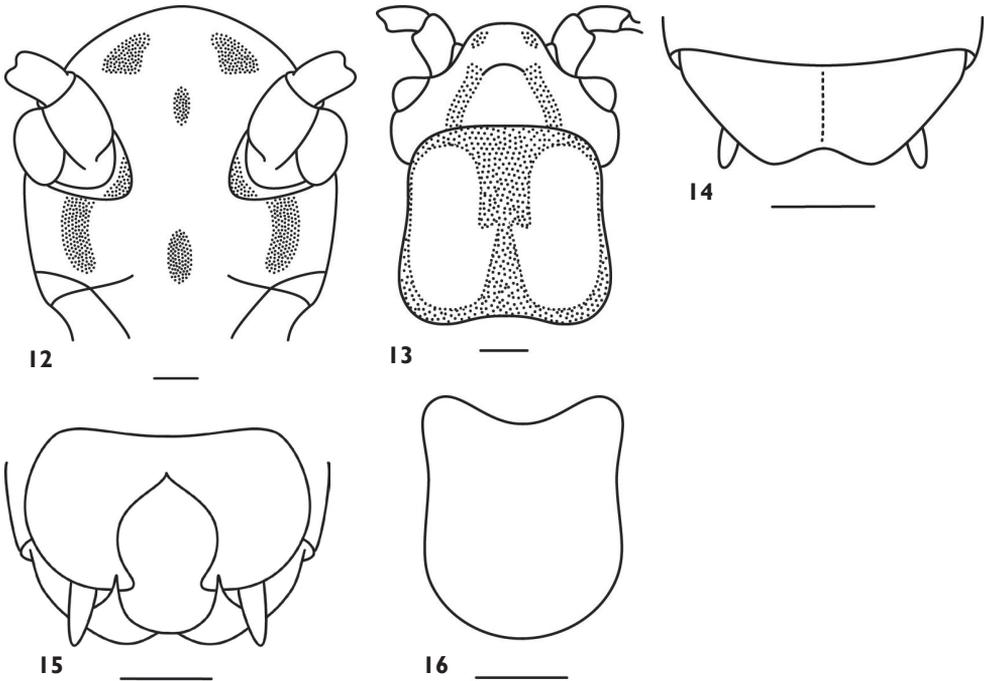
*Apotrechus fallax*: Liu and Bi 2008: 13, figs 1–5; Guo and Shi 2012: 53; Bian et al. 2014: 382.

**Measurements.** (length in mm)

	Body	Pronotum	Hind femur	Ovipositor
♂	14.0	3.8	8.0	–
♀	18.0	3.8	8.0	5.5

**Material.** 1♀, Guizhou, Leigongshan, 1620–2178m, 2.VIII.2004, Pian Xu leg.; 1♂, Guizhou, Leigong Mountain, 1000–1100m, 2–3.VI.2005, Zheng-Guang Zhang leg.; 2♂♂, Guizhou, Jiangkou, Fanjingshan, 1200–1800m, 6.VIII.2014, Miao-Miao Li & Mei-Ling Sun leg..

**Distribution.** China: Guizhou.



**Figures 12–16.** *Apotrechus fallax* Liu & Bi, 2008. **12** head in frontal view **13** head and pronotum in dorsal view **14** end of male abdomen in dorsal view **15** end of male abdomen in ventral view **16** subgenital plate of female in ventral view. Scale: 1 mm.

**5. *Apotrechus truncatolobus* Li & Liu, sp. n.**

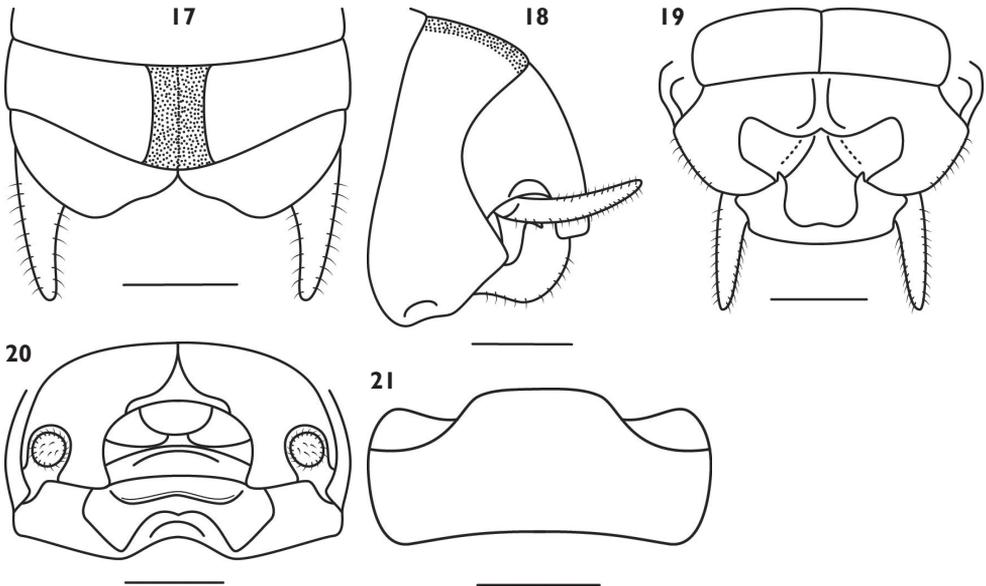
<http://zoobank.org/76C1D15F-B014-454D-855A-365A94B4E267>

Figs 17–21

**Description.** Male. Body medium sized. Wings absent. Fastigium of vertex rounded, about 2 times as wide as scape; eyes ovoid, prominent, ocelli inconspicuous. Cephalic margin of pronotum slightly projected, posterior margin slightly truncated, lateral lobes lower. Fore coxa with a spine, fore tibia on ventral surface with 5 pairs of spurs (included 1 pair of apical spurs); mid tibia without inner upper apical spur but on ventral surface with 4 pairs of spurs (included 1 pair of apical spurs); hind tibia without spine or on dorsal surface with 1–2 minute spines, with 3 pairs of apical spurs. Hind femur with 10–12 internal spines and 7–8 external spines on ventral surface. Lobes of 9<sup>th</sup> abdominal tergite with roundly truncated apex (Fig. 20); cerci shorter, conical; subgenital plate broad, hind margin split into two lobes and with notch in the middle (Figs 18–19).

Female. Cerci short, conical; subgenital plate strongly transverse, with straight hind margin and rounded postero-lateral corner (Fig. 21). Ovipositor shorter than hind tibia, upcurved and with blunt apex.

**Coloration.** Body yellowish brown, occiput slightly with darkish black. Frons without blackish longitudinal stripes; dorsal margin of abdominal with a darkish black longitudinal band in the middle (Fig. 17). Apex of fore femur, base and apex of tibiae slightly darkish black.



**Figures 17–21.** *Apotrechus truncatolobus* sp. n. **17** end of male abdomen in dorsal view **18** end of male abdomen in lateral view **19** end of male abdomen in ventral view **20** end of male abdomen in caudal view **21** subgenital plate of female in ventral view. Scale: 1 mm.

**Measurements.** (length in mm)

	Body	Pronotum	Hind femur	Ovipositor
♂	16.0	3.5	9.0	–
♀	18.0	3.8	9.0	6.0

**Material.** Holotype ♂, paratype 1♂1♀, Guangxi, Wuming, Daming Mountain, 1200m, 28–31.VII.2012, Wen-Xuan Bi leg.

**Distribution.** China: Guangxi.

**Diagnosis.** This new species almost the same as its congeners, but the frons without blackish longitudinal stripe; lobes of male 9<sup>th</sup> abdominal tergite with roundly truncate apex.

**Etymology.** The specific epithet refers roundly truncate lobes of male 9<sup>th</sup> abdominal tergite.

**6. *Apotrechus parvospinus* (Liu & Yin, 2002)**

urn:lsid:orthoptera.speciesfile.org:TaxonName:73813

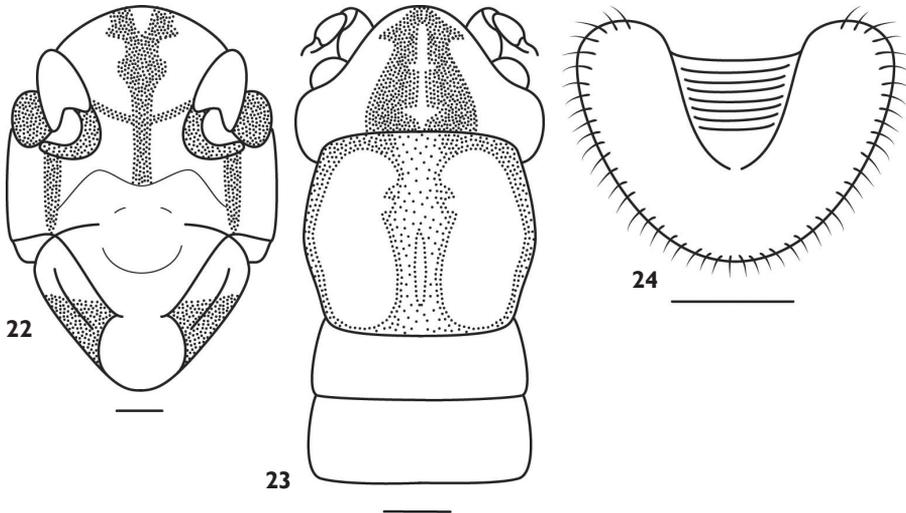
Figs 22–24

*Eremus parvospinus*: Liu and Yin 2002: 417.

*Apotrechus parvospinus*: Guo and Shi 2012: 53; Bian et al. 2014: 384.

**Measurements.** (length in mm)

	Body	Pronotum	Hind femur	Ovipositor
♂	20.0	3.7	8.6	–
♀	20.0	4.0	9.5	5.0



**Figures 22–24.** *Apotrechus parvospinus* (Liu & Yin, 2002). **22** head in frontal view **23** head and pronotum in dorsal view **24** subgenital plate of female in ventral view. Scale: 1 mm.

**Material.** 1♀, Guangxi, Xing'an, Maoer Mountain, 1000m, 22–23.VIII.1992, Xian-Wei Liu & Hai-Sheng Yin leg..

**Distribution.** China: Guangxi.

**7. *Apotrechus transversus* Liu et al., 2010**

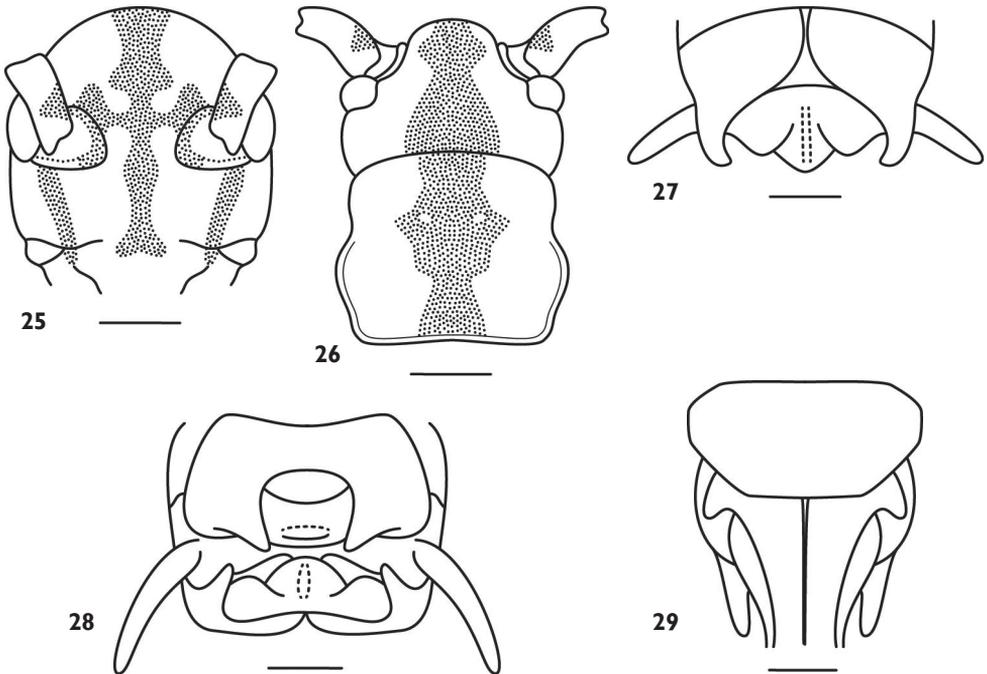
urn:lsid:orthoptera.speciesfile.org:TaxonName:73811

Figs 25–29

*Apotrechus transversus*: Liu et al. 2010: 65, figs 8a–c; Guo and Shi 2012: 53; Bian et al. 2014: 384.

**Measurements.** (length in mm)

	Body	Pronotum	Hind femur	Ovipositor
♂	14.0	3.0	7.0	–
♀	19.0–20.0	3.5–3.8	7.5–8.0	5.0–6.0



**Figures 25–29.** *Apotrechus transversus* Liu et al., 2010. **25** head in frontal view **26** head and pronotum in dorsal view **27** end of male abdomen in dorsal view **28** end of male abdomen in caudal view **29** end of female abdomen in ventral view. Scale: 1 mm.

**Material.** 1♂1♀, Zhejiang, Longquan, Fengyanshan, 1400m, 27.VII.2007, Qiang Fu leg.; 2♀♀, Zhejiang, Longquan, Fengyanshan, Huangmaojian, 1500–1900m, 31.VII–2.VIII.2008, Xian-Wei Liu & Wen-Xuan Bi.

**Distribution.** China: Zhejiang.

**8. *Apotrechus digitatus* Liu & Bi, 2008**

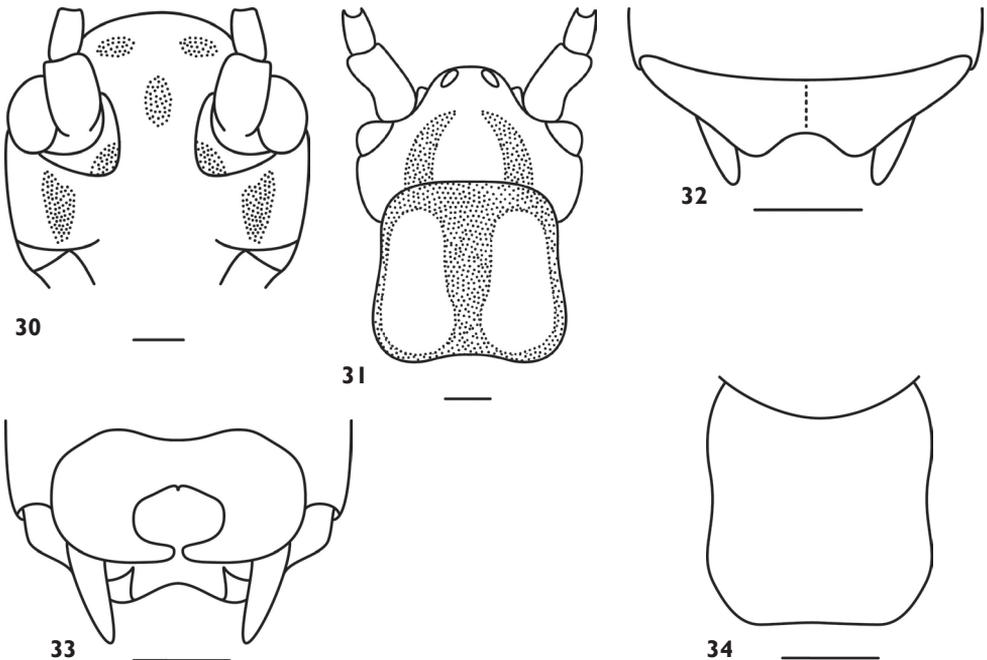
urn:lsid:orthoptera.speciesfile.org:TaxonName:21788

Figs 30–34

*Apotrechus digitatus*: Liu and Bi 2008: 12, figs 1–5; Guo and Shi 2012: 53; Bian et al. 2014: 381.

**Measurements.** (length in mm)

	Body	Pronotum	Hind femur	Ovipositor
♂	15.0	4.0	9.0	–
♀	19.0	4.5	9.0	5.5



**Figures 30–34.** *Apotrechus digitatus* Liu & Bi, 2008. **30** head in frontal view **31** head and pronotum in dorsal view **32** end of male abdomen in dorsal view **33** end of male abdomen in ventral view **34** subgenital plate of female in ventral view. Scale: 1 mm.

**Material.** 1♀1♂, Guizhou, Leigong Mountain, 1620–2178m, 2.VIII.2004, Kai Yan & De-Yan Ge leg.

**Distribution.** China: Guizhou.

### 9. *Apotrechus bilobus* Guo & Shi, 2012

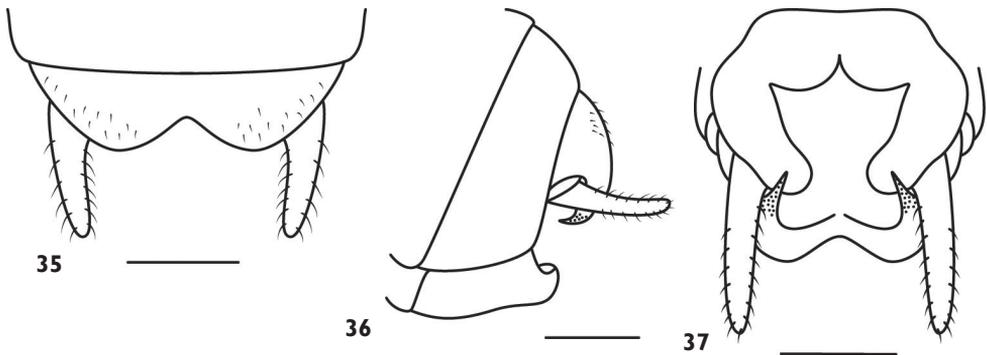
urn:lsid:orthoptera.speciesfile.org:TaxonName:73812

Figs 35–37

*Apotrechus bilobus*: Guo and Shi 2012: 55, figs 1–5, 12–13, 17–18; Bian et al. 2014: 380–381.

**Measurements.** (length in mm)

	Body	Pronotum	Hind femur	Ovipositor
♂	15.0–17.5	3.5	8.0–9.5	–
♀	20.0–22.0	4.0–4.2	9.0	4.7–5.0



**Figures 35–37.** *Apotrechus bilobus* Guo & Shi, 2012. **35** end of male abdomen in dorsal view **36** end of male abdomen in lateral view **37** end of male abdomen in ventral view. Scale: 1 mm.

**Material.** 1♂, Zhejiang, Lin'an, Xitianmu Mountain, 1140m, 28.VII–2.IX.2010, Hui Pan leg.

**Distribution.** China: Zhejiang.

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