**REVIEW ARTICLE** 



# On the uncertainty beneath the name Oithona similis Claus, 1866 (Copepoda, Cyclopoida)

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#### Abstract

The marine cyclopoid *Oithona similis sensu lato* Claus, 1866, is considered to be one of the most abundant and ubiquitous copepods in the world. However, its minimal original diagnosis and the unclear connection with its (subjective) senior synonym *Oithona helgolandica* Claus, 1863, may have caused frequent misidentification of the species. Consequently, it seems possible that several closely related but distinct forms are being named *O. similis* or *O. helgolandica* without explicit and accurate discrimination. Here the current situation concerning the correct assignment of the two species is revised, the morphological characters commonly used to identify and distinguish each species are summarized, and the nomenclatural implications of indiscriminately using these names in current taxonomic and ecological practice is considered. It is not intended to upset a long-accepted name in its accustomed meaning but certainly the opposite. "In pursuit of the maximum stability compatible with taxonomic freedom" (International Commission of Zoological Nomenclature), we consider that reassessment of the diagnostic characters of *O. similis sensu stricto* cannot be postponed much longer. While a consensus on taxonomy and nomenclatural matters can be attained, we strongly recommend specifically reporting the authority upon which the identification of either *O. similis* s.l. or *O. helgolandica* s.l. has been accomplished.

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#### **Keywords**

Nomenclature, Oithona helgolandica Claus, 1863, Oithona similis Claus, 1866, sequence databases, taxonomy

# Introduction

A global-scale baseline assessment of marine zooplankton biodiversity is critically needed to provide a contemporary benchmark against which future environmental changes can be evaluated (Bucklin et al. 2011). The largest obstacle for most zooplankton taxa is the difficulty in identifying specimens, which has resulted in marked underspecification of species and morphological types. The small cyclopoid *Oithona similis* Claus, 1866 is recognized as one of the most important marine copepods in terms of both abundance and breadth of distribution, occupying a key position in the global oceans (Galliene and Robins 2001). However, there is still much confusion regarding not only characters for its recognition but also its name.

*Oithona similis* was first described by Claus in 1866 from specimens collected in the Mediterranean Sea, near Nice, France. Three years earlier, the same author had described a very similar congener from waters off Helgoland (North Sea) that he named *O. helgolandica* (Claus 1863). The original description of the two species were too brief, unfortunately, to allow for adequate discrimination of the two species, and the synonymy between them has been under discussion ever since.

In our opinion, a rather confusing subjective synonymy of the two names has developed in recent practice, and the junior name *similis* has been imposed over *helgo-landica* by prevailing usage, which is in clear contravention of the Principle of Priority (International Commission on Zoological Nomenclature, hereafter ICZN 1999, Article 23). Both specific names have coexisted since 1866, and both are currently in use depending upon authors' taxonomic judgment. In our own experience, the replacement of the name *O. helgolandica* by *O. similis* has very often been requested by reviewers located worldwide, even when there is the possibility that the two names may refer to two distinctive taxa.

Among contemporary records, references to *O. similis* are plentiful from almost everywhere in the world's oceans (Razouls et al. 2005–2015), while references to *O. helgolandica* appear to be restricted to relatively few regions: NW and N Iberian shelf (e.g., Cabal et al. 2008), Gulf of Lion (e.g., Razouls 1972), Ligurean Sea (e.g., Pane et al. 2005), Tyrrhenian and Ionian seas (e.g., Vaissiere and Seguin 1980), SW Mediterranean Sea and Atlantic coast of Morocco (e.g., Hafferssas and Seridji 2010) and Red Sea (e.g., Vaissiere and Seguin 1980). In the SW Atlantic both names have been recorded: *Oithona similis* has been used by, for example, Pallares (1968), Björnberg (1981), Mazzochi et al. (2012), Cepeda et al. (2012), Thompson et al. (2012), and *O. helgolandica* by, for example, Ramírez (1970), Sabatini and Martos (2002), Viñas et al. (2013), Antacli et al. (2014), and Temperoni et al. (2014).

New approaches such as molecular tools are becoming increasingly attractive for identifying plankton. Advancements, however, depend largely on the provision of reference libraries with sequences coming from accurately identified individuals (Lindeque et al. 2013). There is the urgent need to clarify these issues, so both morphological and metagenetic global databases can be refined before upcoming studies enhance the current confusion. Rather than trying to prove a point, we review here the historical debate going back to the assignment of the two specific names, summarize the arguments that give support to the hypothesis that *O. similis* and *O. helgolandica* are not truly objective synonyms and discuss the implications of using both names in present times without exacting discrimination. "In pursuit of the maximum stability compatible with taxonomic freedom" (ICZN 1999; Principle #4), we consider that reassessment of the diagnostic characters of *O. similis* s.s. and *O. helgolandica* s.s. cannot be postponed.

#### Historical background

Original diagnoses of *O. helgolandica* and *O. similis* were in both cases brief and mainly based on the comparison with a third species, *O. spinirostris* Claus, 1863 (= *O. plu-mifera* Baird, 1843). Actually, the first description of the older species *O. helgolandica* makes real sense only when simultaneously looking at drawings by the same author of female *O. spinirostris* from Messina (Italy) (Claus 1863: Plate XI, figs 4–9). Only the male abdomen, antenna and antennule of *O. helgolandica* were figured by Claus in the same plate (Plate XI, figs 10–12). Regarding *O. similis*, Claus's first characterization from specimens collected off Nice was even less complete, and no drawings were provided. Unfortunately, Claus never wrote a comparison of the two species and, to our knowledge, he never deposited any type material for either in a museum.

When studying the copepod fauna from Naples, Giesbrecht (1893) realized that the species *O. spinirostris* described by Claus from Messina and Nice, as well as the one that he was himself recording from waters off Naples at that moment, were actually identical to *O. plumifera* Baird, 1843, although different from the Kiel specimens he had erroneously identified earlier as *O. spinirostris* (Giesbrecht 1881).

Giesbrecht (1893) identified another small form from Naples that he had recorded before as *O. similis* Claus off southern Chile and in the Indian Ocean (Giesbrecht 1891a, 1891b). Only then did he notice the close resemblance between the *O. similis* specimens from Naples and those collected earlier at Kiel. In fact, only the antennule length prevented him from considering both forms to be identical to *O. helgolandica* Claus (Giesbrecht 1893: 539). He described and figured the adult female and male of Neapolitan specimens, thus offering the first detailed description of *O. similis* and a comparison with all other congeners recognized at the time. It is worth highlighting that Giesbrecht also commented extensively on the identity and synonymy between *O. similis* from Naples and Kiel and *O. helgolandica* from Helgoland. Being unable to conclude, he expressed his doubts with question marks when listing synonyms of *O. similis* Claus (Giesbrecht 1893 : 537) and suggested the possibility that the majority of the species recorded in the North Atlantic would be (literally) "*O. helgolandica* Claus = ? *spinirostris* Giesbrecht, 1881 = *O. similis* Claus". As this reads, he gave priority to *O. helgolandica* over *O. similis*.

Overlooking Giesbrecht's hesitation and without any factual justification for his judgment, Farran (1913) accepted *O. similis* as a good species and excluded *O. helgo-landica* (and all other synonyms suggested to that date) from his key for the identification of *Oithona* and *Paroithona*. All known species at the time were therein listed and classified based upon the presence/absence of a rostrum and the external exopod setation of the swimming legs. Farran's deliberate omission of *O. helgolandica* and his oversimplification of characters for the classification of *Oithona* species probably have been applied many times until the present day.

In the same year, Sars (1913) recorded the form occurring abundantly in the fjords and offshore waters of Norway as *O. helgolandica*. In his opinion, *O. helgolandica* was unmistakably identical with *O. similis*. Sars stated then that the former name should be retained in accord with the rules of priority. He extended this synonymy to the doubtful species from Kiel that Giesbrecht (1881) had initially identified as *O. spinirostris*. It may turn out to be non-trivial that the specimens from New Zealand, also examined by Sars (1913), showed no apparent difference from the northern species. In line with Sars, Scott (1914) also alluded to *O. helgolandica* in referring to animals collected off Argentina near to the Malvinas Islands in the SW Atlantic.

In contrast, Rosendorn (1917) named the form he had collected off Chile as *O. similis*, although in this case after Giesbrecht's (1893) description which was based on Neapolitan specimens. While Chilean males fit the description of Mediterranean specimens well, the females differed slightly in the exopod setation of legs 1 and 4. In Rosendorn's own words, "Giesbrecht probably overlooked the distal outer spine on the third segment of leg 4, as well as one inner seta on the third segment of leg 1" (Rosendorn 1917: 24) (Table 1).

In a surprising twist, Sars (1918) radically changed his former opinion and, "on a closer consideration," he concluded that "the two forms recorded by Claus under the names *O. helgolandica* and *O. similis* are in reality very distinct species, the former being in all probability identical with the form subsequently described by Giesbrecht as *O. nana*, which accordingly must bear the older name *helgolandica*." For the Norwegian form "the specific name *similis* given by Claus ought of course to be retained" (Sars 1918: 207).

More recently, Crisafi (1959) reviewed the historical sequence and concluded that *O. similis* should be regarded as synonymous with *O. helgolandica* on the grounds that the singular characters for the junior name, *O. similis*, in Claus's diagnosis were insufficient to establish a new species. Nishida et al. (1977: 151) also discussed the issue but suggested, on the contrary, that the name *helgolandica* "should be rejected because of uncertainty and that Giesbrecht's (1893) description of *O. similis* is accepted as a good species". As did Crisafi (1959), we believe that Claus was unable to find the set

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Species name <sup>a</sup>			Sw	imming legs setatic	h	
Location Reference	Sex TL	Antennule	P1	P2	P4	Urosome
<b>O. helgolandica</b> Helgoland (North Sca) (Claus 1863)	F 0.75	"Hardly reaching the end of thorax"	pu	ри	pu	Ur4 shorter than Ur3 and almost as long as Fu. Fu with short setae
<b>O. similis</b> Nice (Mediterranean Sea) (Claus 1866)	F~1.0	"Nearly reaching the base of the urosome"	pu	pu	pu	Fu with short colorless setae
<ul> <li>O. spinifrons Boeck, 1864</li> <li>Polgolandica Claus, 1863 (Brady 1878)</li> </ul>	F 0.85	"About as long as the cephalothorax"	pu	pu	pu	Ur1 long, Ur2 and Ur4 about equal and of moderate length, Ur3 somewhat shorter. Fu shorter than any Ur segment
<b>O.</b> similis Claus	F 0.73–0.80	"Barely to the genital openings"	(0,1,4;1,1,2)/(1,1,5;0,0,1)	(0,1,5;1,0,1)/ (1,2,5;0,0,1)	(0,1,5;0,0,0)/ (1,2,4;0,0,1)	Ur & Fu relative lengths: 5,12,5,4,5,3.5. CR 2.5 width
Naples (Mediterranean Sea) (Giesbrecht 1893)	M 0.51–0.61	Geniculate	(0,1,4;1,1,2)/ (nd)	(0,1,4;1,1,2)/ (nd)	(0,1,4;1,1,2)/(nd)	pu
<i>O. similis</i> Claus, 1866 Christmas Islands (Indian Ocean) (Farran 1913)	F 0.73–0.80	pu	(nd;1,1,2)/ (nd)	(nd;1,0,1)/ (nd)	(pu)	pu
0. helgolandica Claus, 1863	F 0.70–0.90	"Extending scarcely beyond the anterior division of the body. Length 1.02 times prosome*	(0,1,4;1,1,2)/ (1,6;0,1)	(0,1,5;1,0,1)/ (1,2,5;0,0,1)	(0,1,5;0,0,1?)/ (1,2,4;0,0,1)	Ur & Fu relative lengths: 5,13,5.5,5.5,4.5,4*. CR hardly shorter than Ur4
(0171-0171 star) (2017-0171)	M 0.50–0.60	Geniculate	(nd;1,1,2)/(nd)	(0,1,5;1,1,2)/ (1,2,5;0,0,1)	(nd;1,1,2)/(nd)	pu
<b>O. similis</b> Claus Valdivia (SE Pacific)	F 0.78	"Hardly extending to the genital openings"	(0,1,5;1,1,2)/(nd)	(0,1,5;1,0,1)/ (nd)	(0,1,5;0,0,1)/ (nd)	pu
(Rosendorn 1917)	M 0.67	Geniculate	(0,1,5;1,1,2)/(nd)	(0,1,5;1,1,2)/(nd)	(0,1,5;1,1,2)/(nd)	nd
<b>O. helgolandica</b> Claus [= O. similis Claus]	F 0.73–0.96	"Barely reaching the genital openings"	(nd;1,1,2)/(nd)	(nd;1,0,1)/(nd)	(nd;0,0,0)/(nd)	Fu shorter than Ur4
Adriatic Sea (Pesta 1920)	M 0.59-0.70	pu	(nd;0,0,2)/(nd)	(nd;0,0,2)/(nd)	(nd;0,0,2)/(nd)	

**Table 1.** Worldwide variation in the key characters commonly reported for the determination of *O. similis/helgolandica* s.l.

Craciae nama <sup>il</sup>			THE STREET	imming leas setatio	qu	
Location Reference	Sex TL	Antennule	P1	P2	P4	Urosome
O. similis Claus ?1863 O. helgolandica	F 0.74-0.95	"Reaching the genital openings, located a little before the middle of the genital segment"	(nd;1,1,2)/(nd)	(nd;1,0,1)/(nd)	(nd;0,0,1)/(nd)	pu
Various localities (Kieter 1929)	M 0.60-0.70	pu	(nd;1,1,2)/(nd)	(nd;1,1,2)/(nd)	(nd;1,1,2)/(nd)	pu
O. helgolandica Claus, 1863 (O. similis Claus, 1863)	F 0.73–0.96	"Barely attains the genital openings"	(nd;1,1,2)/(nd)	(0,1,5;1,0,1)/(nd)	(nd;0,0,0)/(nd)	Fu shorter than Ur4. CR twice width
Various localities (Rose 1933)	M 0.59-0.70	pu	pu	(0,1,5;1,1,2)/(nd)	pu	pu
<b>O.</b> similis Claus, 1866	F 0.80	"Reach to the genital pores"	(0,1,4;1,1,2)/(nd)	(0,1,5;1,0,1)/(nd)	(0,1,5;0,0,1)/(nd)	Fu more than twice width. CR equal width
Japan (IVIOTI 1707)	M 0.65	Geniculate	(0,1,5;1,1,2)/(nd)	(0,1,5;1,1,2)/(nd)	(0,1,5;1,1,2)/(nd)	pu
<b>O.</b> helgolandica Claus, 1863	F 0.69–0.96	"Barely reach to genital segment"	(0,1,5;1,1,2)/(nd)	(0,1,5;1,0,1)/(nd)	(0,1,5;0,0,1)/(nd)	Ur 0.75 prosome length. CR shorter than Ur4
INE FACINC (LAVIS 1949)	M 0.50-0.70	Geniculate	(0,1,5;1,1,2)/(nd)	(0,1,5;1,1,2)/(nd)	(0,1,5;1,1,2)/(nd)	pu
0. helgolandica Claus	F 0.78	pu	(0,1,4;1,1,2)/(nd)	(0,1,5;1,0,1)/(nd)	(0,1,5;0,0,1)/(nd)	pu
Messina Strait (Mediterranean Sea) (Crisafi 1959)	M 0.68	Non geniculate <sup>s</sup>	(0,1,4;1,1,2)/(nd)	(0,1,5;1,0,1)/(nd)	(0,1,5;0,0,1)/(nd)	pu
<b>O. helgolandica</b> Claus, 1863 Buenos Aires shelf (Argentine Sea) (Ramírez 1966)	F 0.80	"Reaches the genital openings"	(0,1,4;1,1,2)/(nd)	(0,1,5;1,0,1)/(nd)	(0,1,5;0,0,1)/(nd)	Ur1 2.5 width. Ur4 similar to Ur2 and Ur3. Fu slightly shorter than Ur4. CR twice width
<b>O.</b> similis Claus, 1866	F 0.89–1.10	pu	(nd;1,1,2)/(nd)	(nd; 1, 0, 1)/(nd)	(nd;0,0,1)/(nd)	CR divergent
Río Deseado estuary (Argentine Sea) (Pallares 1968)	M 0.50-0.67	Geniculate	pu	pu	pu	pu
<b>O. helgolandica</b> sensu Sars, 1913	F nd	pu	pu	(0,1,5;1,0,1)/ (1,2,5;0,0,1)	(0,1,5;0,0,0)/ (1,2,4;0,0,1)	pu
Gun of Lion (ivecuterranean Sea) (Razouls 1972)	pu M	pu	(0,1,3;1,1,2)/(1,1,5;0,0,1)	(0,1,5;1,1,2)/(1,2,5;0,0,1)	(0,1,5;1,1,2)/(1,2,4;0,0,1)	pu
<b>O. similis</b> Claus, 1866	F 0.69–0.84	"Extending to the end of thorax 5"	(0,1,4;1,1,2)/(1,1,5;0,0,1)	(1,0.5;1,0,1)/ (1,2,5;0,0,1)	(0,1,5;0,0,1)/ (1,2,4;0,0,1)	pu
ouruga Day (Japan) (Nishida et al. 1977)	M 0.60-0.65	pu	(0,1,4/5;1,1,2)/ (nd)	(0,1,5;1,1,2)/(nd)	(0,1,5;1,1,2)/(nd)	ри

Species name <sup>a</sup>			Sw	imming legs setatic	h	
Location Reference	Sex TL	Antennule	Id	P2	P4	Urosome
O. similis Claus, 1866 ? O. helgolandica Claus, 1863	F 0.78	pu	(0,1,4;1,1,2)/(1,1,5;0,0,1)	(0,1,5;1,0,1)/(nd)	(nd;0,0,1)/(nd)	pu
Various localities (Shuvalov 1980)	M 0.60-0.70	pu	pu	pu	pu	pu
<b>O.</b> similis Claus, 1866	F nd	Extending slightly beyond thorax 5*	pu	nd	nd	nd
(SW Atlantic) (Björnberg 1981)	M 0.70	ри	(nd;1,1,2)/(nd)	(nd; 1, 1, 2)/(nd)	(nd;1,1,2)/(nd)	pu
<b>O. similis</b> Claus, 1866 Various localities (Nishida 1985)	F 0.68–0.96	"Length 1.1–1.3 times prosome"	(0,1,4;1,1,2)/(1,1,5;0,0,1)	(0,1,5;1,0,1)/ (0/1,1/2,5;0,0,1)	(0,1,5;0,0,1)/ (1,2,4;0,0,1)	Ur & Fu relative lengths: 13,34,15,14,14,11. Ur4 1.1–1.3 width. CR 1.9–2.4 width
O. simitis Claus, 1866 Magallanes Strait (Argentina-Chile) (Mazzochi et al. 1995)	F 0.80–0.92	pu	(0,1,4;1,1,2)/(1,1,5;0,0,1)	(0,1,5;1,0,1)/ (1,2,5;0,0,1)	(0,1,5;0,0,1)/ (1,2,4;0,0,1)	Ur & Fu relative lengths: 15,36,14,12,12,11
<b>O. aff.</b> <i>helgolandica sensu</i> Sars, 1913 Buenos Aires and southern Patagonian shelves (Argentine Sea)	щ	Extending to the genital openings. Length 1.1-times prosome.	(0,1,4;1,1,2)/(1,6;0,1)	(0,1,5;1,0,1)/ (1,2,5;0,0,1)	(0,1,5;0,0,1)/ (1,2,4;0,0,1)	Ur & Fu relative lengths: 13.5,34,16,14,13,10.5. Ur1 2.0–2.2 width. CR twice width
(Our unpublished data)	Μ	Geniculate	(0,1,4;1,1,2)/nd	(0,1,5;1,1,2)/nd	(0,1,5;1,1,2)/nd	pu

of differential characters that would have been necessary for the proposal of a new species. He probably described under the new name *similis* individuals that were similar, though not identical, to the species he found formerly in Helgoland.

Given this state of the problem, many authors have subsequently either applied the Principle of Priority or followed Crisafi's (1959) opinion, naming the species *O. helgolandica* (e.g., Pesta 1920; Rose 1933; Davis 1949; Crisafi 1959; Ramírez 1966, 1970; Razouls 1972; Huys and Boxshall 1991). Many others have preferred to refer to *O. similis* (e.g., Farran 1929; Kiefer 1929; Mori 1937; Rose 1957; Nishida et al. 1977; Shuvalov 1980; Nishida 1985), although some of those indicated with question marks their doubts about synonymy with the senior form *O. helgolandica*. This ambiguity has continued until the present day.

## Do the names O. similis and O. helgolandica refer to identical taxa?

Most important morphological features usually used for the identification of *O. similis* / *helgolandica* s.l. have been: (i) body size, (ii) rostrum presence and direction, (iii) relative antennule length, (iv) exopod setation of swimming legs 1-4, and (v) relative lengths of the genital segment, and segment, and furcae.

Morphological differences among specimens worldwide (Table 1; Fig. 1) suggest that at least two forms may be referred to *O. similis / helgolandica* s.l. Strict comparisons across records are not really possible, because they all lack the detail of one or more particular key characters; hence, it seems likely that identification of *O. similis* s.l. */ helgolandica* s.l. has generally been based on elements insufficient for adequate taxonomic judgment. This is not minor when considering that phenetically similar species may differ from one another in only slight differences of the setal formula of the swimming legs (Nishida 1985). We are calling attention here to the fact that the female and male exopod setation of swimming legs do not match identically in the two most complete and detailed redescriptions of *O. similis* by Giesbrecht (1893) and Nishida (1985), and neither is there complete correlation between Nishida et al (1977) and Nishida (1985) (Table 1).

Some subtle differences are apparent among published drawings labelled as *O. similis* s.l. and of *O. helgolandica* s.l. (Fig. 1). In this regard, it may be worth examining closely the drawings of female *O. helgolandica* by Sars (1913, Plate III) and *O. spinifrons* Boeck, 1864 (= ? *O. helgolandica* Claus) by Brady (1878, Plates XIV and XXIV A). In considering *O. similis* as figured by Nishida (1985), note in particular the dissimilar general appearance with respect to the above mentioned species, the two-segmented endopod of the first leg, and the overall setation of legs 1–4 (on the inner and outer borders of both rami). Nishida's descriptions and drawings probably correspond to the "typical" *O. similis*, on which a substantial number of authors have based identifications since 1985.

In our view, when specimens have been identified as *O. similis* s.l., insufficient attention has often been paid to: (i) presence/absence of the small distal outer spine



**Figure 1.** Former selected drawings of *O. similis / helgolandica.* **A, B** *O. spinifrons* Boeck, 1864 (=? *O. helgolandica* Claus), female body and "one of swimming feet" (= leg 4?) (after Brady1878, Plates XIV and XXIV A) **C–F** *O. similis* exopod of legs 1 to 4 (after Gisbrecht 1893, Plate 34) **G–J** *O. helgolandica*, female body, legs 1-2 and leg 4 (after Sars 1913, Plate III) **K–O** *O. similis*, female body and legs 1 to 4 (after Nishida 1985, fig. 50 and 51). Original illustrations were faithfully copied in all details and rearranged to facilitate comparisons. Scale bars only provided in Nishida (1985).

on exopod segment 3 of leg 4, (ii) endopod segmentation of leg 1, and (iii) relative antennule length.

The distal outer spine on the last segment of the exopod of leg 4 is lacking in some early descriptions and drawings of *O. similis / helgolandica* (e.g., Giesbrecht 1893; Pesta 1920; Rose 1933). Sars (1913) gives account of it in the text (p. 8) but it is unclear in his drawing. According to Farran (1913) and Crisafi (1959), this spine can be easily lost, although it may also have been overlooked, as Rosendorn (1917) suggested. From records in the literature, doubt remains whether or not all Mediterranean specimens share this particular character, the presence of this spine (Table 1).

In the genus *Oithona* Baird, both rami of the first swimming leg are 3-segmented (*sensu* Brady 1878), but this is not always the case in *O. similis* s.l. and *O. helgolandica* s.l. To our knowledge, a bi-segmented endopod of leg 1 has only been specifically reported so far for female *Oithona* specimens from Norway (Sars 1913), the Gulf of Lion (Razouls 1972), and off Argentina (our unpublished data). Like most authors listed in Table 1, Giesbrecht (1893) only figured the outer rami of the swimming legs, though he addressed secondarily his observation that "segments 2 and 3 of the endopod were often indistinctly separated in the front pairs of *O. similis*" (on p. 544).

Lastly, the antennule length relative to the prosome appears slightly variable across records worldwide (Table 1). Because this feature has been most often characterized in a subjective way, it is suggested that it be reported quantitatively in the future (e.g., antennule length 1.1–1.3 times prosome length, as reported by Nishida 1985).

From the genetic point of view, the still scarce molecular studies on *Oithona* also support the hypothesis that more than one form is reported under the same specific name, *O. similis* s.l. Cepeda et al. (2012) presented data showing significant genetic differentiation among numerous and widespread locations in the North and South Atlantic Ocean based on 28S rDNA, suggesting some degree of isolation amongst sampled populations. Furthermore, preliminary findings from cytochrome c oxidase I (COI) "barcode" analyses of (apparently) morphologically identical *O. similis* over a broad geographical scale, i.e. Arctic and Southern oceans, North Sea and Mediterranean Sea, revealed the presence of several different haplotypes restricted to particular areas (Wend-Heckmann 2013). There is thus the possibility that *O. similis* s.l. is not a single, broadly distributed, cosmopolitan species but rather, a conglomerate of several cryptic species. This has been the case of many putatively cosmopolitan species (Bucklin et al. 2011). In this regard, markers frequently used to investigate boundary taxa among closely related, cryptic and cosmopolitan species may be helpful (e.g., COI, cytochrome b, 16S rRNA, Internal Transcribed Spacer 1–2).

#### Nomenclatural remarks and perspectives

The nomenclatural implications of the taxonomic uncertainty apparent from the discussions above are not minor. From a historical standpoint, it is clear that over the course of time a substantial number of copepodologists has come to consider that *O*. *similis* and *O. helgolandica* actually denote the same taxon. Prevailing use which, as shown, has depended upon individual judgment and opinion, has made that the junior synonym *O. similis* were very commonly imposed over the older *O. helgolandica*, contradicting the rules of priority (ICZN 1999; Article 23).

On the other hand, morphological differences worldwide in the key characters commonly used for diagnosis (Table 1) suggest that *O. similis* and *O. helgolandica* may not refer to copepods related closely enough to be considered a single taxon. Because the problem focuses on the identity of Claus's types, which unfortunately are not available, we advocate a thorough comparison of the two taxonomic entities, preferably at both the morphological and genetic levels (McManus and Katz 2009), from specimens newly collected at their respective type localities, i.e, Nice and Helgoland.

In the absence of proper holotypes, the designation of neotypes probably will be required because of the points raised above (ICZN 1999; Article. 75), i.e.:

- (i) A neotype each for *O. helgolandica* s.s. Claus, 1863 and for *O. similis* s.s. Claus, 1866 will be needed if specimens from both localities are proved to be different.
- (ii) The appointment of only one neotype will be necessary if specimens from Nice and Helgoland are substantially identical. Strictly speaking, in this situation the senior name *O. helgolandica* should be used because of the rules of priority. Nevertheless, in pursuit of stability and universality and to avoid causing further confusion, it would be still possible to maintain the use of the junior synonym, *O. similis*, as it has largely prevailed through time. To stabilise this, however, the matter must be referred to the ICZN for a ruling under the plenary powers (ICZN 1999; Article 23.9.3).

There are not, in fact, conclusive fundamentals at present in support of an objective synonymy between the names *O. similis* and *O. helgolandica*. Hence, until the diagnostic characters are re-examined and the nomenclatural issues settled, we strongly recommend specifically reporting the authority upon which the identification of either *O. similis* s.l. or *O. helgolandica* s.l. has been undertaken. In this process, particular reference should be made for female specimens in respect to: (i) relative antennule length, (ii) presence/absence of the small distal outer spine on exopod segment 3 of leg 4, and (iii) endopod segmentation of leg 1.

After this review, we find astounding the extent of taxonomic and nomenclatural uncertainty surrounding the name *O. similis*. Poor original diagnosis and frequently the inability of authors to perceive minute morphological differences have very likely caused the assembly of several forms distinct at the species level into a single, nominal species. This circumstance on top of the persistent confusion with its likely sibling, *O. helgolandica*, may have led to a false impression of cosmopolitanism. It is possible that many cryptic species are veiled behind the apparent morphological homogeneity of their forms, and *O. similis* s.l. and *O. helgolandica* s.l. may be an example in an abundant and ecologically important group, the genus *Oithona*. Therefore, we encourage a profound revision of *O. similis* s.l. in order to bring the exact status of this species to light. In accomplishing this goal, species should not be renamed or newly assigned based on morphology alone without the support of molecular genetic sequence information.

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RESEARCH ARTICLE



# New record and redescription of Calanopia thompsoni A. Scott, 1909 (Copepoda, Calanoida, Pontellidae) from the Red Sea, with notes on the taxonomic status of C. parathompsoni Gaudy, 1969 and a key to species

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## Abstract

During a plankton sampling programme around Al-Wajh area, Saudi Arabian coast of the northern Red Sea, a copepod *Calanopia thompsoni* A. Scott, 1909 (Calanoida: Pontellidae) was reported for the first time in the Red Sea. Both sexes are fully redescribed and compared to previous descriptions as well as the closely related species, *Calanopia parathompsoni*. The zoogeographical distribution of the species confirms that it is of Indo-Pacific origin. A dichotomous key for the identification of males and females of the species of *Calanopia* is included.

## Keywords

New record, copepods, Calanopia thompsoni, Pontellidae, Red Sea

# Introduction

Recent studies of the neritic and coastal waters of the Red Sea have revealed an assemblage of calanoid copepods including several species new to science (Ohtsuka et al. 2000, El-Sherbiny and Ueda 2008a, 2010, El-Sherbiny 2011, El-Sherbiny and Al-Aidaroos 2015), in addition to several new records (El-Sherbiny and Ueda 2008b, El-Sherbiny 2009, El-Sherbiny and Al-Aidaroos 2013, 2014). The genus Calanopia accommodates 17 nominal species (Razouls et al. 2015). Most members of this genus (13 species) are Indo-Pacific species, namely C. aurivilli Cleve, 1901, C. australica Bayly & Greenwood, 1966, C. asymmetrica Mulyadi & Ueda, 1996, C. elliptica Dana, 1852, C. herdmani A. Scott, 1909, C. media Gurney, 1927, C. minor A. Scott, 1902, C. parathompsoni Gaudy, 1969, C. sarsi Wilson, 1950, C. thompsoni A. Scott, 1909, C. sewelli Jones & Park, 1967, C. seymouri Pillai, 1969, and C. kideysi Ünal & Shmeleva, 2002 (Silas and Pillai 1973, Mulyadi and Ueda 1996). Of the remaining species, C. biloba Bowman, 1957 and C. americana Dahl, 1894 are known from the Atlantic Ocean (Bowman 1957), while C. levantina Uysal & Shmeleva, 2004 and Calanopia metu Uysal & Shmeleva, 2004 were identified from Mediterranean Sea. In the Red Sea, only four species of the genus Calanopia have been recorded namely: C. elliptica by Giesbrecht (1896), C. minor by A. Scott (1902), Calanopia media by Pesta (1941) and C. kideysi by Ünal and Shmeleva (2002).

The general morphological characteristics of *Calanopia* species collected from the Red Sea were close to those of *C. thompsoni* described from Bay of Kankamaraan, south coast of Kangeang Island by A. Scott (1909) and *C. parathompsoni* collected from neritic waters of Madagascar by Gaudy (1969). Since the original description of *C. thompsoni* is incomplete and the literature from different areas notes morphological variability, the present paper provides a full redescription especially of the mouthparts which have never been described and figured. Also, this paper records the first occurrence of *C. thompsoni* in the Red Sea and discusses its relationship to *C. parathompsoni*.

# Material and methods

Within the plankton sampling framework of a study of the reproductive cycle and larval stages of the spiny lobster, *Panulirus penicillatus* (Decapoda: Palinuridae) in Al-Wajh waters (26°11.855'N, 36°25.58'E) off the east coast of Saudi Arabian Red Sea, an unrecorded species of *Calanopia* was collected. Specimens were sampled using a 50-cm diameter plankton net (500 µm mesh size) towed near the surface for 15 minutes at a speed of about 2 knots. Immediately after sampling, samples were fixed in a 4% formalin-seawater solution and later *Calanopia* specimens were sorted and kept in 70% alcohol. For microscopic examination, dissections were made in polyvinyl lactophenol using bright-field and differential interference microscopes (Nikon DM 6000). Drawings were made with a camera lucida attached to the microscopy, specimens were

washed in filtered seawater, clean distilled water, and dehydrated through an 30-100% ethanol series and subsequently, critical-point-dried. The specimens were mounted on a stub, coated with gold palladium, and observed with a SEM Hitachi S-3500N.

#### Results

#### Description

Order Calanoida G. O. Sars, 1903 Family Pontellidae Dana, 1853 Genus *Calanopia* Dana, 1853

*Calanopia thompsoni* A. Scott, 1909 Figs 1–7

Material examined. Twelve adult females and ten adult males collected at Al-Wajh waters of the east coast of Saudi Arabian Red Sea.

**Body length.** Female 1.92–1.98 mm (mean  $\pm$  SD = 1.95  $\pm$  0.02 mm, n = 12), male 1.79–1.83 mm (1.81  $\pm$  0.01 mm, n = 10).

**Female.** Body robust (Fig. 1A), 1.94 mm in length. Prosome elliptical comprising cephalosome and four pedigerous somites, prosome approximately 2.5 times as long as urosome; cephalosome distinctly separated from first pediger with one median eye and lateral hooks; fourth and fifth pedigerous somites fused, symmetrical with posterolateral corners pointed in dorsal aspect reaching nearly one-third of way along genital compound somite (Fig. 2A). Rostrum bearing pair of pointed processes with very small medial subterminal notch (Figs 1B, C, 2B). Urosome (Figs 1A, B, 2A) of two free somites; genital compound somite symmetrical and ventral surface without any processes (Figs 1B, 2A). Second urosomite symmetrical and slightly shorter than genital compound somite. Caudal rami symmetrical and approximately 2.3 times as long as wide, each ramus carrying five plumose setae along distal margin and reduced seta (seta VII) located on dorsal surface near medial distal angle.

Antennules (Fig. 1D, E) 19-segmented, when extended reaching almost anterior border of second urosomite. Armature formula as follows: ancestral segment I (segment 1) = 1 setae + aesthetasc (ae), II-VI (2) = 5 + 2 ae, VII (3) = 1 + ae, VIII-X (4) = 4 (1 spiniform) + ae, XI-XII (5) = 2 + ae, XIII (6) = 2 (1 spiniform) + ae, XIV (7) = 1 + ae, XV (8) = 1 + ae, XVI (9) = 2 + ae, XVII (10) = 2 + ae, XVIII (11) = 2 + ae, XIX (12) = 2 + ae, XXI (13) = 2 + ae, XXI (14) = 2 + ae, XXII (15) = 1, XXIII (16) = 1, XXIV (17) = 1 + 1, XXV (18) = 1 + 1, XXVI-XXVIII (19) = 6 + ae.

Antenna (Fig. 1F) biramous with short coxa bearing plumose seta at distomedial angle; basis with two subequal setae distomedially; exopod 5-segmented with setal formula of 0, 4, 1, 2, 3. Endopod 2-segmented, proximal segment with two unequal subterminal setae, distal segment bilobed, with medial (proximal) lobe bearing eight



**Figure 1.** *Calanopia thompsoni* female from the Red Sea. **A** habitus, dorsal view **B** habitus, lateral view **C** rostrum, frontal view **D** antennule **E** enlarged proximal part of antennule **F** antenna. Scale bars in mm.



**Figure 2.** SEM micrograph of *Calanopia thompsoni* from the Red Sea. **A** female abdomen, lateral view **B** rostrum, lateral view **C** leg 5, ventral view **D** enlarged distal part of female leg 5.

setae, and with lateral (distal) lobe crowned with six setae and transverse row of fine setules.

Mandibular gnathobase (Fig. 3A) carrying eight teeth on coxal cutting edge, third to seventh teeth ornamented with row of short spinules anterodistally at base. Palp biramous; basis with four unequal setae on medial margin. Exopod 5-segmented with setal formula of 1, 1, 1, 1, 4. Endopod 2-segmented, proximal segment with two setae at distomedial corner, distal segment with seven long and one short setae.

Maxillule (Fig. 3B) with praecoxal arthrite bearing nine marginal strong spines and four setae on posterior surface. Coxal epipodite with nine setae; coxal endite with three setae, basal exite with one seta. Proximal and distal basal endites with three and one setae, respectively. Exopod carrying a total of nine setae; endopod incorporated into basis with three setae laterally and seven setae terminally.

Maxilla (Fig. 3C) praecoxal and coxal endites carrying 3 and 2, 2, 3 bilaterally spinulate setae respectively; basal endite with two setae, one longer than other; endopod 3-segmented, carrying six bilaterally spinulate setae.



**Figure 3.** *Calanopia thompsoni* female from the Red Sea. **A** mandible **B** maxillule **C** maxilla **D** maxilliped. Scale bars in mm.

Maxilliped (Fig. 3D) syncoxal lobes with 1, 3, 3 setae on their medial margins. Basis carrying two setae distally; endopod 4-segmented with setal formula of 2, 2, 1, 3.

Swimming legs 1–4 (Fig. 4A–D) biramous, with 3-segmented exopods and 2-segmented endopods. On leg 1 to leg 3, coxa with one medial seta and patch of fine hairs. All lateral spines on exopods of legs 1-4 with serrated hyaline margins. Leg 5 (Figs 2C, 4E) symmetrical, basis with short seta posteriorly; exopod 2-segmented, first segment with two strong bilaterally serrated processes laterally (distal one longer and pointed slightly mediad). Second exopod segment nearly as long as first one, bearing two bilaterally serrated, lateral spines, one small medial process fused to segment and bilaterally serrated long, distal spine fused to segment (Figs 2C, D, 4E). Armature of legs as follows:

	C	Coxa Basis		Exopod		Endopod	
	Coxa	Dasis	1	2	3	1	2
Leg 1	0-1	0-0	I-1	I-1	II, I, 4	0-3	1, 2, 3
Leg 2	0-1	0-0	I-1	I-1	III, I, 5	0-3	2, 2, 4
Leg 3	0-1	0-0	I-1	I-1	III, I, 5	0-3	2, 2, 4
Leg 4	0-0	1-0	I-1	I-1	III, I, 5	0-3	2, 2, 3

*Male.* Body (Fig. 5A, B) with plump prosome approximately 2.2 times as long as urosome comprising cephalosome and four pedigerous somites. Cephalosome distinctly separated from first pediger; fourth and fifth pedigerous fused and produced posterolaterally into symmetrical and slightly pointed corners reaching end of first urosomite (Figs 5A, 6A). Rostrum bearing pair of pointed processes directed posteroventrally (Fig. 5B). Urosome (Fig. 5A, B) comprising five free symmetrical urosomites, second urosomite longest; anal somite shorter preceding somite. Caudal rami symmetrical, 2.2 times longer than wide; caudal setae as in female. Some male specimens from Red Sea revealed the presence of one and/or two fine spinules, ventrally on the right side in the first and second urosomite respectively (Fig. 6A).

Right antennule (Fig. 5C–E) 17-segmented, geniculate between segments XX (13) and XXI-XXIII (14). Armature as follows: ancestral segment I (segment 1) = 1 setae + aesthetasc (ae), II-V (2) = 6 + ae, VI-VII (3) = 5 + 3 ae, VIII (4) = 1 + ae, IX (5) = 2 + ae, X (6) = 1 + ae, XI (7) = 1 + ae, XII (8) = 2 + ae, XIII-XIV (9) = 3 + 2 ae, XV (10) = naked, XVI-XVII (11) = 3 (1 spiniform) + 2 ae, XVIII-XIX (12) = 2 + process + 2 ae, XX (13) = 1 + ae, XXI-XXIII (14) = 2 + 2 processes , XXIV (15) = 1 + 1, XXV (16) = 1 + ae + 1, XXVI-XXVIII (17) = 5 + ae.

Left antennule, antenna, mouthparts and swimming legs 1-4 as in female. Leg 5 uniramous and asymmetrical. Left leg (Fig. 7A) with short coxa; basis 1.8 times longer than coxa with plumose seta located posteriorly near proximal end. Exopod 2-segmented, first (proximal) segment slightly shorter than basis with pointed attenuation near distolateral corner, second (distal) segment short, hirsute on posteromedial surface, with curved relatively long spine laterally, short spine with triangular base medially and one rounded and serrated process distally (Figs 6B, C, 7B, C). Right leg (Fig. 7D) longer than left, coxa with one blunt process on posterior surface distally; basis with plumose seta laterally. Exopod 2-segmented, forming a stout subchela, first exopodal segment without thumb and nearly 4 times as long as wide, distal part of



**Figure 4.** *Calanopia thompsoni* female from the Red Sea. **A** leg 1 **B** leg 2 **C** leg 3 **D** leg 4 **E** leg 5. Scale bars in mm.



**Figure 5.** *Calanopia thompsoni* male from the Red Sea. **A** habitus, dorsal view **B** habitus, lateral view **C** right antennule **D** enlarged proximal part of right antennule **E** antennule segments 12–14. Scale bars in mm.



**Figure 6.** SEM micrograph of *Calanopia thompsoni* from the Red Sea. **A** first and second male urosomite (spinules indicated by arrows), ventral view **B** distal segment of male left leg 5, ventral view **C** distal segment of male left leg 5, dorso-lateral view **D** exopod of male right leg 5.



**Figure 7.** *Calanopia thompsoni* male from the Red Sea. **A** left leg 5 **B** distal segment of left leg 5, ventral view **C** distal segment of left leg 5, dorso-lateral view **D** right leg 5. Scale bars in mm.

subchela with elongate depression medially and one seta on proximal border of the depression (Figs 6D, 7D). Second exopodal segment (finger) elongate, curved at one-third its length, not acutely tapering with one medial seta proximally and two setae laterally nearly at midlength, distal part of finger with shallow depression medially.

# Discussion

The present specimens of C. thompsoni, collected and examined from the Red Sea, closely resemble the original description by A. Scott (1909) from the Bay of Kankamaraan, south coast of Kangeang Island although the Red Sea specimens varied in the absence of a rounded ventral protuberance on the female genital compound somite. Analyses of the shape of the urosome of C. thompsoni that have been reported in the literature between 1909 and 2008 reveal extensive variation in the shape of genital compound somite. The protuberance showed by A. Scott (1909) in the original description was absent in specimens collected from Andaman Sea (11°35'00"N, 98°34'15"E) by Sewell (1932), from the Yellow Sea by Chen and Zhang (1965) from Sister Island, Singapore waters by Othman and Toda (2006) and from Thailand waters by Phukham (2008). Also, according to these previous descriptions and illustrations of C. thompsoni from different areas all over the world, there is some variation in the proportions of the genital compound somite (GCS) and second urosomite (UrII), as well as the first and second exopodal segments of the female leg 5. The genital compound somite is greatly variable being as long as the second urosomite to, more usually, longer than the second urosomite. Genital compound somite (GCS)/UrII = 1.2, 1.6, 1.2, 3.6 and 1.8 as described by A. Scott (1909), Chen and Zhang (1965), (1976), Othman and Toda (2006) and Phukham (2008), respectively. The Red Sea specimens are closer to the description of A. Scott from the Indonesia-Malaysia region and Silas and Pillai from the Gulf of Mannar, Indian Ocean. On the other hand, the first exopodal segment of the female leg 5 in relation to the second exopodal segment is Re1/Re2 = 0.8, 1.1, 0.6, 0.9, 0.5 and 0.6 as illustrated by A. Scott (1909), Sewell (1932), Chen and Zhang (1965), Silas and Pillai (1976), Othman and Toda (2006) and Phukham (2008), respectively. Another variation is noticed from descriptions of Chen and Zhang (1965) from Yellow Sea specimens and Mori (1937) from Japanese waters: the second (distal) exopodal segment of the male left leg 5 is longer than in other descriptions.

Some male specimens from the Red Sea revealed that the second urosomite bears two fine spinules located ventrally, on the right side. These spines are reported only in the original description of *C. parathompsoni* by Gaudy (1969), on the left side. This suggests that our specimens of *C. thompsoni* and Gaudy's *C. parathompsoni* are conspecific. The author of *C. parathompsoni* did not explicitly designated or deposited type specimens anywhere and the species has not been illustrated since described. *Calanopia parathompsoni* was distinguished from *C. thompsoni* based mainly on: 1) asymmetry of female genital compound somite in outline (absence of Scott's protuberance), 2) presence of two fine spinules ventrally on the left side of male second urosomite, and 3) presence of a medial small spine swollen at base on the first segment of male right leg 5. Based on the examination of many specimens of *C. thompsoni* from the Red Sea, we consider these differences variability within one species since the structure of leg 5 in both sexes is very similar as are the two fine spines, detected on the ventral right side of the second urosomite. Such variability is common in members of family Pontellidae (e.g., El-Sherbiny and Ueda 2008a, 2010, El-Sherbiny 2009, Jeong et al. 2009, Hirabayashi and Ohtsuka 2014). In conclusion, we are unable to find any reliable characters distinguishing *C. thompsoni* and *C. parathompsoni* and suggest *C. parathompsoni* is a junior synonym of *C. thompsoni*.

We note that the diversity of Red Sea pontellid copepods is remarkably low, given that the Indian Ocean is the origin of the Red Sea plankton. Silas and Pillai (1973) recorded 71 species of pontellid copepods from the Indian Ocean compared to 15 species from the Red Sea (*Calanopia -* 4 species, *Labidocera -* 5 species, *Pontella -* 3 species, *Pontellina -* 1 species and *Pontellopsis -* 2 species) (Razouls et al. 2015). This low number of recorded pontellid species in the Red Sea may be explained by the characteristic neustonic nature of pontellid genera (Mauchline 1998), inappropriate sampling methods or limited sampling effort in space and time. To be certain that we understand the pontellid diversity of the Red Sea, we recommend greater sampling effort.

#### Key to species of Calanopia

#### Females

1	Leg 5 exopod 1-segmented2
_	Leg 5 exopod 2- segmented7
2	Exopod of leg 5 with 4 spines
_	Exopod of leg 5 with 2 or 3 spines
3	Exopod of leg 5 with 3 small spines and 1 long spine
_	Exopod of leg 5 with 4 small finger like spines
4	Exopodal segment of leg 5 with 3 subequal small lateral spines and 1 long
	medial spine (longer than segment itself)
_	Exopodal segment of leg 5 with 2 subequal lateral spines and 1 terminal long
	spine (nearly as long as segment)
5	Exopodal segment of leg 5 with 3 spines6
_	Exopodal segment of leg 5 with 2 spines (lateral very short and long terminal
	one) <i>C. levantina</i>
6	Exopodal segment of leg 5 with 2 small lateral spines and one long medial
	spine (longer than segment itself) <i>C. minor</i>
_	Exopodal segment of leg 5 with 2 small lateral spines and one medial spine
	(smaller than segment itself) <i>C. kideysi</i>
7	Cephalic lateral hooks absent8

_	Cephalic lateral hooks present
8	Leg 5 symmetrical
_	Leg 5 asymmetrical, left one longer C. elliptica
9	Caudal rami symmetrical
_	Caudal rami asymmetrical, right ramus much longer than left, expanded pos-
	teriorly
10	Second exopodal segment of leg 5 longer than first one11
_	Second exopodal segment of leg 5 shorter than first one C. herdmani
11	First exopodal segment of leg 5 with 2 spines distally12
_	First exopodal segment of leg 5 with 1 acuminate spine distally and its length
	nearly as long as second exopodal segment
12	Genital compound somite with ventral spines C. media
_	Genital compound somite without such ventral spines C. biloba
13	Genital compound somite longer than second urosomite14
_	Genital compound somite nearly as long as second urosomite15
14	Caudal rami asymmetrical, left one longer than right; second exopodal seg-
	ment of leg 5 nearly as long as first one
_	Caudal rami slightly asymmetrical, second exopodal segment of leg 5 shorter
	than first one
15	Caudal rami asymmetrical, right one with more concave medial margin; sec-
	ond exopodal segment of leg 5 longer than first one
_	Caudal rami symmetrical; second exopodal segment of leg 5 slightly shorter
	than first one

# Males (*C. kideysi* and *C. metu* are not included in this key since there are no descriptions for adult males)

1	Left leg 5 longer than right one; basis of left leg 5 swollen proximally2
_	Left leg 5 shorter than right one; basis of left leg 5 not swollen proximally5
2	Second exopodal segment of right leg 5 nearly two-fifth length of first exopodal
	segment; coxa of right leg 5 about or less than 1.4 times as long as basis
_	Second exopodal segment of right leg 5 nearly two-third length of first exopo-
	dal segment; coxa of right leg 5 about 1.7 times as long as basis4
3	Basis of left leg 5 swollen proximally and produced into a small curved
	tooth C. minor
_	Basis of left leg 5 swollen proximally without any spines or processes
4	Basis of left leg 5 swollen proximally and produced into a prominent tooth-
	like process; second exopodal segment long, second exopodal segment of leg
	5 with a deep incision at the base of the thumb; third exopodal segment of
	right leg 5 with a distinct medial process

_	Basis of left leg 5 swollen proximally and produced into a small spine; second exopodal segment of leg 5 short; third exopodal segment of right leg 5 with-
~	out medial process
5	Prosomal posterolateral corner symmetrical
_	Prosomal posterolateral corners asymmetrical (right one wider and longer than left one and distinctly notched on its margin)
6	Cephalic lateral hooks absent7
_	Cephalic lateral hooks present
7	Second urosomite symmetrical and without any processes
_	Second urosomite asymmetrical with one or two processes on right side10
8	Second exopodal segment of right leg longer than first one, curved at one-
	third its length; basis of left leg 5 shorter than first exopodal segment9
_	Second exopodal segment of right leg 5 shorter than first one, curved at mid-
	length with 1 short and 1 long setae; basis of left leg 5 longer than first exopo-
	dal segment
9	First exopodal segment of right leg 5 subequal to basis, and 4.5 times as long
-	as wide: second exopodal segment of left leg 5 with 2 lateral spines
	C. asymmetrica
_	First exopodal segment of right leg 5 shorter than basis, and 3.4 times as long
	as wide: second exopodal segment of left leg 5 with 1 lateral spine
	<i>C. herdmani</i>
10	Second urosomite with 2 processes postero-laterally on right side: left leg rela-
10	tively short not reaching distal end of first exopodal segment of right leg
	C. biloba
_	Second urosomite with one acuminate-tip spinose process postero-laterally
	on right side: left leg relatively long reaching beyond distal end of first exopo-
	dal segment of right leg
11	Caudal rami symmetrical and divergent posteriorly: second exopodal seg-
11	ment of left leg nearly as long as first one
_	Caudal rami symmetrical and not divergent posteriorly: second exopodal seg-
	ment of left leg 5 shorter than first one
12	First exopodal segment of right leg 5 (chela) without thump, medial margin
12	of the chela with a group of needle-like spines and 2 smoothly curved pro-
	cesses: second exonodal segment of left leg 5 with short terminal spine
	<i>C. australica</i>
_	First exopodal segment of right leg 5 (chela) with a sharp thumb and a small
	seta on its lateral margin medial margin of the chela smooth and without any
	processes: second exopodal segment of left leg 5 with long terminal spine
	processes, second exopotial segment of left leg y with long terminal spine
13	First exopodal segment of right leg 5 with 2 smoothly curved protuberances
1.5	medially and 1 long seta proximally
_	First exonodal segment of right leg 5 with elongate distomedial depression
	with 1 short sets on provinal border of depression <i>C</i> thompsoni
	with a short seta on proximal border of depression

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RESEARCH ARTICLE



# New records of Protura (Entognatha, Arthropoda) from Romania, with an identification key to the Romanian species

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#### Abstract

The Romanian Protura were studied based on 175 specimens collected from Romania, along with bibliographic data. The main publication on the Romanian proturans was written by M.A. Ionescu (1951), who described 13 species mainly from soil and forest litter from 15 collecting points. The current paper represents the first study at a national level. Faunal data on Protura were obtained from 22 sites, mostly from forests of the Romanian Carpathians and also from a peri-urban area of Bucharest, which had not been studied before. As a result, the Romanian Protura fauna now consists of 27 known taxa in 6 genera and 4 families. Of the 27 taxa, 15 species are new records for Romanian fauna. An identification key to the Romanian Protura species is provided.

#### Keywords

Protura, Romania, distribution, ecology, remarks, identification key

#### Introduction

Proturans are found world-wide except in the Arctic and Antarctic regions (Szeptycki 2007) and primarily live in soil, leaf litter, mosses, and decaying wood. These minute soil-inhabiting hexapods also can be collected from animal burrows, meadows, and agriculture soils or urban areas.

The first report on Romanian Protura was that of Ionescu (1930) who described five species (*Acerentomon robustum* Ionescu, 1930, *A. mesorhinus* Ionescu, 1930, *Acerella muscorum* (Ionescu, 1930), *Acerentulus aureus* Ionescu, 1930 (= *A. confinis* Berlese, 1908)) and *Paraentomon carpaticum* (now *Ionescuellum carpaticum* Ionescu, 1930 (Tuxen 1960)), and reported two other species: *Eosentomon semiarmatum* Denis, 1927 and *E. transitorium* Berlese, 1909 from forest humus at Sinaia-Cumpătul, 850 m elevation. To date, 13 species of Protura have been reported from Romania (Ionescu 1951). All of these records originated from soil and forest litter samples from 15 collecting sites. One species, *Acerentomon robustum* Ionescu, 1930, was established as "species inquirenda" (Szeptycki 2007) because the species was insufficiently described and type material was lost (Tuxen 1961). We have not taken into account this species in the present paper. Falcă (1972) identified four species of Protura from the Retezat Mountains from three types of forests along an elevational gradient of 850–1800 m.

The fauna of Romanian proturans is poorly known in contrast to some other European countries: Luxembourg, 30 species in 10 genera (Szeptycki et al. 2003); Poland, 69 species of Protura in 11 genera (Szeptycki 2007); Ukraine, 58 species in12 genera (Shrubovych 2010); Austria, 58 species in 10 genera (Christian 2011); Italy, 40 species in 8 genera (Galli et al. 2011); Serbia, 38 species in 10 genera (Blesić and Mitrovski-Bogdanović 2012).

The aim of this study is to improve the study of this little known taxon in Romania by providing new records and distributional data on proturan species.

#### Materials and methods

Protura were extracted from samples of leaf litter, soil and mosses in Berlese funnels. The material has been deposited in the Institute of Systematics and Evolution of Animals, Polish Academy of Sciences, Kraków (ISEA). Specimens were mounted on slides in Marc Andre medium and were observed and identified with a phase-contrast microscope. In total 175 specimens from 22 sampling sites were examined. In our analysis we also considered the data taken from 17 Romanian collecting sites mentioned in the literature. Species were identified based on a key to European Protura (Nosek 1973) and other papers (Shrubovych et al. 2012, 2014, Szeptycki 1980, 1985, 1986, 1991). The taxonomic system of Protura presented by Szeptycki (2007) was followed in this paper. Species distributions were taken from Szeptycki (2005, 2007), Shrubovych (2010) for Ukraine, Galli et al. (2011) for Italy and Blesić and Mitrovski-Bogdanović (2012) for Serbia. All collecting sites are shown in Fig. 1.



Figure 1. Locations of Protura collection sites in Romania. Octagons indicate collections studied by authors; triangles represent sites recorded by Ionescu (1930, 1932, 1937, 1951) and Falcă (1972).

#### Abbreviations

The following abbreviations are used throughout the paper: pi – preimago, mj - maturus junior, LII - larva II, LI - larva I.

Chaetal nomenclature follows Nosek (1973) and Szeptycki (1986): A-setae – anterior setae, *P*-setae – posterior setae, aa and ap-setae on head – anterior and posterior additional setae, respectively.

# List of sampling sites in Romania

- Ilfov County: Periş, 44°40'18"N; 26°1'44"E, elevation 100 m, mixed forest, soil, 06. XI.2012.
- 2. Ilfov County: Jilava, 44°19'00.038"N; 26°03'54.579"E, elevation 50 m, mixed forest, soil, 02. XI.2013.
- Prahova County: Valea Largă, 45°18'20.638''N; 25°34'19.943''E, elevation 770 m, beech forest, in dead trunk, 13.XI.2013.

- 4. Prahova County: Şotriile, 45°13'39''N; 25°43'44''E, elevation 600 m, located on the mountainside above the Doftana River, mountain beech forest with *Luzula luzuloides* (Lam.) Dandy and Wilmott, soil and litter, 12.XI.2013.
- Prahova County: Voila, 45°09'58''N; 25°45'10''E, elevation 500 m, Quercus petraea (Mattuschka) Liebl. and Fagus sylvatica L. mixed forests, soil and litter, 12.XI.2013.
- 6. Prahova County: Cheile Brezei: 45°10'31.906"N; 25°41'16.153"E, elevation 455 m, shrubs and soil on rocks, 11.IX.2014.
- Prahova County: Cheile Posadei, 45°17'39.947"N; 25°36'00.001"E, elevation 720 m, mosses and litter on rocks, 12.XI.2013.
- Suceava County: Adam Peak, 47°30'58.17"N; 25°29'09.09"E, elevation 950 m, spruce forest, mosses on soil, 26.VIII.2014.
- Suceava County: Iacobeni, 47°26'45.913"N; 25°18'41.182"E, elevation 915 m, *Larix decidua* Mill., soil, 26.VIII.2014.
- Făgăraş Mountains: Valea Arpaşului, 45°40'52"N; 24°40'12"E, elevation 685 m, beech forest with *Abies alba* Mill. and *Acer* sp., soil, 10.IX.2014.
- 11. Făgăraș Mountains: Valea Arpașului, 45°39'21.937"N; 24°40'13.930"E, elevation 850 m, forest with *Abies alba* and *Fagus sylvatica* L., soil, 10.IX.2014.
- 12. Făgăraș Mountains: Valea Arpașului, 45°40'01.337"N; 24°40'15.289"E, elevation 820 m, harvested forest with *Abies alba*, soil, 10.IX.2014.
- 13. Făgăraș Mountains: Valea Brescioarei, 45°39'16.773"N; 24°53'09.207"E, elevation 930 m, spruce forest, 31.VII.2014.
- 14. Bârgău Mountains: Lunca Ilvei, 47°19'37.267"N; 25°58'20.189"E, elevation 785 m, forest with *Abies alba* and *Fagus sylvatica*, soil, 28.VIII.2014.
- Bârgău Mountains: Piatra Fântânele, 47°17'27.107"N; 24°59'45.294"E, elevation 915 m, spruce forest, soil, 28.VIII.2014.
- Bârgău Mountains: Valea Străjii, 47°13'05.330"N; 24°53'36.495"E, elevation 800 m, beech forest mixed with spruce, soil, 29.VIII.2014.
- 17. Bârgău Mountains: Tureac, 47°15'26.614"N; 24°50'54.282"E, elevation 795 m, meadow, soil, 29.VIII.2014.
- Vălcea County: Voineasa, 45°25'00"N; 23°57'20"E, elevation 705 m, beech forest, soil, 01.XI.2012.
- 19. Cozia National Park: Călinești Valley near Brezoi, 45°19'48"N; 24°14'30"E, elevation 610 m, litter of beech forest mixed with *Pinus* sp., 21.X.2012.
- 20. Olt Valley: Malaia, 45°21'11.18"N, 24°01' 11.74' E, elevation 495 m, beech forest, litter near rocks, 01.XI.2012.
- 21. Giurgiu County: Călugăreni, 44°10'48.839"N, 26°00'42.400"E, elevation 70 m, mixed forest, soil, 03.XI.2013.
- 22. Constanța County: Cernavoda, 44°20'11.92'N, 28°01'05.211''E, elevation 55 m, shrubs, soil, 10.XI.2012.
## Results

Twenty-two species of Protura were identified in this study based on our sampling material and 15 new records for Romanian proturan fauna were established. In total, 27 species belonging to 6 genera and 4 families (Hesperentomidae, Protentomidae, Acerentomidae and Eosentomidae) are now recorded from Romania.

Some data about ecology, distribution in Europe and in Romania are given for each species and, where appropriate, remarks are provided. An identification key to the Romanian Protura species follows the species accounts.

## Order Acerentomata Family Hesperentomidae Subfamily Hesperentominae

#### 1. Ionescuellum carpaticum (Ionescu, 1930)

**Ecology.** This species prefers dry to moderately humid rock mountain biotopes (Nosek 1973).

**Distribution in Romania.** This species was hitherto known only from Sinaia, Prahova County; lives under rocks in the forest (Ionescu 1930).

**Distribution in Europe.** Austria (Szeptycki 2005); Bosnia and Herzegovina, Croatia, Greece, Poland (Szeptycki 2007); Serbia (Blesić and Mitrovski-Bogdanović 2012).

## Family Protentomidae Subfamily Protentominae

### 2. Proturentomon minimum (Berlese, 1908)

### Material examined. Site 1, 2 females.

**Ecology.** Usually occurs in grasslands (Nosek 1973); peri-urban forest (in present study).

**Distribution in Romania.** This species is known only from Periş forest (Ilfov County) (this study).

**Distribution in Europe.** Austria, Bosnia and Herzegovina, Czech Republic, Italy, Germany, Great Britain, Greece, Luxembourg, Poland, Portugal, Switzerland, Slovakia, European Russia (Szeptycki 2007); Serbia (Blesić and Mitrovski-Bogdanović 2012).

Remarks. New record for the Romanian fauna.

#### 3. Proturentomon sp.

#### Material examined. Site 3, one female.

**Remarks.** Probably a new species, more material is needed for description. This species has four anterior setae on tergites II–VI (*A1* and *A2*), whereas 10 *Proturentomon* species have only two anterior setae (*A1*) and three species lack them entirely.

## Family Acerentomidae Subfamily Berberentulinae

#### 4. Acerentulus alni Szeptycki, 1991

**Material examined.** Site 8, 2 females; site 3, 3 females; site 4, 3 females, 2 mj; site 10, one male, 1 pi; site 11, one female, 1 mj; site 13, 2 females, one male, 1 pi, 4mj; site 15, 2 females, one male 1LII.

**Ecology.** Lives in various types of forests and meadows (Szeptycki 1991, Shrubovych 2010).

**Distribution in Romania.** Adam Peak, Prahova County: Valea Largă, Șotriile, Făgăraș Mountains: Valea Arpașului and Valea Brescioarei, Bârgău Mountains (this study).

**Distribution in Europe.** Poland, Slovakia (Szeptycki 2007) and Ukraine (Shrubovych 2010).

Remarks. New record for the Romanian fauna.

#### 5. Acerentulus confinis (Berlese, 1908)

**Ecology.** Eurytopic species; previously recorded from soil, litter and mosses of both humid and xerothermic forests, in garden soil, in mosses on limestone rocks, in detritus, and along the Black Sea coast (Nosek 1973).

**Distribution in Romania.** Sinaia (Prahova County) and in Pantelimon forest, near Bucharest (Ilfov County), in litter; Agigea (Constanța County), in litter of *Crataegus* bushes, on dunes from zoological station at Agigea (Ionescu 1951).

**Distribution in Europe.** Austria, Belgium, Bosnia and Herzegovina, Great Britain, Bulgaria, Corsica, Czech Republic, France, Germany, Greece, Hungary, Ireland, Italy, Portugal, Slovakia, Switzerland (Szeptycki 2007); Canary Islands, Madeira; Poland and Ukraine (Shrubovych 2006, Szeptycki 2007); Serbia (Blesić and Mitrovski-Bogdanović 2012); doubtful in: Balearic Islands, Slovenia, Spain (Szeptycki 2005).

#### 6. Acerentulus cf. confinis

Material examined. Site 18, one female, one male.

**Remarks.** Probably a new species or an intrapopulation variation. Our species differs from *A. confinis* (Berlese, 1908) in the absence of setae *P3a* on tergite VII and in a longer foretarsus (135 µm versus 100 µm in *A. confinis*).

#### 7. Acerentulus exiguus Condé, 1944

**Material examined.** Site 5, one female; site 10, one male; site 12, 3 females, one male; site 13, one female.

**Ecology.** Eurytopic species; abundant in soil, litter, mosses, decaying wood and plant-debris of forests, meadows, xerothermic grasslands and shrubs on rocks (Szep-tycki 1991, Shrubovych 2010).

**Distribution in Romania.** Voila forest (Prahova County), Făgăraş Mountains: Valea Arpaşului and Valea Brescioarei (this study).

**Distribution in Europe.** Greek mainland and Ukraine (Szeptycki 2005); Austria, Bosnia and Herzegovina, Corsica, Czech Republic, France, Germany, Poland, Sardinia, Slovakia (Szeptycki 2007); Serbia (Blesić and Mitrovski-Bogdanović 2012).

Remarks. New record for the Romanian fauna.

#### 8. Acerentulus halae Szeptycki, 1997

Material examined. Site 6, one female, one male.

**Ecology.** Xerophilous species; the species was found in plant debris in meadowsteppes (Shrubovych 2010).

**Distribution in Romania.** This species was reported only from Adam Peak (this study).

Distribution in Europe. Known only from Ukraine (Szeptycki 2007).

Remarks. New record for the Romanian fauna.

#### 9. Acerentulus traegardhi Ionescu, 1937

#### Material examined. Site 6, one male.

**Ecology.** Xerophilous species; abundant in soil and litter of forests, meadow-steppes and green patches inside cities squares (Szeptycki 1991, Shrubovych 2010).

**Distribution in Romania.** Comarova, near Black Sea, south of Agigea (Constanța County), litter in forest (Ionescu 1937); Retezat Mountains, litter and humus of three sampling sites: 1) *Festuco drymejae-Fagetum* community, elevation 850 m; 2) *Hieracio transilvanico-Piceetum* community, elevation 1250 m; 3) *Calamagrostio villosae-Pine-tum mugo* community, elevation 1800 m (Falcă 1972).

**Distribution in Europe.** Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Denmark, France, Germany, Greece, Hungary, Ireland, Italy, Poland, Slovakia, Spain,

Sweden and Ukraine; some records from Europe have been misidentified as *A. insignis* and should be confirmed, especially from western Europe (Szeptycki 2007); Serbia (Blesić and Mitrovski-Bogdanović 2012).

#### 10. Acerentulus xerophilus Szeptycki, 1979

Material examined. Site 9, 2 females, 2 males.

**Ecology.** Xerophilous species; reported from soil and litter of forests, meadow-steppes, dry grasslands and city squares (Szeptycki 1991, Shrubovych 2010).

**Distribution in Romania.** This species is known only in Iacobeni (Suceava County) (this study).

**Distribution in Europe.** Poland and Ukraine (Szeptycki 2007, Shrubovych 2010), Serbia (Blesić and Mitrovski-Bogdanović 2012).

Remarks. new record for the Romanian fauna.

#### 11. Acerentulus sp. cunhai-group

#### Material examined. Site 20, one female.

**Remarks.** The Romanian specimen belongs to the *cunhai*-group according to Nosek's criteria (1973). It differs from other members of the group in absence of seta *P1a* on tergites II-III and possession of this seta on tergites IV-V. This specimen probably represents a new species, but more material is necessary.

**Distribution in Romania.** Malaia (Olt Valley) (this study). **Remarks.** New record for the Romanian fauna.

#### Subfamily Acerentominae

#### 12. Acerentomon affine Bagnall, 1912

Material examined. Site 7, one female, one male.

**Ecology.** This species prefers forest biotopes (Nosek 1973).

**Distribution in Romania.** Calafat (Dolj County) and Ciocăneasa, in forest litter (Ionescu 1951).

**Distribution in Europe.** Austria, Bosnia and Herzegovina, Great Britain, France, Germany, Ireland, Luxembourg, Spain and Sweden (Szeptycki 2007), Italy (Galli et al. 2011).

#### 13. Acerentomon carpaticum Nosek, 1961

Material examined. Site 3, one female, 1 mj, 2 LII; site 16, 1 mj, site 17, 5 females, 2 males.

**Ecology.** This species prefers forest biotopes (Nosek 1973, Shrubovych 2006).

**Distribution in Romania.** Valea Largă (Prahova County); Bârgău Mountains (Valea Străjii and Tureac) (this study).

Remarks. New record for the Romanian fauna.

**Distribution in Europe.** Ukraine (Shrubovych 2006); Bosnia and Herzegovina, Poland and Slovakia (Szeptycki 2007).

#### 14. Acerentomon mesorhinus Ionescu, 1930

Ecology. Reported from forest and meadow biotopes (Shrubovych 2006).

**Distribution in Romania.** Cumpatul - Sinaia (Prahova County, beech forest (Ionescu 1930); Retezat Mountains, litter and humus of three sampling sites: 1). *Festuco drymejae-Fagetum* community, elevation 850 m; 2) *Hieracio transilvanico-Piceetum* community, elevation 1250 m; 3) *Calamagrostio villosae-Pinetum mugo* community, elevation 1800 m (Falcă 1972).

**Distribution in Europe.** Germany, Slovakia, Ukraine; Serbia (Blesić and Mitrovski-Bogdanović 2012).

### 15. Acerentomon microrhinus Berlese, 1909

Ecology. This species prefers forest biotopes (Nosek 1973, Shrubovych 2006).

**Distribution in Romania.** Parang Mountains, forest humus, 1000 m elevation, and in litter of oak forest in Pantelimon, near Bucharest (Ilfov County) (Ionescu 1951).

**Distribution in Europe.** Austria, Bosnia and Herzegovina, Corsica, France, Italy, Slovakia, Slovenia and Ukraine (Szeptycki 2007), Serbia (Blesić and Mitrovski-Bogdanović 2012).

#### 16. Acerentomon quercinum Ionescu, 1932

Material examined. Site 20, one female, 1 mj.

Ecology. Prefers forest biotopes (Nosek 1973, Szeptycki 1980, Shrubovych 2006).

**Distribution in Romania.** Forest humus, Cernica (Ilfov County) and litter of oak forest, Ciocăneasa (Ionescu 1951); Retezat Mountains, litter and humus of three sampling sites: 1) *Festuco drymejae-Fagetum* community, elevation 850 m; 2) *Hieracio transilvanico-Piceetum* community, elevation 1250 m; 3) *Calamagrostio villosae-Pine-tum mugo* community, elevation 1800 m (Falcă 1972).

**Distribution in Europe.** Austria, Bosnia and Herzegovina, Hungary, Slovakia, Poland and Ukraine (Szeptycki 2007); data from France should be confirmed (Szeptycki 2007); Serbia (Blesić and Mitrovski-Bogdanović 2012).

#### 17. Acerentomon cf. quercinum

Material examined. Site 19, 3 males, 4 females, 1 mj.

**Remarks.** These specimens probably represent an undescribed species. *Acerentomon* cf. *quercinum* differs from *A. quercinum* Ionescu 1932 in having foretarsal sensillum *a* shorter, and maxillary and labial sensilla with a different shape; in our opinion these characters are not sufficient for description of a new species. Molecular analysis could clarify their status.

#### 18. Acerentomon rostratum Ionescu, 1951

Material examined. Site 18, 2 females, 4 males, 1 LII, 1 LI.

Ecology. Lives in oak forest (Ionescu 1951).

**Distribution in Romania.** Bumbești-Pițic, Copaci forest, oak forest (Gorj County) (Ionescu 1951).

Distribution in Europe. Known only from Romania (Szeptycki 2007).

#### Subfamily Acerentominae

#### 19. Acerella muscorum (Ionescu, 1930)

Ecology. This species prefers forest ecosystems (Nosek 1973, Shrubovych 2006, 2010).

**Distribution in Romania.** Sinaia-Cumpătul (Prahova County), in mosses (Ionescu 1930); beech forest and in litter of oak forests from Tăgădău and Galaleu (Arad County) (Ionescu 1951).

**Distribution in Europe.** Germany (Szeptycki 2005), Austria, Bosnia and Herzegovina, Bulgaria, Czech Republic, France, Greece, Hungary, Italy, Poland, Sardinia, Slovakia, Spain, Switzerland and Ukraine (Szeptycki 2007), Serbia (Blesić and Mitrovski-Bogdanović 2012).

## Order Eosentomata Family Eosentomidae

## 20. Eosentomon armatum Stach, 1926

Material examined. Site 9, 2 mj; sit 21, 2 females.

**Ecology.** In soil and litter of forests (beech-hornbeam and oak) (Szeptycki 1985), found also in urban parks (Shrubovych 2006).

Distribution in Romania. Ponicova (Cazane) (Mehedinți County), in forest humus; in mosses on soil in Sinaia (Prahova County); Snagov (Ilfov County), Săbăreni, Tăgădău and Galaleu (Arad County) and under bark of Jepi, at 2000 m elevation near Caraiman Peak, Bucegi Mountains (Ionescu 1951).

**Distribution in Europe.** Austria, Belgium, Czech Republic, Denmark, France, Great Britain, Iceland, Germany, Luxembourg, Poland, Portugal, Slovakia, Spain, Switzerland and Ukraine. All data before 1986 needs verification as some records are mixed with similar species (Szeptycki 2007), Italy (Galli et al. 2011).

#### 21. Eosentomon carpaticum Szeptycki, 1985

**Material examined.** Site 4, 2 females; site 5, 2 females, one male, 1 LI; site 7, one male, 1 mj; site 14, 1 mj; site 19, one female, 2 males; site 20, one female.

**Ecology.** Found in soil and moss in beech forest and under dense overgrown shrubs (Szeptycki 1985, Shrubovych 2006).

**Distribution in Romania.** Șotriile, Cheile Posadei and Voila (Prahova County); Bârgău Mountains: Lunca Ilvei; Cozia National Park: Călinești Valley; Olt Valley: Malaia (this study).

**Distribution in Europe.** Endemic Carpathian species, Ukraine and Poland (Sz-eptycki 2007).

Remarks. New record for the Romanian fauna.

#### 22. Eosentomon enigmaticum Szeptycki, 1986

Material examined. Site 3, one female, 2 males, 1 LII.

**Ecology.** This species prefers forest ecosystems (Szeptycki 1986). **Distribution in Romania.** Known only from Valea Largă (Prahova County) (this study). **Distribution in Europe.** Poland and Ukraine (Shrubovych 2006, Szeptycki 2007). **Remarks.** New record for the Romanian fauna.

#### 23. Eosentomon pinetorum Szeptycki, 1984

**Material examined.** Site 1, 4 females, one male; site 4, one male; site 10, 3 females; site 12, 1 mj.

**Ecology.** Xerophilous species; lives in beech, oak, hornbeam, pine forests and mixed forests with spruce, thermophilous fir forest and steppe localities (Szeptycki 1998, Shrubovych 2010).

**Distribution in Romania.** Periș (Ilfov County); Șotriile (Prahova County); Făgăraș Mountains: Valea Arpașului (this study).

**Distribution in Europe.** Austria, Czech Republic, Germany, Poland and Ukraine (Shrubovych 2006, Szeptycki 2007).

**Remarks.** New record for the Romanian fauna.

#### 24. Eosentomon semiarmatum Denis, 1927

Material examined. Site 22, 3 females.

**Ecology.** Eurytopic species; reported from different forest and steppe localities (Szeptycki 1986, Shrubovych 2006).

**Distribution in Romania.** Forest litter from Sinaia (Prahova County); Cernica (Ilfov County) and Snagov (Ilfov County) (Ionescu 1951).

**Distribution in Europe.** Balearic Islands, France, Germany, Poland and Ukraine (Szeptycki 2007).

## 25. Eosentomon silvaticum Szeptycki, 1986

Material examined. Site 3, one male, 1 LII.

**Ecology.** The species prefers woodlands (fir and mixed forests with fir, pine, beech, hornbeam) (Szeptycki 1986).

**Distribution in Romania.** This species is known only from Valea Largă (Prahova County) (this study).

**Distribution in Europe.** Poland and Luxembourg (Szeptycki 2007). **Remarks.** New record for the Romanian fauna.

#### 26. Eosentomon stachi Rusek, 1966

Material examined. Site 2, 3 females, one male, 2 mj.

**Ecology.** Xerophilous species; lives in different forests, meadows, dry pasture ground and in petrophilous turf on limestone (Szeptycki 1985, Shrubovych 2006).

**Distribution in Romania.** This species is known only from Jilava forest (Ilfov County) (this study).

Remarks. New record for the Romanian fauna.

**Distribution in Europe.** Austria, Luxembourg, Poland, Slovakia and Ukraine (Szeptycki 2007).

#### 27. Eosentomon transitorium Berlese, 1908

Material examined. Site 5, one female, 1 mj; site 7, one female; site 11, one male, 1 LII.

**Ecology.** Eurytopic species; it has been recorded from soil and litter of various forests, town parks, alpine bushes *Salix herbacea* L. and *Dryas octopelata* L., in debris of tall herbs on rock shelves, dry meadows, grasslands, in xerothermic turf, in deep soil under stones (Nosek 1973, Szeptycki 1986, Shrubovych 2006).

**Previous records**: Sinaia (Prahova County), in beech litter; Agigea, near zoological station (Constanța County), in litter, *Acacia* forest (Ionescu 1951); Retezat Mountains,

litter and humus of three sampling sites: 1) *Festuco drymejae-Fagetum* community, elevation 850 m; 2) *Hieracio transilvanico-Piceetum* community, elevation 1250 m; 3) *Calamagrostio villosae-Pinetum mugo* community, elevation 1800 m (Falcă 1972).

**Distribution in Europe.** Latvia, Estonia; most of these records should be confirmed (Szeptycki 2005); Austria, Bosnia and Herzegovina, Czech Republic, Denmark, Finland, France, Great Britain, Greece, Hungary, Germany, Italy, Ireland, Norway, Poland, Slovakia, Sweden, Switzerland and Ukraine; doubtful records from: Balearic Islands, Belgium, Bulgaria, Corsica, Croatia, Iceland, Portugal, Sardinia, Spain (Szeptycki 2007), Serbia (Blesić and Mitrovski-Bogdanović 2012).

## Key to Romanian Protura

1	Spiracles present on meso- and metanota (Eosentomata, <i>Eosentomon</i> )2
_	Spiracles absent (Acerentomata)9
2	Head setae <i>aa</i> and <i>ap</i> present, notal setae <i>P2a</i> and <i>P3a</i> of equal length ( <i>E. delicatum</i> -group)
_	Head setae <i>aa</i> absent, <i>ap</i> present, notal seta <i>P2a</i> shorter than <i>P3a</i> ( <i>E. transito-rium</i> -group)
3	Foretarsal sensillum $c'$ on the line $\alpha 6-\delta 5$
_	Foretarsal sensillum <i>c</i> ' proximal to the line $\alpha 6-\delta 5$
4	Sensillum c'broadened, Pla on tergite VIII without basal dilation, notal seta
	P2a longer than P3a Eosentomon stachi
_	Sensillum <i>c</i> 'slender, <i>P1a</i> on tergite VIII with basal dilation, notal seta <i>P2a</i> the
	same length as P3a Eosentomon armatum
5	Seta <i>P1a</i> on tergite VII at the same level as <i>P2</i>
_	Seta <i>P1a</i> on tergite VII posterior to level of <i>P2</i> 7
1	
6	Seta D2 on metatarsus sienderEosentomon transitorium
6	Seta D2 on metatarsus siender
6  7	Seta D2 on metatarsus siender
- 7 -	Seta D2 on metatarsus siender
6  7  8	Seta D2 on metatarsus siender
6  7  8	Seta D2 on metatarsus siender       Eosentomon transitorium         Seta D2 on metatarsus spine-like       Eosentomon enigmaticum         Sternites IX–X with 6 setae       Eosentomon pinetorum         Sternites IX–X with 4 setae       8         Seta P1a on tergites II–IV longer than P1, foretarsal sensillum t3 longer than       c'         Eosentomon semiarmatum       Eosentomon semiarmatum
- 7 - 8	Seta D2 on metatarsus siender       Eosentomon transitorium         Seta D2 on metatarsus spine-like       Eosentomon enigmaticum         Sternites IX–X with 6 setae       Eosentomon pinetorum         Sternites IX–X with 4 setae       8         Seta P1a on tergites II–IV longer than P1, foretarsal sensillum t3 longer than         c'       Eosentomon semiarmatum         Seta P1a on tergites II–IV shorter than P1, foretarsal sensillum t3 same length
6  7  8 	Seta D2 on metatarsus siender       Eosentomon transitorium         Seta D2 on metatarsus spine-like       Eosentomon enigmaticum         Sternites IX–X with 6 setae       Eosentomon pinetorum         Sternites IX–X with 4 setae       8         Seta P1a on tergites II–IV longer than P1, foretarsal sensillum t3 longer than       c'
6  7  8  9	Seta D2 on metatarsus siender       Eosentomon transitorium         Seta D2 on metatarsus spine-like       Eosentomon enigmaticum         Sternites IX–X with 6 setae       Eosentomon pinetorum         Sternites IX–X with 4 setae       8         Seta P1a on tergites II–IV longer than P1, foretarsal sensillum t3 longer than         c'
6  7  8  9 	Seta D2 on metatarsus siender       Eosentomon transitorium         Seta D2 on metatarsus spine-like       Eosentomon enigmaticum         Sternites IX–X with 6 setae       Eosentomon pinetorum         Sternites IX–X with 4 setae       8         Seta P1a on tergites II–IV longer than P1, foretarsal sensillum t3 longer than       c'         Seta P1a on tergites II–IV shorter than P1, foretarsal sensillum t3 same length       as c'         Abdominal appendages I–II two-segmented       10         Abdominal appendage I two-segmented, appendage II not segmented
6  7  8  9 	Seta D2 on metatarsus siender       Eosentomon transitorium         Seta D2 on metatarsus spine-like       Eosentomon enigmaticum         Sternites IX–X with 6 setae       Eosentomon pinetorum         Sternites IX–X with 4 setae       8         Seta P1a on tergites II–IV longer than P1, foretarsal sensillum t3 longer than       c'
6 - 7 - 8 - 9 - 10	Seta D2 on metatarsus siender       Eosentomon transitorium         Seta D2 on metatarsus spine-like       Eosentomon enigmaticum         Sternites IX–X with 6 setae       Eosentomon pinetorum         Sternites IX–X with 4 setae       8         Seta P1a on tergites II–IV longer than P1, foretarsal sensillum t3 longer than       c'
6  7  8  9  10	Seta D2 on metatarsus siender       Eosentomon transitorium         Seta D2 on metatarsus spine-like       Eosentomon enigmaticum         Sternites IX–X with 6 setae       Eosentomon pinetorum         Sternites IX–X with 4 setae       8         Seta P1a on tergites II–IV longer than P1, foretarsal sensillum t3 longer than       c'         c'       Eosentomon semiarmatum         Seta P1a on tergites II–IV shorter than P1, foretarsal sensillum t3 same length         as c'       Eosentomon silvaticum         Abdominal appendages I–II two-segmented       10         Abdominal appendage I two-segmented, appendage II not segmented       12         Tergites II–VII with 4 pairs of A-setae, calyx of maxillary gland small
6 - 7 - 8 - 9 - 10	Seta D2 on metatarsus siender       Eosentomon transitorium         Seta D2 on metatarsus spine-like       Eosentomon enigmaticum         Sternites IX–X with 6 setae       Eosentomon pinetorum         Sternites IX–X with 4 setae       8         Seta P1a on tergites II–IV longer than P1, foretarsal sensillum t3 longer than       c'         c'       Eosentomon semiarmatum         Seta P1a on tergites II–IV shorter than P1, foretarsal sensillum t3 same length       as c'         Abdominal appendages I–II two-segmented       10         Abdominal appendage I two-segmented, appendage II not segmented       12         Tergites II–VII with 4 pairs of A-setae, calyx of maxillary gland small.       12         Tergites II–VII with at most 2 pairs of A-setae, calyx of maxillary gland en-       14

11	Tergites II–VI with one pair of $A$ -setae, foretarsal sensillum $b$ about $2/3$ length
	of <i>cProturentomon minimum</i>
-	Tergites II–VI with 2 pairs of $A$ -setae, foretarsal sensillum $b$ nearly as long as
	<i>cProturentomon</i> sp.
12	Meso- and metanota with 2 pairs of A-setae, abd. appendages II–III each with
	3 setae14
_	Meso- and metanota with 3 or 4 pairs of A-setae, abd. appendages II–III each
	with 2 setae
13	Meso- and metanota both with 3 pairs of A-setae, foretarsal sensillum t1 fili-
	form, calyx of maxillary gland with racemose appendices
	Acerella muscorum
_	Mesonotum with 3 pairs of A-setae, metanotum with 4 pairs of A-setae, sen-
	sillum <i>t1</i> claviform, calyx of maxillary gland smooth ( <i>Acerentomon</i> )21
14	Sternite XI with 4 setae
_	Sternite XI with 6 setae
15	Foretarsal sensillum <i>b</i> very long, nearly reaching the base of claw, tergite VII with seta <i>P3a</i>
_	Foretarsal sensillum $b$ shorter, nearly equal to length of sensillum $c$ , tergite
	VII without seta <i>P3a</i>
16	Foretarsal sensillum a short, passing the base of sensillum t2 (A. cunhai-
	group)
_	Foretarsal sensillum <i>a</i> long, nearly reaching or surpassing the base of seta $\sqrt{3}$
	(A. confinis-group)
17	Tergite VII with 3 pairs of A-setae
_	Tergite VII with 4 pairs of <i>A</i> -setae <b>19</b>
18	Tergite VII with seta <i>P3a</i> , sternite VII with seta <i>Pc Acerentulus xerophilus</i>
_	Tergite VII without seta <i>P3a</i> , sternite VII without seta <i>Pc</i>
	Acerentulus exiguus
19	Tergite VII with seta <i>P3a</i>
_	Tergite VII without seta P3aAcerentulus cf. confinis
20	Maxillary sensilla spindle-shaped, foretarsal sensillum a' slender, sternites II-
	III without pores
_	Maxillary sensilla parallel-sided and slender, foretarsal sensillum <i>a</i> ' thickened,
	sternites II-III with pores
21	Tergite VII with pair of x-setae(A. doderoi-group) Acerentomon rostratum
_	Tergite VII without <i>x</i> -setae
22	Sternite VIII with a pair of posterior setae ( <i>A. affine</i> -group)
	Acerentomon affine
_	Sternite VIII without posterior setae (23)
23	Labrum slightly protruded (LR = 9), foretarsal sensilla $a$ , $b$ and $c$ of the same
	length
_	Labrum clearly protruded (LR = 7 or less), sensilla $a$ , $b$ and $c$ of unequal
	lengths

24	Foretarsal sensillum <i>b</i> broadened25
_	Foretarsal sensillum <i>b</i> slender <b>26</b>
25	Foretarsal sensillum <i>a</i> long, reaching the base of seta $\gamma$ 3, maxillary sensilla
	spindle-shaped, labial sensillum slender Acerentomon quercinum
_	Foretarsal sensillum <i>a</i> short, slightly surpassing the base of seta $\gamma 2$ , maxillary
	sensilla parallel-sided, labial sensillum broadened
	Acerentomon cf. quercinum
26	Foretarsal sensillum <i>a</i> longer than <i>c</i> , sternite VI with 5 <i>A</i> -setae
	Acerentomon carpaticum
_	Foretarsal sensillum <i>a</i> shorter than c, sternite VI with 7 <i>A</i> -setae
	Acerentomon mesorhinus

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RESEARCH ARTICLE



## Nylanderia deceptrix sp. n., a new species of obligately socially parasitic formicine ant (Hymenoptera, Formicidae)

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## Abstract

Obligately socially parasitic ants are social parasites that typically lack the sterile worker caste, and depend on the host species for survival and brood care. The genus *Nylanderia* has over 130 described species and subspecies, none of which, until this study, were known social parasites. Here we describe the first social parasite known in the genus, *Nylanderia deceptrix*. Aspects of the biology of the host species, *Nylanderia parvula* (Mayr 1870), and *N. deceptrix* are examined. The data from both the host and the parasite species are combined to better understand the host-parasite relationship.

#### **Keywords**

Ants, Formicinae, Nearctic, New Species, Social Parasitism

## Introduction

Social parasitism consists of an array of fascinating life history strategies that are expressed in several different ways among the ants (Nonacs and Tobin 1992, Bekkevold and Boomsma 2000, Buschinger 2009, Rabeling and Bacci Jr. 2010). Among the socially parasitic ants are those that are obligate social parasites. Obligately socially parasitic ants are characterized by a combination of life history traits where one ant species parasitizes another free-living ant species and relies on the host species for brood care and nourishment (Wilson 1971, Hölldobler and Wilson 1990, Buschinger 2009). For most ants the "typical" colony structure is one where there are one or more queens responsible for egglaying and workers responsible for colony functions related to colony growth and development (Fischman et al. 2011). Conversely, obligate social parasites insert themselves into the colonies of other species, live with the host workers and possibly queen(s), and have their brood, which is usually only reproductives, reared by the host workers (Bekkevold and Boomsma 2000, Maschwitz et al. 2000). Of the over 13,000 described ant species, obligate social parasites are seemingly rare with about 80 known species displaying this life history strategy (Buschinger 1990, Mardulyn et al. 2014). The origin of socially parasitic ants has been of interest to myrmecologists for over a century. Emery's Rule, which states social parasites tend to be closely related to their host species, was one of the earliest observations regarding the evolution of social parasitism in ants (Emery 1909). It can be expressed in either loose (likely closely related, but parasite and host are not sister taxa) or strict (parasite and host are sister taxa) forms. Examination of Emery's Rule in the strict sense has provided evidence for sympatric speciation among obligate social parasites such as in Myrmica (Leppänen et al. 2015) and Mycoceperus (Rabeling et al. 2014).

The Nearctic *Nylanderia* currently consists of 14 native and 5 introduced species ranging from southern Canada to central Mexico (Kallal and LaPolla 2012). Most *Nylanderia* species around the world appear to nest in leaf litter and rotting wood (LaPolla et al. 2010), but there are habitat specialists in the Nearctic as well, such as the white sand nesting *Nylanderia phantasma* (Trager 1984) and the acorn inhabiting *Nylanderia querna* (Kallal and LaPolla 2012). All Nearctic *Nylanderia* overwinter their reproductives, which then emerge in the spring and early summer (Trager 1984, Kallal and LaPolla 2012).

Until recently *Nylanderia* species were all thought to display the "typical" colony life history discussed above, and social parasites were unknown. This changed, however, when one of us (SPC) discovered an unusual (only known from winged queens and wingless males), new *Nylanderia* species in Myles Standish State Forest in Massachusetts (USA) seemingly living in the colonies of *Nylanderia parvula* (Mayr 1870). This study is about that unusual *Nylanderia*, which we here describe as a new, obligately socially parasitic species, *Nylanderia deceptrix*, sp. n. Given that so little is known about obligately socially parasitic ant biology, the study of any obligately socially parasitic ant can provide valuable insights into this interesting biological phenomenon. Aspects of the biology of the host species, *Nylanderia parvula* (Mayr 1870), and *N. deceptrix* are examined with the hope of shedding light on how this example obligate social parasities is a set within *Nylanderia*.

## Materials and methods

*Field Site, sampling and rearing conditions*: The field site for this study was Myles Standish State Forest in southeastern Massachusetts, the only known location of *N. deceptrix* (Fig. 1). The forest is part of the Atlantic coast pine-barrens system that stretches through the northeastern United States, including New York, New Jersey and Massachusetts (Dinerstein et al. 2015). The forest itself is open canopy, largely composed of pitch pine (*Pinus rigida*), bear/scrub oak (*Quercus ilicifloia*), and very sandy soil. Previous fieldwork had found a high density of *N. parvula* colonies in Myles Standish State Forest with the obligately socially parasitic species being collected from several colonies on at least three different collecting trips prior to this study.

Within Myles Standish State Forest collections were along Southeast Line Road (41°49.12'N, 70°39.75'W, elev. 31 m) a sandy horse trail, in June, July and September of 2013 and May, June, July and September of 2014. During these trips, colonies were excavated, and then collected and/or observed for data collection purposes described below.

Whole colonies were collected in order to determine the general population size and temporal changes within colonies of N. parvula. Entire colonies were excavated using a shovel and trowel, digging in the area around active nest entrances and following active chambers until observed activity ended and no part of the colony remained. Each excavated colony was examined for the presence of obligate social parasites. A minimum of eight colonies were collected and preserved for each month (May n=12, June n=10, July n=13, and September n=19 between June 2013-September 2014) for population census analysis, and the GPS coordinates of each colony was recorded. Sampled colonies were stored in large Ziploc bags, preserved in 95% ethanol and stored in a -23°C freezer until sorting. Individual ants were separated from the soil samples manually by hand and stored in vials containing 95% ethanol in a -23°C freezer. The pupal brood from each colony was determined to species (either N. parvula or N. deceptrix) by measuring queen pupae (N. deceptrix 2.73-3.20 mm, n=31 and N. parvula 3.31-3.89 mm, n=84) and wing buds on male pupae (N. parvula is fully winged and *N. deceptrix* has highly reduced wing buds). Eleven colonies sampled from September 2013 were removed from analysis due to lack of whole colony collection.

Colonies taken for laboratory observation had as many individuals collected as possible via aspiration and housed temporarily in a plaster bottom nest box. In the lab live colonies were transferred to larger nest boxes composed of a nesting area and a foraging area where their food was located. The nesting area had a plaster bottom that was used to maintain moisture levels within the nest to prevent desiccation of the ants within. The colonies were fed a mixture of agar, water, egg, honey and a crushed vitamin mineral capsule. This mixture was placed inside a small cap in the foraging area and was monitored to ensure mold did not form in the food and if mold was found the food was replaced. Colonies were given 5 ml of water every 2–3 days to avoid desiccation. All gaps between tubes and the nest boxes were sealed with a silicone sealant to prevent any individuals from escaping the nest box.



**Figure 1.** Land conservation map of Massachusetts (orange and green represent protected areas), with the location of Myles Standish State Forest indicated. Modified from http://files.usmre.com/175/MA%20 Map%202009.

*Reproductive cycle*: For each colony of *N. parvula* collected (completed as explained above for a total of n=43) the number of individuals in each caste and developmental stage was determined: alate queens, dealate queens, males, workers, larvae ( $1^{st}-4^{th}$  instars) and pupae. Population census data was also compared across seasons to elucidate any temporal changes within colonies. These seasonal difference analyses included: average number of alates and average brood count.

*Taxonomic description of Nylanderia deceptrix*: All material examined was gathered from field sampling at Myles Standish State Forest (locality as specified above). Specimens of *N. deceptrix* were collected between 6 June 2013 and 16 September 2014, and preserved in 95% ethanol, and then mounted for morphological study.

Measurements were undertaken using a Leica MZ16 dissecting microscope and an ocular micrometer. Measurement terminology, abbreviations and definitions follow LaPolla et al. (2011) and Kallal and LaPolla (2012):

- **EL** (Eye Length): maximum length of compound eye in full-face view.
- **GL** (Gaster Length): the length of the gaster in lateral view from the anteriormost point of the first gastral segment (third abdominal segment) to the posteriormost point (in males this included through the posterior end of parameres).
- **HL** (Head Length): the length of the head proper, excluding the mandibles; measured in full-face view from the midpoint of the anterior clypeal margin to a line drawn across the posterior margin from its highest points (to accommodate species where the posterior margin is concave).

HW	(Head Width): the maximum width of the head in full-face view (in males, por- tion of the eves that extends past the lateral margins of the head is included).
MMC	(Mesonotal Macrosetae Count): the number of erect macrosetae on mesono- tum to one side of sagittal plane.
MtMC	(Metanotal Macrosetae Count): the number of erect macrosetae on metano- tum to one side of sagittal plane.
MW PW PDH	(Mesonotal Width): the maximum width of the mesonotum in dorsal view. (Pronotal Width): the maximum width of the pronotum in dorsal view. (Propodeum Height): height of the propodeum as measured in lateral view
	from the base of the metapleuron to the maximum height of the propo- deum.
PFL	(Profemur Length): the length of the profemur from its margin with the coxa to its margin with the tibia.
PFW	(Profemur Width): the maximum width of the profemur.
PL	(Paramere Length): the maximum length of the paramere.
РМС	(Pronotal Macrosetal Count): the number of erect macrosetae on pronotum to one side of sagittal plane.
SL	(Scape Length): the maximum length of the antennal scape excluding the condylar bulb.
SMC	(Scape Macrosetal Count): the number of erect macrosetae on the scape vis- ible in full frontal view.
TL	(Total Length): HL+WL+GL
WL	(Weber's Length): in lateral view, the distance from the posteriormost bor- der of the metapleural lobe to the anteriormost border of the pronotum, excluding the neck.
CI	(Cephalic Index): (HW/HL) × 100
FI	(Profemur Index): (FW/FL) × 100
REL	(Relative Eye Index): (EL/HL) × 100
SI	(Scape Index): (SL/HW) × 100

Each measurement was recorded to the nearest 0.001 mm and rounded to the nearest 0.01 mm. A total of 10 queens from six different colonies and five males from a single nest were used for the body measurement data. Color images were taken using a JVC KY-F75 digital camera and Syncroscopy Auto-Montage (v 5.0) software.

The male's 9<sup>th</sup> gastral sternite and penis valve were dissected under a Leica MZ16 dissecting microscope. The male's gaster was placed in a potassium hydroxide (KOH) solution to dissolve/weaken any connective tissues and then the sternite and penis valve were separated from the gaster. The sternite and penis valves were dyed with double stain, slide mounted in glycerin and drawn using an ocular grid with a Leica DM2500 light microscope.

*Prevalence of host species and parasitism rate*: Nest entrance density for *N. parvula* was determined by counting the number of nest entrances found within four 50 m  $\times$  0.5 m transects and dividing the number found by the area (Kaspari et al. 2000, Ab-

bott 2005, Braschler 2005). Transects were laid out along the edge of the trail that served as the study site. Once counted, a nest entrance was marked by a flag to ensure that a nest entrance was not counted twice in the same transect. One of the 50 m transects intersected with a trail, as a result the length of the transect that was intersecting the trail was excluded, resulting in two smaller transects measuring 14 m  $\times$  0.5 m and 25 m  $\times$  0.5 m.

The parasitism rate of *N. deceptrix* was determined by excavating 356 *N. parvula* colonies over the course of two collecting seasons (as stated above). In excavating to determine if *N. deceptrix* was present, a colony was excavated using a shovel and the sand containing the colony was visually inspected for *N. deceptrix*. The number of host colonies containing *N. deceptrix* (n=9) was then divided by the total number of *N. parvula* nests excavated (n=356) to calculate the parasitism rate.

*Flight and dispersal:* Morphological calculations for forewing length and Weber's length were made and compared against each other. The forewing length (FWL) (maximum length of the forewing from mesosomal attachment to wingtip) and Weber's length (WL) were measured for *N. deceptrix* (n=22) and the following other Nearctic *Nylanderia* species that are known to fly: *Nylanderia arenivaga* (Wheeler 1905) (n=1), *Nylanderia austroccidua* (Trager 1984) (n=1), *Nylanderia concinna* (Trager 1984) (n=3), *Nylanderia faisonensis* (Forel 1922) (n=9), *N. parvula* (n=20), *N. phantasma* (n=1), *N. querna* (n=5), *Nylanderia terricola* (Buckley 1866) (n=1), *Nylanderia vividula* (Nylander 1846) (n=13), and *Nylanderia wojciki* (Trager 1984) (n=10). For *N. deceptrix* and *N. parvula* the measurements converted to a ratio (FWL:WL), and a Student's t-test was used to determine if there was a significant difference between the proportionate size of forewings to Weber's length between the two species. This was done specifically to see if the wings of *N. deceptrix* were proportionally smaller than the wings of *N. parvula*, and potentially link reduced wing size to their dispersal method. All species measurements were plotted on a scatter plot for comparison.

To determine whether or not *N. deceptrix* queens could fly (males are wingless), individual queens were tested by allowing them to walk to the tip of a pencil to see if they would fly off (Rabeling and Bacci Jr. 2010). Additionally queens were dropped to see if they would fly once put into free-fall. The pencil test was conducted with five individuals with five trials each and the drop test on two individuals with two trials each.

Aggression behavior: Pairings for aggression tests consisted of the following combinations (all workers are of *N. parvula*; parasitized refers to coming from a colony that had *N. deceptrix* queens within it): not parasitized colony worker-foreign not parasitized colony worker (control) (n=6), parasitized colony worker-not parasitized colony worker (n=5), *N. deceptrix* queen-not parasitized colony worker (n=2), *N. deceptrix* queen-not parasitized colony *N. parvula* queen (n=16), parasitized colony workerparasitized colony worker (n=3), and *N. deceptrix* queen-foreign parasitized colony worker (n=2). Assessment of the aggression level followed a slightly modified scale used by Abbott (2005): 1=antennation then tolerance; 2=prolonged antennation (>5 seconds) followed by tolerance; 3=rapid flight or brief gaster flexion for chemical defense; 4=brief aggression consisting of biting legs, antennae, or other body parts followed by avoidance and flight; 5=prolonged fight between individuals, potentially to the death. The number of trials for each combination varied based on the available number of individuals/colony at the time of testing.

Introduction tests were also conducted to observe behaviors at the colony level in response to foreign individuals being introduced. Introduced individuals were placed into the foraging area of colonies (see Fig. 2) and observed. Combinations for the introduction tests consisted of the following (all workers are of *N. parvula*): not parasitized nest worker-foreign not parasitized nest (control) (n=5), *N. deceptrix* queenforeign parasitized nest (n=3), parasitized nest worker-foreign parasitized nest (n=3), *N. deceptrix* queen-not parasitized nest (n=4), parasitized nest worker-not parasitized nest (n=5), and not parasitized nest worker-parasitized nest (n=4). The introduction tests were scored on the same scale as the aggression tests. These tests allowed for any behaviors that occur within or around the nest to be observed that may have been missed due to the inability to see within the nest during field observations (Heinze 1989, Johnson 1994).

## Results

#### Nylanderia deceptrix sp. n.

http://zoobank.org/B5A11117-4638-4B6D-9908-6208C05CF558 Figs 2, 3 (queen); 4–11 (male)

**Holotype queen**, USA. Massachusetts: Plymouth County: Myles Standish State Forest; Southeast Line Road; 41°49.12'N, 70°39.75'W; elev. 31 m; in *N. parvula* nest; 06 June 2013 (S. Messer) (MCZC); 10 paratype queens and 7 paratype males same locality information as holotype except different collection dates (MCZC and USNM).

**Diagnosis.** *Queen*: smallest of Nearctic *Nylanderia* (TL less than 3.5 mm); mesosoma color mottled with areas of lighter and darker brown to yellowish-brown; *Male*: very small, nonfunctional wings present.

QUEEN. *Measurements* (*n*=10): TL: 2.91–3.40; HW: 0.55–0.63; HL: 0.58–0.69; EL: 0.22–0.24; SL: 0.73–0.78; MW: 0.52–0.57; PW: 0.55–0.67; WL: 0.99–1.07; GL: 1.24–1.69; PDH: 0.35–0.42; PFL: 0.67–0.72; PFW: 0.15–0.17; SMC: 0–3; PMC: 4–5; MMC: 21–27; MtMC: 3–4.

Indices: CI: 92-97; REL: 33-37; SI: 121-130; FI: 21-24.

Overall brown to yellowish-brown; head and gaster darker brown with generally lighter mesosoma; mesosoma color mottled with areas of lighter and darker brown to yellowish-brown; antennae, mandibles and legs yellow; body covered with dense pubescence; macrosetae dark brown but usually with lighter yellowish-brown tips. Eyes bulge slightly beyond head outline in full-frontal view; three prominent ocelli present. Scapes long; yellow; exceed posterior margin of the head by the length of first 3 funicular segments; scapes with dense pubescence and sometimes with up to three short standing macrosetae, but often with none. Head with abundant macrosetae and



**Figures 2–11.** *Nylanderia deceptrix* (queen USNMENT00755074; male **4, 5** USNMENT00755083; male **6–11** USNMENT00755073): **2** queen in lateral view **3** queen head in full-frontal view **4** male in lateral view **5** male head in full-frontal view **6–9** male genitalia in dorsal, lateral, and ventral view, and ventral view close-up of digitus and cuspis **10** male 9<sup>th</sup> sternite **11** penis valve (ectal view).

layer of pubescence; slightly longer than broad; becoming slightly wider at posterior of head. Mesosoma covered with erect macrosetae and pubescence; most macrosetae on mesonotum and metanotum show strong curvature. Gaster covered in pubescence and a large cluster of macrosetae on first gastral tergite.

MALE. *Measurements* (*n*=5): TL: 1.91–2.05; HW: 0.45–0.46; HL: 0.48–0.53; EL: 0.17–0.18; SL:0.57–0.59; MW: 0.28–0.32; PW: 0.37–0.39; WL: 0.66–0.69; GL: 0.74–0.88; PDH: 0.24–0.26; PFL: 0.52–0.54; PFW: 0.11–0.13; PL: 0.20–0.24; SMC: 0; PMC: 0; MMC: 7–12; MtMC: 1–2.

Indices: CI: 88-97; REL: 34-36; SI: 125-127; FI: 22-25.

Overall color brown to brownish-yellow; head and gaster darker brown with generally lighter mesosoma; antennae, mandibles, legs, and parameres yellow; body covered with dense pubescence; macrosetae dark brown but usually with lighter yellowishbrown tips; cuticular surface dull, covered in a dense layer of appressed setae. Head longer than broad; eyes large and bulging beyond head outline in full-frontal view; three prominent ocelli present; scapes long, exceeding posterior margin of the head by length of first 3 funicular segments; scapes absent of macrosetae and with a dense layer of pubescence; clypeus roughly rectangular, with anterior margin emarginated; mandible broad, with 4 teeth; all but apical tooth are weakly developed; apical tooth distinct, curves in toward body midline. Mesosoma relatively small; very small nonfunctional wings present; mesosoma covered in pubescence, with erect setae of varying lengths dorsally and on legs. Pronotum collar-like; mesonotum offset from pronotum at sulcus; mesonotum rises sharply above height of pronotum; mesonotum flat dorsally with many erect setae of varying lengths; marcosetae on mesonotum and metanotum show strong curvature of about 90°; propodeum indistinct from remainder of mesosoma, but with steep declivity; petiole short, triangular, upright, with posterior face only slightly longer than anterior face. Gaster with a dense layer of pubescence and erect setae; parameres especially setose; parameres roughly triangular, turning slightly mesad posteriorly; long setae extend off of parameres; cuspi small and tubular, reaching digiti dorsally; digiti weakly anvil-shaped, with poorly developed point directed ventrally; volsellar lobes flat, slightly indented relative to digital margin.

**Etymology.** The species epithet *deceptrix* (Latin = deceiver) is attributed to the parasitic lifestyle, deceiving the host to allow cohabitation.

**Notes.** *Nylanderia deceptrix* can be identified from other Nearctic species because it has the smallest queens of all Nearctic *Nylanderia*, ranging between 2.91–3.40 mm (Trager 1984, Kallal and LaPolla 2012). Compared to other Nearctic species with no macrosetae on the scape such as *N. parvula* and *Nylanderia trageri* (Kallal and LaPolla 2012), *N. deceptrix* is the only species with queens showing bicoloration, with the head and gaster being darker in color than the mesosoma. Additionally the queens have a mottled coloration on the mesosoma with areas of darker brown and yellow-brown. *Nylanderia deceptrix* males are currently the only Nearctic *Nylanderia* to display highly reduced wings. The male parameres display dense and very long macrosetae compared to those of other Nearctic species. The digitus displays a narrower area towards the base of the structure that expands towards the tip and ends with a narrow point. The end of the digitus also has distinct foveolate (pitted) sculpturing. The head of both the queen and the male are worker-like in overall appearance (except for the presence of distinct, large ocelli; never strongly developed in workers), and are longer than wide, whereas *Nylanderia* reproductives, especially queens, typically have wider than long heads. Additionally, *Nylanderia* queens usually have heads covered in dense pubescence, and this is not the case in *N. deceptrix*.

**Prevalence of host species and parasitism rate.** Across the seven transects, the average *N. parvula* nest entrance density was 2.35 nest entrances/m<sup>2</sup> (SD=0.15), ranging from 1.64–2.64 nest entrances/m<sup>2</sup> for the individual transects. Transect 1 was excluded from all calculations because of inexperience in locating nest entrances and insufficient surveying effort resulting in a density 81.3% less than the average across all other transects.

In total, 356 *N. parvula* colonies were excavated and checked for the presence of *N. deceptrix*. Of those 356 colonies, nine had *N. deceptrix* present, resulting in a parasitism rate of 2.53%. The number of *N. deceptrix* queens found in a single colony ranged from 1–8 per colony. *Nylanderia deceptrix* males were only found in one of the nine parasitized colonies, and contained a total of nine males. *Nylanderia deceptrix* brood were found in two of the nine parasitized colonies. One colony contained only a single *N. deceptrix* queen pupa. The range for *N. parvula* pupal length was 3.31–3.89 mm (n=84) and the range for *N. deceptrix* pupal length was 2.73–3.20 mm (n=30). On the other end of the spectrum one colony contained 74 *N. deceptrix* queen pupae and 4 *N. deceptrix* male pupae (male *N. deceptrix* pupae could be determined by highly reduced wing buds and the presence of genitalia).

**Reproductive cycle.** All colonies that were found to have dealate queens (n=17) only possessed one queen and we are taking this as evidence of monogyny in *N. par-vula*. A total of 43 colonies were excavated and used for population census data collection. Among the 43 colonies, the average number of adult *N. parvula* reproductives (alate queens and males) found in colonies was: 15.4 ( $\pm$ 23.3) for May, 0 for June, 6.1 ( $\pm$ 4.1) for July, and 20.4 ( $\pm$ 11.77) for September (Fig. 12). Compared to the number of alates, the total brood (larvae and pupae combined) within colonies shows the opposite trend (Figs 12, 13). Counts were low in May (37  $\pm$ 134.2) and September (15.8  $\pm$ 209.6), moderate in July (177.6  $\pm$ 65.2), and at the highest in June (722.7  $\pm$ 116.1). *Nylanderia parvula* reproductive pupae were only found in July, and *N. deceptrix* reproductive pupae were only observed in July as well.

**Flight and dispersal.** Forewing length (FWL) measurements were used along with Weber's Length to determine a ratio of forewing to Weber's length to examine if the wings of *N. deceptrix* were smaller in proportion to *N. parvula*. The FWL:WL for *N. parvula* ranged from 2.27–2.59, with an average of 2.47 (±0.018), and for *N. deceptrix* the ration ranged from 2.07–2.31, averaging 2.18 (±0.014). Comparing the averages using a Student's t-test, the difference between the two was significant (P<0.00001, t=12.59 for a two-tailed test), meaning the wings of *N. deceptrix* were smaller in proportion to Weber's length compared to *N. parvula*. When examining



Figure 12. Box-and-Whisker plot of within colony *N. parvula* alate reproductive counts from May, June, July and September.



Figure 13. Box-and-Whisker plot of within colony *N. parvula* brood counts from May, June, July and September.

the scatter plot of Weber's length to forewing length of all the *Nylanderia* species used (see material and methods for list), *N. deceptrix* falls well below the trendline created from the data of the other species (Fig. 14). The R<sup>2</sup> value of the trendline was significant with a P-value<0.00001 (F=98.12), indicating a true relationship between forewing length and Weber's length for the non-obligately socially parasitic Nearctic *Nylanderia* species.

Both *N. deceptrix* and *N. parvula* queens were allowed to climb to the top of a pencil to see if they would use it as a location to take off and fly from. Five *N. parvula* queens were tested and each of them flew off of the pencil tip within two trials, however, none of the five *N. deceptrix* flew off of the pencil tip after five trials for each individual. In the lab, attempts at dropping two *N. deceptrix* queens over a white surface to provoke flight while freefalling were conducted, but neither of them flew. As *N.* 



**Figure 14.** Scatter plot displaying mesosoma length (=Weber's length) to forewing length and trendline fitting non-parasitic Nearctic *Nylanderia*: *N. arenivaga*, *N. austroccidua*, *N. concinna*, *N. faisonensis*, *N. parvula*, *N. phantasma*, *N. querna*, *N. terricola*, *N. vividula*, and *N. wojciki* (diamonds) with added *N. deceptrix* data (squares, not part of trendline data).

Table 1. Average Aggression scores (see text for details) for aggression and introduction tests (n=sample
size). W/W-Colony = N. parvula worker to N. parvula worker; Dec/W-Colony = N. deceptrix queen to
<i>N. parvula</i> worker; Dec/Queen = <i>N. deceptrix</i> queen to <i>N. parvula</i> queen.

	W/W-Colony (N)	Dec/W- Colony (N)	Dec/Queen (N)
Parasitized to Parasitized			
Solo Aggression	2.67 (3)	1 (2)	
Introduction Test	3.33 (3)	2.33 (3)	
Parasitized to			
Not Parasitized			
Solo Aggression	4.4 (5)	5 (2)	1.88 (16)
Introduction Test	5 (5)	5 (4)	
Not Parasitized to			
Not Parasitized			
Solo Aggression	2.5 (6)		
Introduction Test	4.8 (5)		
Not Parasitized to			
Parasitized			
Introduction Test	4.75 (4)		

*deceptrix* individuals were hard to collect and maintain in a laboratory setting; only two drop trials were done per individual to avoid harming or losing individuals.

**Aggression.** The aggression tests between workers, the pairing of both *N. parvula* workers from not parasitized colonies had an average score of 2.5 (n=6, range 1–3), from one parasitized and one not parasitized colony averaged 4.4 (n=5, range 3–5), and from both parasitized colonies averaged 2.67 (n=3, range 1–4) (here colony is always referring to *N. parvula* colonies). Pairings with an *N. deceptrix* queen and a *N. parvula* worker from a not parasitized colony had an average of 5 (n=2), and with a *N.* 

*parvula* worker from a parasitized colony averaged 1 (n=2). Also, the average aggression between a *N. deceptrix* queen and a *N. parvula* queen was 1.88 (n=16, range 1–3). Introduction tests placing a *N. parvula* worker from a parasitized colony into another parasitized colony had an average score of 3.33 (n=3, range 2–5), and introducing a *N. deceptrix* queen to an already parasitized colony averaged 2.33 (n=3, range 1–5). Two of the three *N. deceptrix* introductions into an already parasitized colony resulted in acceptance of the queen into the new colony (score=1), while the third was attacked and rejected (score=5). When taking *N. deceptrix* queens or parasitized colony workers and introducing them to not parasitized colonies, the average score was 5 for each case (n=4 and 5, respectively). Similarly, workers from not parasitized colonies introduced to a parasitized colony resulted in an average score of 4.75 (n=4). The final set of introductions involved taking a *N. parvula* worker from a not parasitized colony and introducing her to another not parasitized colony. The resulting average score for that case was 4.8 (n=5, range 4–5). See Table 1 for all the aggression and introduction test average scores.

## Discussion

The data collected about the biology and natural history of *N. deceptrix* indicates it is an obligate social parasite of *N. parvula. Nylanderia deceptrix* has not been observed to produce a worker caste (we observed no features among the thousands of *N. parvula* workers examined that would indicate *N. deceptrix* workers were present; i.e. all conformed to the expected worker morphology of *N. parvula*), it is functionally polygynous, host-queen tolerant, and has only been found within colonies of *N. parvula*. The intermediate size of *N. deceptrix* queens between that of *N. parvula* workers and queens is a morphological indication of its obligate social parasite status, as obligately socially parasitic ants are smaller than their host queens (Buschinger 2009). They are also often the size of their host workers but that is not the case with *N. deceptrix*. The males of *N. deceptrix* have highly reduced wings and cannot fly, a trait seen in several obligate social parasites such as *Anergates atratulus* (Schenck, 1852), *Pheidole inquilina* (Wheeler, 1903), *Plagiolepis xene* (Stärcke, 1936), and *Pogonomyrmex colei* (Snelling, 1981).

Nylanderia deceptrix seems to have a much more restricted range than its host and resides in an area with a high density of host colonies, traits that appear to be common among obligately socially parasitic species (Heinze 1989, Nonacs and Tobin 1992, Savolainen and Vepsäläinen 2003). The likelihood of a restricted range is enhanced by the fact *N. deceptrix* queens either have very poor flight capability, or do not fly at all, coupled with the fact that males have very small, non-functional wings. The incidence of colonies parasitized with *N. deceptrix* supports this as well, since all the colonies were clustered in close proximity to one another. The presumed poor flight capability coupled with the observed clustering of parasitized colonies leads us to suspect that *N. deceptrix* disperses by walking to nearby host colonies.

Once at a host colony, the data presented here suggest it is difficult for *N. deceptrix* to become established in a *N. parvula* colony if that colony does not already possess *N. deceptrix* queens. Our aggression data shows that *N. parvula* workers act very aggressively towards any individual (*N. parvula* worker or *N. deceptrix* queens) from a colony already parasitized with *N. deceptrix*. Comparatively, *N. parvula* displays lower aggression towards *N. parvula* workers from colonies not parasitized with *N. deceptrix*. Our data suggest that *N. parvula* can detect some kind of cue that indicates whether a *N. parvula* worker has had contact with *N. deceptrix*, resulting in the observed higher level of aggression. The reason for this high aggression towards individuals from parasitized colonies is still unknown, but it could be the result of *N. deceptrix* actually having a significant fitness cost to *N. parvula* colonies.

Conversely, when an individual from a colony containing *N. deceptrix* encounters an individual from a different colony that also contains *N. deceptrix*, the aggression that results is noticeably lower. This suggests that *N. deceptrix* is influencing the amount of aggressive behavior displayed by *N. parvula*. This decrease in aggression could also be responsible for acceptance of *N. deceptrix* queens from one colony into another foreign colony already containing *N. deceptrix*. Although the mechanism and cause of acceptance for foreign *N. deceptrix* queens has not been determined, it seems likely that a contributing cause is a general decrease in aggression, a disruption in recognizing foreign individuals, or *N. deceptrix* having the ability to somehow not be recognized as a foreign individuual. Overall the parasitism rate of *N. deceptrix* within *N. parvula* colonies was seemingly low at 2.5%, but it is comparable to that of several other obligate social parasites. Examples include: *Acromyrmex charruanus* at 2% (Rabeling et al. 2015), *Leptothorax wilsoni* at 1.9% (Heinze 1989), and *Cataglyphis hannae* at less than 1% (Agosti 1994). But not all obligate social parasites have such low parasitism rates. Study of *Vollenhovia nipponica* found it in over 56% of the host colonies sampled (Kinomura and Yamauchi 1992).

Our field and lab observations confirm that *Nylanderia deceptrix* is an obligate social parasite, the first known within the genus. An important next step will be to examine the phylogenetic position of *N. deceptrix* among the Nearctic *Nylanderia*, especially to see how closely related or not it is to *N. parvula* and to test whether or not a strict or loose sense Emery's Rule applies in this example of obligate social parasitism.

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RESEARCH ARTICLE



# A taxonomy review of Oreoderus Burmeister, 1842 from China with a geometric morphometric evaluation (Coleoptera, Scarabaeidae, Valgini)

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## Abstract

The species of the genus *Oreoderus* are morphologically similar, and can be challenging to distinguish without dissecting the male genitalia. In this study, the *Oreoderus* species from China are reviewed. Three new species of *Oreoderus* are described: *O. dasystibialis* Li & Yang, **sp. n.**, *O. brevitarsus* Li & Yang, **sp. n.** and *O. oblongus* Li & Yang, **sp. n.** A key of the male *Oreoderus* and a distribution map are provided. *Oreoderus coomani* Paulian, 1961 was found as a new record in China. The first description of the female of *O. arrowi* Ricchiardi, 2001 is provided. *Oreoderus humeralis* Gestro, 1891, *O. quadricarinatus* Arrow, 1944, *O. crassipes* Arrow, 1944, and *O. momeitensis* Arrow, 1910 are excluded from the Chinese fauna. Furthermore, we utilize geometric morphometric approaches (GM) to analyze the shape variation of four characters (pronotum, elytra, protibia and aedeagus) in *Oreoderus*. The morphological variations of *Oreoderus* and the taxonomic value of each character are discussed. The combined analysis of geometric morphometrics and comparative morphology support recognition of the three new species.

#### **Keywords**

Beetles, Cetoniinae, China, new species, GM

## Introduction

*Oreoderus* Burmeister, 1842 is a genus of Valgini (Coleoptera: Scarabaeidae) which comprises 29 species, distributed only in the Oriental Region. Adults are flower-visitors, the larvae develop in the rotten wood (with or without termites) (Krikken 1984). This genus can be separated from most of the other Valgini (5-7 teeth on the protibia) by two character states: two or three external teeth on the protibia and the relatively shorter first joint of the hind tarsus compared to the second one. In contrast, the external morphology of *Oreoderus* is very subtly differentiated among species. For the majority of species, the aedeagus has been the only reliable character widely used in species identification. Some minor differences are observed in external characters (e.g., protibia, pronotum, elytra, etc.) as reported by Ricchiardi (2001), but these characters have not been systematically studied. Furthermore, many of these characters vary in their shape, which is not easily described and compared by traditional morphological approaches.

Geometric morphometrics (GM) is a useful tool for shape analysis in biology. This tool has an important advantage: not only does it offer precise and accurate description, but it also serves the equally important purposes of visualization, interpretation and communication of results (Zelditch et al. 2004, Bai and Yang 2014). With the help of GM, the minor morphological variation of characters (e.g., protibia, pronotum, elytra) can be statistically and scientifically defined and compared. In this paper, the *Oreoderus* species from China are reviewed. Furthermore, four characters (protibia, pronotum, elytra, and aedeagus) are selected to investigate the morphological variation of *Oreoderus* based on GM approach and the taxonomic values of these characters are discussed.

### Material and methods

#### Materials

In this study, all known species and three new species described in this paper (32 species and 82 specimens total) of *Oreoderus* and 2 species (2 specimens) of the out groups *Hybovalgus* Kolbe, 1904 and *Dasyvalgus* Kolbe, 1904 were selected for geometric morphometric analyses (Table 1). We selected *Hybovalgus* and *Dasyvalgus* as out groups because they are close to *Oreoderus* and members of subtribe Valgina according to Krikken's classification (1984). Most images were taken by the authors, except of *O. arrowi* and *O. waterhousei*, which were provided by Roberto Poggi (MCSN). Others are from the original references.

The specimens are deposited in the following collections:

- **ERC** Enrico Ricchiardi Collection, Turin, Italy;
- IEZU Institute of Applied Entomology, Zhejiang University, Hangzhou, Zhejiang, China;

			Characters			
	Species	Pronotum	Elytra	Protibia	Aedeagus (&)	
1.	Oreoderus aciculatus Paulian, 1961	1	1	1	1	
2.	Oreoderus ahrensi Ricchiardi, 2001	1	1	1	1	
3.	Oreoderus argillaceus (Hope, 1841)	1	1	1	1	
4.	Oreoderus arrowi Ricchiardi, 2001	6	6	6	5	
5.	Oreoderus bengalensis Ricchiardi, 2001	1	1	1	1	
6.	Oreoderus bhutanus Arrow, 1910	1	1	1	1	
7.	Oreoderus bidentatus Ricchiardi, 2001	2	2	2	1	
8.	Oreoderus birmanus Ricchiardi, 2001	1	1	1	1	
9.	Oreoderus brevicarinatus (Pic, 1928)	2	1	1	1	
10.	Oreoderus brevipennis Gestro, 1891	1	1	1	1	
11.	Oreoderus brevitarsus sp. n.	10	10	7	6	
12.	Oreoderus clypealis Arrow, 1944	1	1	1	1	
13.	Oreoderus coomani Paulian, 1961	9	9	9	7	
14.	Oreoderus crassipes Arrow, 1944	1	1	1	1	
15.	Oreoderus dasystibialis sp. n.	3	3	3	3	
16.	Oreoderus gestroi Ricchiardi, 2001	1	1	1	1	
17.	Oreoderus gracilicollis Paulian, 1961	1	1	1	1	
18.	Oreoderus gravis Arrow, 1910	1	1	1	1	
19.	Oreoderus humeralis Gestro, 1891	1	1	1	1	
20.	Oreoderus insularis Ricchiardi, 2001	1	1	1	1	
21.	Oreoderus longicarinatus Ricchiardi, 2001	1	1	1	1	
22.	Oreoderus maculipennis Gestro, 1891	15	15	11	4	
23.	Oreoderus meridionalis Paulian, 1961	1	1	1	1	
24.	Oreoderus momeitensis Arrow, 1910	1	1	1	1	
25.	Oreoderus oblongus sp. n.	10	10	7	6	
26.	Oreoderus pseudohumeralis Ricchiardi, 2001	1	1	1	1	
27.	Oreoderus quadricarinatus Arrow, 1944	1	1	2	1	
28.	<i>Oreoderus quadrimaculatus</i> Miyake, Yamaguchi & Aoki, 2004	-	-	1	1	
29.	Oreoderus rufulus Gestro, 1891	1	1	1	1	
30.	Oreoderus siamensis Ricchiardi, 2001	1	1	1	1	
31.	Oreoderus sikkimensis Ricchiardi, 2001	1	1	1	1	
32.	Oreoderus waterhousei Gestro, 1891	1	1	1	1	
33.	Dasyvalgus ichangcius Moser, 1915	1	1	1	1	
34.	Hybovalgus yunnanus Moser, 1906	1	1	1	1	

**Table 1.** The materials used in the geometric morphometric analyses.

IZAS	Institute of Zoology, Chinese Academy of Sciences, Beijing, China
MCSN	Museo Civico di Storia Naturale "Giacomo Doria", Genoa, Italy;
MNHN	Muséum national d'Histoire naturelle, Paris, France;
NHML	The Natural History Museum, London, United Kingdom;
PCRD	Private Collection of Ran DAI, Kunming, Yunnan, China.

#### **Taxonomic approaches**

The description of morphological characters follows the terminology of Krikken (1984) and Ricchiardi (2001). Specimen length was measured from the anterior margin of the pronotum to the apex of the pygidium. Specimen width represents the maximum width of the elytra. Type specimens of the new species are deposited in the Institute of Zoology, Chinese Academy of Sciences, Beijing, China (IZAS) and private collection of Enrico Ricchiardi, Turin, Italy (ERC). The images of female genitalia were drawn using Adobe Illustrator CS5, others were taken using a Nikon D5100 digital camera fitted to a Zeiss Stemi 2000-C stereomicroscope and processed in Helicon Focus 5.1 software and Adobe Photoshop CS5. The distribution map was made in ArcGis 10.0.

#### Character selection

Four characters (pronotum, protibia, elytra, and aedeagus) were examined and analyzed. There was negligible difference in the shape of pronotum and elytra for the male and female. However, sexual dimorphism often occurs in the protibia of cetoniines and other scarabs (Ricchiardi and Perissinotto 2014, McQuate and Jameson 2011, Holm 1993). Differences between both sexes include the number and acuteness of external teeth. Taking this into account, only male specimens were examined for protibia variation.

#### Geometric morphometric approaches

The morphology of the four characters (pronotum, protibia, elytra, and aedeagus) was represented by curves. Each curve was based on homologous or corresponding criteria. The pronotum was represented by 5 curves. Curve 1 represented the outline of the pronotum, which resampled into 50 semi-landmarks (SLM). Curve 2 and Curve 3 represented the outline of the carinae, which resampled into 15 SLM. Curve 4 and Curve 5 represented the outline of lateral carinae, which resampled into 10 SLM. The pronotum, elytra and aedeagus were each represented by a single curve, which resampled into 50 SLM (Fig. 1A–D).

These curves were digitized with tps-DIG 2.05 (Rohlf 2006) and all semi-landmarks were converted to landmarks. Landmark configurations were scaled, translated and rotated against the consensus configuration using the GLS Procrustes superimposition method (Bookstein 1991). The principal component analysis (PCA) and canonical variate analysis (CVA) were analyzed in MorphoJ 1.06c (Klingenberg 2011). Because shape differences among species were studied in the PCA analysis, the average or consensus configuration of landmarks for each species was computed. Minimum spanning trees (MST), based on Euclidean distance of the original data points, was computed in PAST 2.04 (Hammer et al. 2001).



**Figure 1.** Curve selection of four characters. **A** the red curve (Curve 1) is the outline of pronotum, which resampled into 50 semi-landmarks (SLM); the two green curves (Curve 2, 3) are outline of the carinae, which resampled into 15 SLM; two blue curves (Curve 4, 5) are the outline of lateral carinae, which resampled into 10 SLM **B** the curve is the outline of elytra, which resampled into 50 SLM **C** the curve is the outline of protibia, which resampled into 50 SLM **D** the curve is the outline of the left paramere, which resampled into 50 SLM.

The Procrustes distances and Mahalanobis distances computed from canonical variate analysis (CVA) can be used to explain the differences and modes of evolution. Procrustes distance is a measure of the absolute magnitude of the shape deviation and indicates how big the differences are between the average group shape. Mahalanobis distance provides an indication of how different an individual is relative to the others in the sample, and how distinctly groups are separated from one another.

## Results

Taxonomy

#### Genus Oreoderus Burmeister, 1842

Oreoderus Burmeister, 1842: 726.

Type species. Valgus argillaceus Hope, 1841, by monotypy.

**Diagnosis.** *Oreoderus* can be distinguished from all other genera within the tribe Valgini by the following characters: a) protibia with only two or three external teeth; b) the first joint of the hind tarsus shorter than the second one; c) pronotum elongated with four carinae; d) visible sternite V twice longer than sternite IV.

**Distribution.** China, India, Sikkim, Bhutan, Myanmar, Vietnam, Laos, Thailand, Cambodia, Sri Lanka, Malaysia (Fig. 2).



Figure 2. Distribution Map. A Distribution of Oreoderus. B Enlargement of Yunnan Province.

## Key to the species of the male Oreoderus

1	Pronotal carinae forms two noticeable hooked tubercles at the anterior mar-
	gin2
_	Pronotal carinae do not forms any tubercles at the anterior margin
2	Pronotal scale tufts not present; propygidial spiracles completely obsolete;
	propygidium without any scale tufts at the hind margin
	O. argillaceus (Hope, 1841)
_	Pronotum with scale tufts on the small lateral carinae; propygidial spiracles
	moderately elevated; propygidium with two scale tufts at the hind margin
3	Pronotal carinae very long, reaching over 3/4 of the pronotum length4
_	Pronotal carinae not reaching over 2/3 of the pronotum length
4	Pronotal carinae obsolete
_	Pronotal carinae interrupted twice, sharp
	O. longicarinatus Ricchiardi, 2001
5	Pronotal carinae long, reaching about 2/3 of the pronotum length
_	Pronotal carinae very short, not reaching 1/2 of the pronotum length27
6	Pronotal carinae interrupted once, sharp7
_	Pronotal carinae never interrupted9
7	Pronotal scale tufts on the small lateral carinae
_	Pronotal scale tufts close to the scutellum O. brevipennis Gestro, 1891
------------	--
8	Propygidial spiracles moderately elevated; propygidium without any scale
	tufts at the hind margin
_	Propygidial spiracles completely obsolete; propygidium with two scale tufts at
	the hind margin
9	Pronotal carinae obsolete10
_	Pronotal carinae sharp11
10	Elytra with four patches of dark-colored scales
_	Elytra without patches of scales
11	Pronotal lateral carinae join the lateral margin or arrive very close12
_	Pronotal lateral carinae stop well before the lateral margin14
12	Propygidial spiracles completely obsolete
_	Propygidial spiracles sharply elevated O. momeitensis Arrow, 1910
13	Propygidium without any scale tufts at the hind margin
	<i>O. quadricarinatus</i> Arrow, 1944 and <i>O. rufulus</i> Gestro, 1891 <sup>*</sup>
_	Propygidium with two scale tufts at the hind margin
14	Third teeth of protibia not present15
-	Third teeth of protibia present18
15	Mesotibia without bush of thick scales16
_	Mesotibia with bush of thick scales17
16	Meso- and metatibia without a spine at the middle of posterior margin
	O. brevitarsus Li & Yang, sp. n.
-	Meso- and metatibia with a spine at the middle of posterior margin
. –	<i>O. ahrensi</i> Ricchiardi, 2001
17	Protibia sharp, cariane reaching over the middle of the pronotum
	De tit 11 de la constante de l
_	Protibia blunt, cariane not reaching the middle of the pronotum
10	
18	Third tooth of protible much smaller than first and second
_	Inird tooth of protibla similar in size as the second
10	Antonion mancin of alumous circuited with a hifd macrosof
19	Anterior margin of cippeus sinuated, with a bind processes
	Anterior margin of clypeus pointed, simply sinuated or rounded but without
_	a bifd process
20	Hind margin of propyridium centrally projected toward the back, not pointed
20	0 humeralis Cestro 1891
_	Hind margin of propygidium centrally rounded or smoothly curved inward 21
21	First joint of hind tarsi shorter than the second <b>22</b>
<u>_</u> 1	First joint of hind tarsi as long as the second 25
22	Propygidium covered by simple not coffee grain shaped scales <b>23</b>
	210P/ Brandin covered by simple, not conce Brand shaped scales

-	Propygidium centrally or near the scale tufts with areas of raised c-shaped
22	scales
23	Propygidial spiracles moderately elevated
-	Propygidial spiracles completely obsolete
24	Meso- and metatibia with a spine at the middle of posterior margin
-	Meso- and metatibia without a spine at the middle of posterior margin
	O. oblongus Li & Yang, sp. n.
25	Pronotal carinae continue after the middle of the length with a triangular area
	made by C- shaped, black, raised scales that reaches the hind margin; pro-
	pygidium centrally or near the scale tufts with areas made by raised c-shaped
	scales; propygidium with two scale tufts at the hind margin
_	No triangular black scales area is present at the end of the pronotal carinae;
	propygidium covered by simple, not coffee grain shaped, scales; propygidium
	without any scale tufts at the hind margin
26	Metatibial intrusion interposed between the two mobile spurs present: pronotal
	carinae not parallel but arched or sinuated <b>O</b> <i>birmanus</i> <b>Ricchiardi</b> , 2001
_	Metatibial intrusion internosed between the two mobile spurs not present:
	propotal carinae almost parallel and the included area is parrow
	pronotal carmae annost paranet and the included area is narrow
27	Dropotal carinae obsolate 28
27	Promotel estimate obsolete
-	Frontial carinae sharp
28	First joint of hind tarsi shorter than the second
-	First joint of hind tarsi as long as the second O. crassipes Arrow, 1944
29	Propygidium without any scale tufts at the hind margin
-	Propygidium with two scale tufts at the hind margin
30	Third tooth of protibia much smaller than first and second; meso- and metat-
	ibia without any scales brush covering the median posterior tooth; first hind
	tarsi joint shorter than the secondO. clypealis Arrow, 1944
_	Third and second teeth of protibia similar in size; meso- and metatibia with
	a well noticeable brush made by ochraceous scales covering the medial poste-
	rior tooth; first hind tarsi joint as long as the second

\*To separate them see the shape of the parameres.

# Review of Oreoderus from China

The genus *Oreoderus* was recently revised by Ricchiardi (2001), though the Chinese *Oreoderus* species received little attention. Ma (1993, 1995) recorded four *Oreoderus* 

species from China: O. humeralis Gestro, 1891, O. quadricarinatus Arrow, 1944, O. crassipes Arrow, 1944, O. momeitensis Arrow, 1910. Unfortunately, Ma misidentified these four species. Based on our examination of specimens deposited in IZAS, we identified O. humeralis Gestro, 1891 sensu Ma (1993) as O. maculipennis Gestro, 1891; O. quadricarinatus Arrow, 1944 sensu Ma (1995) as O. arrowi Ricchiardi, 2001; and O. crassipes Arrow, 1944 sensu Ma (1995) as the new species O. oblongus Li & Yang, sp. n. Moreover, O. momeitensis Arrow, 1910 sensu Ma (1995) is determined to be a new record of O. coomani Paulian, 1961 for China. As a result, O. humeralis Gestro, 1891, O. quadricarinatus Arrow, 1944, O. crassipes Arrow, 1944, and O. momeitensis Arrow, 1910 are to be excluded from the Chinese fauna.

Seven species are now known from China, including the three new species (*O. brev-itasus* Li & Yang, sp. n., *O. dasystibialis* Li & Yang, sp. n., and *O. oblongus* Li & Yang, sp. n.), plus a range extension (*O. coomani*). The three species previously known from China and confirmed in our study are *O. arrowi*, *O. bidentatus*, and *O. maculipennis*.

# Oreoderus brevitarsus Li & Yang, sp. n.

http://zoobank.org/6A8CE269-C798-4B12-9CF8-90F3DFD6092E Fig. 3A–F

**Type material examined.** Holotype  $\mathcal{E}$ , P.R. CHINA, **Zhejiang**, Mt. Gutianshan, G45-G15, 560m, broad-leaved mixed forest, 2009.VIII.2-5, leg. Liu Chongling. Holotype deposited in IZAS. Paratypes: P.R. CHINA, 13, Zhejiang, Mt. Gutianshan, G24ha-140, 446-715m, Broad-leaved mixed forest, 2009.VII. 5-8, leg. Liu Chongling, (IZAS); 1<sup>Q</sup>, Zhejiang, Mt. Gutianshan, G24ha-157, 446–715m, broadleaved mixed forest, 2009.IX. 24–27, leg. Liu Chongling, (IZAS); 1<sup>Q</sup>, Zhejiang, Mt. Gutianshan, G24ha-83, 446-715m, broad-leaved mixed forest, 2009.VII. 26-29, leg. Liu Chongling, (IZAS); 1<sup>Q</sup>, Zhejiang, Mt. Gutianshan, G24ha-111, 446–715m, Broad-leaved mixed forest, 2009.VII. 5–8, leg. Liu Chongling, (IZAS); 13, Zhejiang, Mt. Gutianshan, 1992.VII.27, leg. Wu Hong, IOZ(E)902215, (IZAS); 13, Fujian, Zhang???hu (unrecognized name), 1981.VI.19, IOZ(E)902216, (IZAS); 1Å, Yunnan, Qiubei, Shupi 1278, Quercus, 1500m, leg. Kui Meihua, 1979.VII.6, IOZ(E)902199, (IZAS); 1<sup>♀</sup>, Yunnan, Xishuangbanna, Mengzhe, 1200m, 1958.VIII.23, leg. Pu Fuji, IOZ(E)902201, (IZAS); 1∂, Yunnan, Xishuangbanna, Xiaomengyang, 850m, 1958. IX.4, leg. MengXuwu, IOZ(E)90221, (IZAS); 1<sup>(2)</sup>, Yunnan, Yiwu, Banna, Menglun, 650m, 1959.VIII.3, leg. Pu Fuji, IOZ(E)902211, (ERC).

Additional material examined. 1<sup>o</sup>, P.R. CHINA, Zhejiang, Thousand island Lake (IEZU).

**Diagnosis.** Based on the morphological comparison and PCA analysis of four characters (see below), this new species is close to *O. dasystibialis* and *O. bidentatus*, but differs from *O. bidentatus* by the shape of the carinae of the pronotum and can be separated from *O. dasystibialis* by the sharp teeth on the protibia and the absence of a thick brush on meso- and metatibia in the male. Finally, the aedeagi are very distinc-



Figure 3. Habitus of *Oreoderus brevitarsus* (holotype). A dorsal view B pygidium C aedeagus. Habitus of *Oreoderus brevitarsus* (female). D dorsal view E pygidium F female genitalia. Scale bars: 1.0 mm.

tive in the three species. The parameres are much slender than the other two species and the outer margin is sinuate. The female *O. brevitarsus* can be distinguished from *O. bidentatus* by the short stylus and the presence of a brush on the inner margin of the protibia.

**Description of the holotype, male.** Length 8.2 mm; width 3.9 mm. Color: light brown to brown. *Head*: clypeus anteriorly rounded, lateral margin extended, with erected setae. Frons densely covered with testaceous scales. Ocular canthus short and broad, covered with same scales as clypeus. Antenna with 10 segments, clubs much longer than antennomeres 2–7. *Pronotum*: widest at the base, lateral margins sinuate. Surface covered with oblong lied-down scales. Carinae sharp, highly prominent, ending over 1/2 of the pronotum length; lateral small carinae short, sharp, not reaching the lateral margin of the pronotum. *Scutellum*: triangular, rounded at the apex, covered with shorter oval scales than pronotum. *Elytra*: with rows of punctate lines, covered with similar scales as scutellum. *Propygidium*: anteriorly glabrous and slightly punctate, posterior densely punctate and covered with scales. Spiracles moderately elevated. *Py-gidium*: with thick, lied-down scales and one central scale tuft at the hind margin. *Venter*: coarsely and densely punctate. Visible sternite V smooth and bald in the middle.

Visible sternite V twice longer than sternite IV. *Legs*: slender, femora and tibia covered with testaceous scales except for protibia. Outer margin of mesometatibia covered with more dense scales. Protibia short and bidentate, external teeth sharp. Tarsomeres with short setae. *Parameres:* short, lateral margin sinuate, the apex covered with yellow setae.

**Description of female.** Length 7.5–10.4 mm; width 3.5–4.7. Pronotum broader than the male one; carinae much shorter, reaching about 1/3 of the disc. Propygidium much longer, and pygidium with a sharp stylus. Visible sternite V much broader. Protibia short and with thick brush in the inner margin; tooth slightly blunt, mesometatibia with same brush on the inner and outer margin.

**Variability.** Male paratypes: length 9.0–9.5 mm; width 4.7–5.1 mm, and very similar to the holotype.

**Etymology.** The new species is named for the short tarsi of protibia. **Distribution.** China: Zhejiang, Fujian, Yunnan.

#### Oreoderus dasystibialis Li & Yang, sp. n.

http://zoobank.org/EC995BA6-62C2-41A2-9BFA-64C94A25478D Fig. 4A–C

**Type material examined.** Holotype, ♂, P.R. CHINA, **Hainan**, Mt. Jiangfengling, Heiling, 1982.VII.10, leg. Hua Lizhong, Sun Yat-sen University/100/IOZ(E)1658787. Holotype deposited in IZAS. Paratypes: P.R. CHINA: 1♂, Hainan, Mt. Jiangfengling, Wufenqu, 1981.VI.29, leg. Wang (26), Sun Yat-sen University/99/IOZ(E)1658786, (IZAS); 1♂, Hainan, Kwangtung, 1934.IX.1, leg. He Chi, Fan Inst. Biol Peiping/IOZ(E)902260, (ERC).

**Diagnosis.** based on the morphological comparison and PCA analysis of four characters (see below), this new species is close to *O. brevitarsus* and *O. bidentatus*, but differs from *O. bidentatus* by the smaller lateral carinae of the pronotum and can be separated from *O. brevitarsus* by the blunt teeth on protibia and the appearance of a thick brush on meso- and metatibia in the male. The aedeagi are very distinctive among these three species. The apex of the parameres in the new species is much wider than in the other two.

**Description of the holotype, male.** length 8.5 mm; Width 4.3 mm. Color: light brown to brown. *Head*: clypeus short, anteriorly straight, with erected setae. Frons densely punctate, covered with testaceous scales. Ocular canthus short, covered with same scales. Antenna with 10 segments, clubs much longer than antennomeres 2–7. *Pronotum*: widest at the base, lateral margins sinuate. Surface densely punctate, covered with thick testaceous scales. Carinae sharp, highly prominent, ending at 2/3 of the pronotum length; lateral small carinae long, sharp, reaching the lateral margins of the pronotum. *Scutellum*: triangular, rounded at the apex, covered with testaceous scales. *Elytra*: with rows of punctate line, covered with same scales as scutellum. *Propygidium*: covered with lied down scales. Spiracles moderately elevated. *Pygidium*: triangular form, coarsely punctate, covered with thick lied down oval scales. *Venter*: coarsely



Figure 4. Habitus of *Oreoderus dasystibialis* (holotype). A dorsal view B pygidium C aedeagus. Scale bars: 1.0 mm.

and densely punctate with each point bearing a testaceous scale. A longitudinal groove is visible in the middle of visible sternites I–IV; visible sternite V longer twice than the sternite IV. *Legs*: slender, covered with testaceous scales except protibia. Protibia extended, bidentate, teeth blunt. Meso- and metatibia with thick brush on the outer margins. Tarsomeres with short setae. *Parameres*: relatively longer and much broader, the apex is the widest part.

Female. unknown.

**Variability.** paratypes length 7.5–7.7 mm; width 3.8–4.2 mm, and very similar to the holotype.

**Etymology.** the new species is named according to its thick brush on meso- and metatibia.

Distribution. China: Hainan.

**Remarks.** only three males were collected in Hainan Island, two of them on Mt. Jianfengling.

## Oreoderus oblongus Li & Yang, sp. n.

http://zoobank.org/6CDA60F6-63CC-4720-80A6-57AE6B9F04E9 Fig. 5A–F

Type material examined. Holotype, ♂, P.R. CHINA, Yunnan, Xishuangbanna, Jinghong, 650m, 1958.VIII.12, leg. Meng Xuwu, IOZ(E)902189. Holotype deposited in IZAS. Paratypes: P.R. CHINA: 1♂, Yunnan, Xishuangbanna, Xiaomengyang, 850m, 1958.VIII.19, leg. Zhang Yiran, IOZ(E)902182, (IZAS); 1♂, Yunnan, Xishuangbanna, Xiaomengyang, 850m, 1958.VIII.20, leg. Pu Fuji, IOZ(E)902183, (IZAS); 1♂, Yunnan, Xishuangbanna, Xiaomengyang, 850m, 1958.IX.2, leg. Zheng Leyi, IOZ(E)902185, (IZAS); 1♂, Yunnan, Xishuangbanna, Xishuangbanna, Jinghong, 650m, 1958.



Figure 5. Habitus of *Oreoderus oblongus* (holotype). A dorsal view B pygidium C aedeagus. Habitus of *Oreoderus oblongus* (female). D dorsal view E pygidium F female genitalia. Scale bars: 1.0 mm.

VIII.26, leg. Meng Xuwu, IOZ(E)902186, (IZAS); 1♂, Yunnan, Xishuangbanna, Jinghong, 650m, 1958.VII.15, leg. Meng Xuwu, IOZ(E)902188, (IZAS); 1♂, Yunnan, Xishuangbanna, Menglun, 580m, 1993.IX.10, leg. Xu Huanli, IOZ(E)902204, (IZAS); 1♂, Yunnan, Xishuangbanna, Menglun, 600m, 1993.IX.9, leg. Yang Longlong, IOZ(E)902205, (IZAS); 1♂, Yunnan, Xishuangbanna, Jinghong, 650m, 1958. VII.27, leg. Meng Xuwu, IOZ(E)902208, (ERC); 1♀, Yunnan, Xishuangbanna, Xiaomengyang, 850m, 1957.X.20, leg. Pu Fuji, IOZ(E)902223, (IZAS).

**Diagnosis.** Based on the morphological comparison and PCA analysis of four characters (see below), this new species is close to *O. maculipennis*, but lacks a spine on the outer margin of meso- and metatibia and elytra without white patch scales in the new species. The parameres are very short in *O. oblongus*.

**Description of the holotype, male.** Length 8.4 mm; width 4.0 mm. Color: light brown to brown. *Head*: clypeus anteriorly rounded, with erect setae on the anterior margin. Frons covered with testaceous scales. Ocular canthus short, covered with same scales. Antenna with 10 segments, clubs not much longer than antennomeres 2–7. *Pronotum*: widest at base, lateral margins sinuate. Surface densely punctate, covered with lied down scales. Carinae sharp, highly prominent, ending around 2/3 of the

pronotum length; Lateral small carinae short, sharp, not joining the lateral margin of the pronotum. *Scutellum*: triangular, rounded at the apex, covered with testaceous scales. *Elytra*: with rows of punctate line, densely covered with oval scales. *Propygidium*: broad, punctate, covered with lied down scales. Spiracles moderately elevated. *Pygidium*: triangular, punctuation rounded, with thick lied down scales. *Venter*: coarsely and densely punctate with testaceous scales. Visible sternite V twice longer than sternite IV. *Legs*: slender, covered with oval scales except for protibia. Protibia tridentate; the third tooth small, far from the first two teeth. Meso- and metatibia covered with only sparse scales. Tarsomeres with short setae. *Parameres*: perpendicular to phallobase, the apex is sharp.

**Description of female.** Length 9.7 mm; width 4.5 mm. Pronotum a little broader than the male; carinae slightly shorter. Propygidium much longer, and pygidium more highly prominent. Visible sternite V much broader. External tooth of protibia apparently blunt. Tarsomeres more robust.

**Variability.** paratypes length 7.0–9.2 mm; width 3.7–4.3 mm, and very similar to the holotype.

**Etymology.** the new species is named for the oblong shape of the body. **Distribution.** China: Yunnan.

#### Oreoderus coomani Paulian, 1961

Oreoderus coomani Paulian, 1961: 31.

**Type material examined.** Lectotype (designated by Ricchiardi, 2001), ∂, Tonkin, Hoa-Binh, A. de Cooman, (MNHN).

Additional material examined. P.R. CHINA: 1Å, Yunnan, Xihuangbanna, Xiaomengyang, 850m, 1957.X.20, leg. ZangLingchao, IOZ(E)902180; 1Å, Yunnan, Xihuangbanna, Menglun, 600m, 1993.IX.11, Mt. Shihuishan, leg. Yang Longlong, IOZ(E)902190; 1Å, Yunnan, Xihuangbanna, Menghai, 1100m, 1957.VIII.15, leg. Wang Shuyong, IOZ(E)902191; 1Å, Yunnan, Xihuangbanna, Menga, 1050–1080m, 1958.VIII.12, leg. Wang Shuyong, IOZ(E)902192; 1Å, Yunnan, Xihuangbanna, Menga, 1050–1080m, 1958.VIII.7, leg. Pu Fuji, IOZ(E)902193; 1Å, Yunnan, Xihuangbanna, Menga, 1050–1080m, 1958.VIII.20, leg. Pu Fuji, IOZ(E)902194; 1Å, Yunnan, Xihuangbanna, Menga, 1050–1080m, 1958.VIII.19, leg. Wang Shuyong, IOZ(E)902195; 1Å, Yunnan, Xihuangbanna, Menga, 1050–1080m, 1958.VIII.10, leg. Wang Shuyong, IOZ(E)902196; 1Å, Yunnan, Xihuangbanna, Xiaomengyang, 850m, 1957.X.26, leg. Wang Shuyong, IOZ(E)902197; 1Å, Yunnan, Malipo, 1958. VII.21, (IZAS).

Distribution. China: Yunnan; Vietnam and Laos.

**Remarks.** This species was previously known from Vietnam and Laos. This is the first record for Yunnan, China.



Figure 6. Habitus of *Oreoderus arrowi* (female). A dorsal view B pygidium C female genitalia. Scale bars: 1.0 mm.

Oreoderus arrowi Ricchiardi, 2001

Fig. 6A-C

Oreoderus arrowi Ricchiardi, 2001: 521.

**Type material examined.** Holotype, ♂, S. China, 10–14.VII.1990, Jinghong, Prov., Yunnan, leg. S. Bečvář, (MCSN).

Additional material examined. P.R. CHINA: 1♂, Yunnan, Xihuangbanna, Jinghong, 650m, 1958.VII.7, leg. MengXuwu, IOZ(E)902175; 1♂, Yunnan, Xihuangbanna, Damenglong, 650m, 1958.VII.11, leg. ZhengLeyi, IOZ(E)902177; 1♂, Yunnan, Xihuangbanna, Mengzhe, 870m, 1958.IX.7, leg. Wang Shuyong, IOZ(E)902178; 1♂, Yunnan, Xihuangbanna, Xiaomengyang, 850m, 1958. IX.2, leg. MengXuwu, IOZ(E)902179; 1♂, Yunnan, Xihuangbanna, Xiaomengyang, 850m, 1958. IX.2, leg. MengXuwu, IOZ(E)902179; 1♂, Yunnan, Xihuangbanna, Xiaomengyang, 1400m, 1957.X.4, leg. Wang Shuyong, IOZ(E)902187; 1♀, Yunnan, Naban River Nature Reserve, Mengsong, Danuoyou, 2007.XII.14, 770m, Danuoyou IV A, 14.XII.2007, leg. A. Weigel, 22.20699°N, 100.63761°E (trap), leg. A. Weigel, IOZ(E)1945434, (IZAS).

**Description of female.** Length 8.4 mm; width 2.8mm. Color: light brown to brown. *Head*: clypeus anteriorly rounded, sharp in the apex, with erected setae. Frons covered with testaceous scales. Ocular canthus short and broad, covered with same scales. Antenna with 10 segments, club much longer than antennomeres 2–7. *Pronotum*: widest at base, lateral margin sinuate. Surface densely punctate, covered with testaceous scales. Carinae and lateral carinae sharp, highly prominent, ending before middle of pronotum. *Scutellum*: triangular, rounded at apex, covered with testaceous scales. *Elytra*: coarsely punctate, covered with testaceous scales. *Propygidium*: apparently longer than in male, hind margin rounded. Propygidial spiracles moderately el-

evated. *Pygidium*: narrower than in male, with thick lied down scales. *Venter*: coarsely and densely punctate with testaceous scale. Sternite V twice longer than Sternite IV; Sternite VI much narrower than male. *Legs*: slender, covered with testaceous scales except protibia. Protibia tridentate, tooth blunter than in male; meso- and metatibia with a spine on the outer margin. Tarsomeres much shorter than in male, covered with short setae.

Distribution. China: Yunnan.

#### Oreoderus bidentatus Ricchiardi, 2001

Oreoderus bidentatus Ricchiardi, 2001: 526.

**Type material examined.** Holotype, ♂, India, Meghalaya, Kashia Hills. Paratype, 1♀, Yunnan, Bao Shan, 1700 m, 1993.V.1–3, (NHML).

Additional material examined. 1<sup>Q</sup>, Yunnan, Mt. Gaoligong, (PCRD). Distribution. China: Yunnan; North East India.

**Remarks.** Oreoderus bidentatus was described from three males from Assam (2 paratypes) and Meghalaya (holotype) and one female from Yunnan (Ricchiardi 2001). One of the authors (Ricchiardi 2001) decided to determine the female specimen from Yunnan as belonging to this species because its two-teethed protibia and other characters similar to the males of *O. bidentatus* (shape of pronotum and carinae; anterior margin of clypeus, etc.). The second female specimen from the same Chinese Province was identical to the paratype. We hope that the finding of a male specimen from Yunnan will definitively confirm the distribution of this species. The absence of findings of *O. bidentatus* in Myanmar is probably only due to the lack of research in that country.

#### Oreoderus maculipennnis Gestro, 1891

Oreoderus maculipennis Gestro, 1891: 869.

Type material examined. Holotype, ♂, MCSN, Birmania, Bhamo, VI-1885, Leg. Fea. Additional material examined. 1♂, Fujian, Shanghang, 650m, 1988.VII.24, IOZ(E)902212; 1♂, Fujian, Shanghang, 650m, 1988.VII.23, IOZ(E)902213; 1♂, Yunnan, Xishuangbanna, Xiaomengyang, 850m, 1957.X.26, leg. Wang Shuyong, IOZ(E)902203; 1♂, Yunnan, Naban, II/3D, 10.XI.2008, leg. L.Z. Meng, Yunnan, Jinghong, Naban River Nature Reserve Chachang (Forest), 2008.XI.10, 729m, 22.15810°N, 100.66543°E, leg. Meng Lingzeng; 1♀, Yunnan, 991 Fengqing, Fengshan, 1600m, leg. Zhang Fu, 1980.VII.26, IOZ(E)902214; 1♀, Yunnan, Xishuangbanna, Xiaomengyang, 850m, 1957.X.26, leg. Wang Shuyong, IOZ(E)902218; 1♂, Yunnan, Xiaomengyang, 850m, 1957.X.26, leg. Wang Shuyong, IOZ(E)902218; 1♂, Yunnan, Xiaomengyang, 850m, 1957.X.26, leg. Wang Shuyong, IOZ(E)902218; IOZ(E)902219; 1♂, Yunnan, Xishuangbanna, Xiaomengyang, 850m, 1957.X.26, leg. Wang Shuyong, IOZ(E)902220; 1♂, Yunnan, Xishuangbanna, Xiaomengyang, 850m, 1957.X.25, leg. Wang Shuyong, IOZ(E)902221; 1♂, Yunnan, Xishuangbanna, Xiaomengyang, 850m, 1957.X.21, leg. Zang Lingchao, IOZ(E)902222; 1♀, Yunnan, Xishuangbanna, Menghai, 1200–1600m, 1958.VII.22, leg. Pu Fuji, IOZ(E)902224; 1♀, Yunnan, Xishuangbanna, Mengzhe, 1200m, 1958.VIII.28, leg. Wang Shuyong, IOZ(E)902226; 1♂, Naban II/3D, 10.XI.2008, leg. L.Z. Meng, Yunnan, Jinghong, Naban River Nature Reserve Chachang (Forest), 2008.XI.10, 729m, 22.15810°N, 100.66543°E, leg. Meng Lingzeng; 1♂, Naban II/3D, 20.XI.2008, leg. L.Z. Meng, Yunnan, Jinghong, Naban River Nature Reserve Chachang (Forest), 2008.XI.20, 729m, 22.15810°N, 100.66543°E, leg. Meng Lingzeng, (IZAS).

Distribution. China: Yunnan; Myanmar.

**Remark.** First record of *Oreoderus maculipennis* from Yunnan Province which confirmed the prediction of Ricchiardi (2001).

#### Morphological variations of Oreoderus

*Oreoderus* is the largest genus in the tribe Valgini and easily distinguished by its covering of scales. The clypeus is usually rounded in front except for *O. clypealis* (the front margin straight and recurved), *O. gestroi*, *O. gravis* and *O. waterhousei* (with a process on the front margin). The pronotum is nearly trapezoidal, longer than wide. There are two pairs of carinae on the pronotum, the length of carinae varies among species. The middle carinae are moderately prominent except *O. insularis*, *O. argillaceus* (highly prominent, forming two tubercles) and *O. coomani* (only slightly prominent). The elytra are short and broad, similar morphologically and sometimes decorated with patches of scales (*O. bidentatus*, *O. maculipennis* and *O. birmanus* etc.). The pygidium is nearly triangular, covered with thick scales. Females of some species have a stylus on the hind margin (*O. bidentatus*, *O. brevitasus*).

The morphological variation of four characters (pronotum, protibia, elytra and aedeagus) was investigated based on 34 species (84 specimens) using geometric morphometrics. The shape information was extracted from the landmark data using the Procrustes fit. To see the variations, we used the principal component analysis (PCA). The first two PCs together accounted for 77.11%, 89.14%, 60.50% and 55.96% of the total variance in the analysis of pronotum, elytron, protibia and aedeagus, respectively. The main shape change of the pronotum was observed in the length/width ratio of the pronotum and the carinae (Fig. 7A). The main shape change of the elytra was observed in the length/width ratio (Fig. 7B). The main shape change of the protibia was observed in the length/width ratio, while a secondary shape change can be observed in the curvature of the second teeth on protibia (Fig. 7C). The main shape change of the paramera was in their base, while a secondary shape change can be observed in the length/width ratio of the external part of parameres (Fig. 7D). Morphological variation in the out groups fell within the morphological space



**Figure 7.** Principal component analysis (PCA) based on the shape variations of different characters. The averaged shape of extreme specimens is depicted as deformations using thin plate splines. **A** pronotum **B** elytra **C** protibia **D** aedeagus.

Characters	Total variance
pronotum	0,015
elytra	0,002
protibia	0,016
aedeagus	0,020

Table 2. Total variance of four characters.

of *Oreoderus* in all four characters. The similarity among species in these four characters is also reflected in the Minimal Spanning Tree (MST) (Suppl. material 1: Fig. A.1).

Based on the PCA results, the morphological diversity in these four characters suggest they are not equally diagnostic in *Oreoderus* (Table 2). The highest morphological variation and clearest differentiation among species is found in the parameres. The second most diagnostic character is the protibia and the third is the pronotum. The elytron provides the least morphological resolution among *Oreoderus* species.

# Validity of the new species

To extend the results of the comparative morphological analysis, a canonical variate analysis (CVA) of Chinese *Oreoderus* including the new species was conducted to quantitatively assess the differences among species, with a particular focus on differentiating the new species. The canonical variates scores of pronotum variables showed the 90% equal frequency ellipse, although there is some overlap between *O. maculipennis* and *O. oblongus* (Fig. 8A). The morphological differences based on Mahalanobis distances among the seven species are all highly significant in all pairwise comparisons (p<0.05). Similar results were found for the other morphological variables, as Mahalanobis distances based on the morphology of elytra, protibia and aedeagus were all highly significant in all pairwise comparisons (p<0.05) (Suppl. material 1: Table A.1–4; Fig. 8B–D).

Most obtained *p*-values from permutation tests (10000 permutation rounds) for Procrustes distances based on the morphology of four characters (pronotum, elytra, protibia and aedeagus, respectively) among the seven species were smaller than 0.05 (Suppl. material 1: Table A.1–4).



**Figure 8.** Canonical variate analysis (CVA) based on the shape variations of different characters showing 90% confidence ellipses of population means. **A** pronotum **B** elytra **C** protibia **D** aedeagus.

# Discussion

In this study, the taxonomy values of four characters (pronotum, elytra, protibia and aedeagus) were evaluated in *Oreoderus*. According the CVA analyses above, the studied specimens were clustered into seven groups for all four morphological characters. Comparisons among species were significantly different when quantified by Mahalanobis distances. This meant the morphological boundary of species based on the sample specimens from the *Oreoderus* species were distinctly separated from each other. In other words, the *Oreoderus* species could be statistically separated and determined based on Mahalanobis distances of the four characters. However, the average shape of these four characters was not always significantly different when measured by Procrustes distance, and may not be a useful metric for taxonomic evaluations of *Oreoderus*. Our results demonstrate that geometric morphometric analysis of external and internal characters can enhance species diagnosis in cryptic species.

The taxonomical value of the four characters examined was not equivalent. The aedeagus of *Oreoderus* is very distinctive in Valgini, with an overall longer and more robust shape. Also, the aedeagus contains the most morphological variation in *Oreoderus*, and provides the best character for taxonomic determination in this genus.

The GM analysis suggests that the pronotum and protibia can also be informative in the taxonomy of *Oreoderus*. The shape of pronotum in *Oreoderus* is nearly trapezoidal, longer than it is wide. The apical part is usually narrow and the lateral margin is sinuate. The main shape variations are the outline of pronotum, length and relative position of the carinae on the pronotum according to the result of PCA. The protibia of *Oreoderus* is usually short and flat, dentate with only one spur. The main variation of the protibia is on the external teeth according to the result of PCA.

The numbers of the external teeth of protibia are already used in the taxonomy of Valgini (Paulian 1961, Ricchiardi 1994, Krajčík 2011). For example, the presence of two to three teeth on the outer margin of the protibia is diagnostic of *Oreoderus*, whereas five or more teeth are found in other genera within Valgini. For other members of the Cetoniinae, the male and female usually differ in the number of protibial teeth and the last teeth are always absent or very small in the females. Compared with the common use of the numbers of teeth, the shape of the protibia is rarely used in the taxonomy of *Oreoderus* and other Valgini. Our results suggest that the shape of the protibia is diagnostic among the species of *Oreoderus*.

The elytra of *Oreoderus* are flat and covered with scales. The elytra contained the least morphological variation among four characters in this study. Additionally, the out groups were not separated from *Oreoderus*. The taxonomic value of the elytral shape is not highly supported.

Traditionally, discrete characters are commonly used in taxonomy. However it is often difficult to find enough discrete characters to resolve confusing taxonomic problem, such as the morphological convergence of *Oreoderus*. In such a case, geometric morphometric (GM) can been used (Villemant et al. 2007, Hájek and Fikáček 2010, Xu et al. 2013, Bai et al. 2014, Zúñiga-Reinoso and Benitez 2015). Our study is the

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first to apply this approach to analyze shape variation in Valgini and demonstrate that this tool can be used to resolve this sort of problem. Based on our results, we suggest that future studies will benefit from by incorporating geometric morphometric techniques, and could, for example, examine unknown species of *Oreoderus* in combination with our data to investigate the possible status of an unknown specimen. Additionally, other characters, such as continuously variable characters, could be examined in addition to those we studied, in order to help resolve morphological differences in other species.

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# Supplementary material I

# Figure A.1 Minimum spanning tree mapped onto a PCA plot; Table A.1–4 Difference in shapes of four characters among species.

Authors: Sha Li, Enrico Ricchiardi, Ming Bai, Xingke Yang

Data type: calculation results

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RESEARCH ARTICLE



# Revision of the subgenus Orthoscymnus Canepari of Scymnus Kugelann (Coleoptera, Coccinellidae), with descriptions of four new species

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# Abstract

The subgenus Orthoscymnus Canepari, 1997 of Scymnus Kugelann, 1794 is herein revised. Seven species of the Orthoscymnus fauna are recognized, of which four species, Scymnus (O.) jilongicus **sp. n.**, S. (O.) paradoxus **sp. n.**, S. (O.) crispatus **sp. n.** and S. (O.) duomaculatus **sp. n.**, are described as new to science. Scymnus (O.) rhododendri Canepari is recorded from China for the first time. Scymnus (Pullus) robustibasalis Yu is transferred to the subgenus Orthoscymnus (**comb. n.**). All species are diagnosed, described and illustrated, and distributions are provided for each species. A key to the species is included.

## Keywords

Taxonomy, Coccinelloidea, new species, new combination, Himalaya, China, Nepal

# Introduction

Most members of the family Coccinellidae are important natural enemies of pest, such as whiteflies, aphids, mealybugs, scales and mites, and playing an important role in regulating their populations. Recently, this family was classified in the superfamily Coccinelloidea along with eight other families (Robertson et al. 2015).

The genus *Scymnus* Kugelann, 1794 comprises eight subgenera and more than 800 species distributed worldwide (Chen et al. 2013, 2015). In the modern classification, *Scymnus* has been placed within the tribe Scymnini Mulsant, 1846 in the subfamily Scymninae (Sasaji 1968; Kovář 1996). However, Ślipiński (2007) proposed only two subfamilies, Microweiseinae and Coccinellinae, for the family Coccinellidae, *Scymnus* was classified in the tribe Coccidulini of the broadly defined subfamily Coccinellinae. This classification was supported by Giorgi et al. (2009) and Seago et al. (2011) based on molecular and morphological studies.

The subgenus Orthoscymnus Canepari, 1997 of Scymnus Kugelann, 1794 was established for two new species from Nepal, Scymnus (Orthoscymnus) smetanai and Scymnus (Orthoscymnus) rhododendri (Canepari, 1997). So far, this subgenus only occurred in the Himalaya region and included two species.

In the present paper, seven species of the subgenus *Orthoscymnus* are recognized, including four new species described here. *Scymnus* (*O.*) *rhododendri* Canepari, 1997 is newly recorded from China. *Scymnus* (*Pullus*) *robustibasalis* Yu, 2000 is transferred into the subgenus *Orthoscymnus* based on the characters of the male genitalia, particularly the robust penis capsule. Diagnoses, detailed descriptions and illustrations are provided for each species.

#### Materials and methods

The morphological terms follow Ślipiński (2007) and Ślipiński and Tomaszewska (2010). Depositories of the type materials are abbreviated as follows:

SCAU	South China Agricultural University, Guangzhou, China;
BAAF	Beijing Academy of Agricultural and Forestry Science, Beijing, China;
MNHG	Museum National d'Histoire Naturelle, Genéve;
SMNS	Staatliches Museum für Naturkunde, Stuttgart, Germany.

Measurements were made using a micrometer attached to a SteREO Discovery V20 dissecting stereoscope and are defined as follows: (TL) total length, from apical margin of clypeus to apex of elytra; (TW) total width, across both elytra at widest part; (TH) total height, at highest part of elytra; (HW) head width, at widest part including eyes; (PL) pronotal length, from the middle of anterior margin to the base of pronotum; (PW) pronotal width at widest part; (EL) elytral length, along suture from base to apex including scutellum; (EW) elytral width, equal to TW.

Male genitalia were dissected, cleared in a 10% solution of NaOH, and placed on slides for further study. Illustrations of morphological details were made from slide preparations using a camera (Coolsnap-Procf & CRI Micro\*Color) attached to an Olympus BX51 compound microscope. After examination, they were transferred to a small card covered with neutral balsam and pinned beneath the specimen.

Photographs of the whole beetles were executed using digital cameras (AxioCam HRc) and composite images generated with AXIO VISION REL. 4.8 softwares. The final plates were prepared using ADOBE PHOTOSHOP CS 8.0.

# Taxonomy

#### Genus Scymnus Kugelann, 1794

#### Subgenus Orthoscymnus Canepari, 1997

Orthoscymnus Canepari, 1997: 16. Type species: Scymnus (Orthoscymnus) smetanai Canepari, 1997, by original designation.

**Diagnosis.** Body compact, round oval or elongate oval, slightly convex, dorsum densely pubescent. Head small, frons finely punctate. Eyes finely faceted. Antennae composed of 11 antennomeres. Antennal club compact, composed of 3 antennomeres. Clypeus transverse with anterior margin straight. Labrum transverse, entirely exposed. Mandible bifid apically. Pronotum moderately convex. Prosternum T-shaped. Prosternal process bearing distinct lateral carinae, convergent and extending to anterior margin. Abdomen with six ventrites. Abdominal postcoxal lines recurved and complete laterally. Tarsi with 4 tarsomeres; claws bifid, each with sharp basal tooth. Male genitalia with penis guide symmetrical. Penis stout with an irregular basal capsule, usually highly sclerotized. Female genitalia with sub-horizontal coxites, infundibulum elongate, spermatheca worm-shaped.

**Remarks.** Orthoscymnus shares many characters with subgenus Pullus Mulsant, such as antennae composed of 11 antennomeres and the complete abdominal post-coxal lines, but can be distinguished from the latter by the female genitalia with sub-horizontal coxites (see Canepari 1997). In the subgenus Pullus, coxites are elongate, triangular.

#### Key to the species of the subgenus Orthoscymnus

1	Elytra black; apex of penis without thread-like appendage2
_	Elytra entirely reddish brown (Fig. 1a); apex of penis with short thread-like
	appendage (Fig. 1f); length 1.49–1.59 mm S. (O.) smetanai Canepari
2	Head and pronotum brown; penis capsule with short inner arm and large
	outer arm
_	Head and pronotum black; penis capsule with both arms well developed 6
3	Elytra with apical margin narrowly brown
_	Elytra with large X-shaped yellow area extending from basal 1/4 to elytral apex
	(Fig. 2a); length 1.96–2.06mm S. (O.) jilongicus Chen & Ren, sp. n.

4	Parameres shorter than penis guide in lateral view; penis guide not spade-
	shaped in ventral view5
_	Parameres longer than penis guide in lateral view (Fig. 3h); penis guide ex-
	tremely broad, spade-shaped in ventral view (Fig. 2a); length 1.64-1.96
	mmS. (O.) paradoxus Chen & Ren, sp. n.
5	Penis guide sub-rectangular through 3/4 of its length in ventral view (Fig.
	4g); parameres narrow at base and expanded toward their apices in lateral
	view (Fig. 4h); length 1.60–1.67 mmS. (O.) rhododendri Canepari
-	Penis guide sub-triangular in ventral view (Fig. 5g); parameres regularly elon-
	gate oval in lateral view (Fig. 5h); length 1.59–1.65 mm
	S. (O.) crispatus Chen & Ren, sp. n.
6	Elytra without brown spot (Fig. 6a); parameres distinctly shorter than penis guide
	in lateral view (Fig. 6h); length 1.60–1.67 mm S. (O.) robustibasalis Yu
_	Elytra with two kidney-shaped brown spots near suture (Fig. 7a); parameres
	slightly longer than penis guide in lateral view (Fig. 7h); length 1.62-1.83
	mmS. (O.) duomaculatus Chen & Ren, sp. n.

#### Scymnus (Orthoscymnus) smetanai Canepari, 1997

Figs 1a-h, 8

Scymnus (Orthoscymnus) smetanai Canepari, 1997: 17; Poorani 2002: 357; Kovář 2007: 586.

**Diagnosis.** This species can be easily separated from other members of the subgenus *Orthoscymnus* by having entirely reddish brown body. It is also similar to *Scymnus* (*Pullus*) *martensi* Canepari in general appearance and particularly in the shape of abdominal postcoxal lines, but can be distinguished from it by the much smaller body and the swollen apex of penis bearing short thread-like appendage (Fig. 1f).

**Description.** TL: 1.49–1.59 mm, TW: 1.09–1.19 mm, TH: 0.69–0.80 mm, TL/ TW: 1.25–1.46, PL/PW: 0.56–0.64, EL/EW: 1.03–1.17, HW/PW: 0.54–0.59, PW/ EW: 0.66–0.74.

Body rounded oval, moderately convex, entirely reddish brown, dorsum covered with white pubescence (Figs 1a–c).

Head with fine frontal punctures, slightly larger than eye facets, 1.0–2.0 diameters apart. Eyes densely faceted, interocular distance 0.45 times head width. Pronotal punctures as large as those on frons, 1.0–2.0 diameters apart. Surface of elytra with punctures larger than those on pronotum, separated by 2.0–3.0 diameters. Prosternal process trapezoidal, 2 times as long as its width at base; with lateral carinae extending to anterior margin of prosternum, distinctly convergent anteriorly. Abdominal postcoxal lines reaching 3/4 length of abdominal ventrite 1 (Fig. 1d), area enclosed by lines coarsely punctate, narrowly smooth along line. Abdominal ventrite 5 with apex truncate in male.



**Figure 1.** *Scymnus (Orthoscymnus) smetanai* Canepari, 1997: **a** dorsal view **b** frontal view **c** lateral view **d** abdomen **e** penis **f** apex of penis **g** tegmen, ventral view **h** tegmen, lateral view. Scale bars: **a–d**: 0.5 mm, **e–h**: 0.1 mm.

Male genitalia. Penis stout; penis capsule with small and curved inner arm, outer arm large bearing horn-shaped appendage (Fig. 1e); apex of penis distinctly swollen, bearing short thread-like appendage (Fig. 1f). Tegmen stout (Fig. 1g–h) with penis guide widest at base, gradually tapering to blunt apex in ventral view (Fig. 1g). Parameres longer than penis guide, densely covered with long setae at apices and inner sides (Fig. 1h).

Female externally similar to male but with abdominal ventrite 5 rounded apically.

**Type material. Holotype:** male, "Nepal, Khandbari Distr., forest above Ahale, (27°27.62'N, 87°11.49'E), 2300m, 26. III. 82, leg. Smetana" (MNHG).

**Other material examined. Nepal: Koshi:** 1*3*, on the way from Dharan to Dhankuta, 26°52.94'N, 87°19.74'E, 400-700 m, 20. X. 2011, Chen XS leg.

**Distribution.** Nepal (Koshi).

*Scymnus* (*Orthoscymnus*) *jilongicus* Chen & Ren, sp. n. http://zoobank.org/9BFB1A7E-BDE1-4F86-83E2-1E0592F0490D Figs 2a–h, 8

**Diagnosis.** This species can be separated from other species within the subgenus *Or*thoscymnus by having a large X-shaped yellow macula on elytra, extending from basal



**Figure 2.** *Scymnus (Orthoscymnus) jilongicus* Chen & Ren, sp. n.: **a** dorsal view **b** frontal view **c** lateral view **d** abdomen; **e** penis **f** apex of penis **g** tegmen, ventral view **h** tegmen, lateral view. Scale bars: **a**–**d**: 0.5 mm, **e**–**h**: 0.1 mm.

fourth to elytral apex (Fig. 2a). It is also similar to *Scymnus (Pullus) testacecollis* Kapur in male genitalia, but can be distinguished from it by having slender parameres slightly shorter than penis guide in lateral view (Fig. 2h). In *S. (P.) testacecollis*, the elytra is black with apical 1/4 testaceous; the parameres are narrow at base and expanding gradually toward apex, nearly as long as penis guide in lateral view (see Kapur 1963).

**Description.** TL: 1.96–2.06mm, TW: 1.15–1.25mm, TH: 0.81–0.82mm, TL/ TW: 1.65–1.70, PL/PW: 0.53–0.55, EL/EW: 1.27–1.34, HW/PW: 0.59–0.61, PW/ EW: 0.74–0.76.

Body elongate oval, slightly convex, dorsum covered with white pubescence (Fig. 2a– c). Head, antennae and mouthparts yellowish brown. Pronotum yellow. Scutellum black. Elytra black with large X-shaped, yellow macula at middle, extending to its apex (Fig. 4a). Prothoracic hypomeron yellow. Prosternum brown to black. Mesoventrite and metaventrite black. Elytral epipleuron brown with inner and outer margins black. Legs yellowish brown.

Head with fine frontal punctures, as large as eye facets, 1.0–2.0 diameters apart. Eyes densely faceted, interocular distance 0.51 times head width. Pronotal punctures similar to those on frons, 1.0–1.5 diameters apart. Surface of elytra with punctures much coarser than those on pronotum, separated by 1.0–2.0 diameters. Prosternal process rectangular, 3.5 times as long as its width at base; with lateral carinae parallel, extending to anterior margin of prosternum. Abdominal postcoxal lines reaching 2/3

length of abdominal ventrite 1 (Fig. 2d), area enclosed by lines coarsely punctate, narrowly smooth along line. Abdominal ventrite 5 in male with apical margin shallowly emarginate and ventrite 6 strongly emarginate medially.

Male genitalia. Penis stout and long (Fig. 2e); penis capsule highly sclerotized with short inner arm and large outer arm; apex of penis with membranous appendage (Fig. 2f). Tegmen extremely stout (Figs 2g–h) with penis guide parallel-sided from base to apical 3/4 length, then tapering gradually to pointed apex in ventral view (Fig. 2g), flattened and nearly straight in lateral view (Fig. 2h). Parameres narrow, slightly shorter than penis guide, densely covered with long setae at apices (Fig. 2h).

Female externally similar to male but with apex of abdominal ventrite 5 truncate and ventrite 6 rounded apically.

**Type material. Holotype:** male, No. SCAU (E) 13196, **China: Tibet:** Jilong Town, Jilong County, 28°23.00'N, 85°19.60'E, ca 2900 m, 29. X. 2011, Huo LZ leg. **Paratypes (17):**  $2313^{\circ}$  with same data as holotype. 23, Zhangmu Port, Nielamu, Rikaze, 27°58.47'N, 85°58.15'E, ca 3000 m, 28. IX. 2009, Chen XS leg. (SCAU)

Etymology. The species name is derived from the type locality, Jilong Town, Tibet.

## Scymnus (Orthoscymnus) paradoxus Chen & Ren, sp. n.

http://zoobank.org/3FF40A9D-ED14-4140-9923-7B9FB0989248 Figs 3a–h, 8

**Diagnosis.** This species can be easily recognized by its elongate and compressed body and the peculiar characters on male genitalia, particularly the extremely broad, spade-shaped penis guide in ventral view (Fig. 3g).

**Description.** TL: 1.64–1.96 mm, TW: 0.97–1.09 mm, TH: 0.70–0.77 mm, TL/ TW: 1.69–1.79, PL/PW: 0.55–0.56, EL/EW: 1.29–1.37, HW/PW: 0.59–0.61, PW/ EW: 0.74–0.79.

Body elongate oval, slightly convex, dorsum covered with white pubescence (Figs 3a– c). Head, antennae and mouthparts yellowish brown. Pronotum yellow. Scutellum black. Elytra black with apical margin narrowly brown. Prothoracic hypomeron and prosternum yellow. Mesoventrite, metaventrite and elytral epipleura black. Legs yellowish brown.

Head with fine frontal punctures, as large as eye facets, 0.5–1.0 diameter apart. Eyes densely faceted, interocular distance 0.47 times head width. Pronotal punctures larger than those on frons, 1.0–2.0 diameters apart. Surface of elytra with punctures much larger than those on pronotum, separated by 2.0–3.0 diameters. Prosternal process rectangular, 5 times as long as its width at base; with lateral carinae parallel, extending to anterior margin of prosternum. Abdominal postcoxal lines reaching 4/5 length of abdominal ventrite 1 (Fig. 3d), area enclosed by lines finely punctate, broadly smooth along line. Abdominal ventrites 5 and 6 in male strongly emarginate apically.

Male genitalia. Penis slender (Fig. 3e); penis capsule highly sclerotized with short inner arm and large outer arm; apex of penis with membranous appendage (Fig. 3f). Tegmen extremely stout (Fig. 3g-h) with penis guide broad, spade-shaped in ventral



**Figure 3.** *Scymnus (Orthoscymnus) paradoxus* Chen & Ren, sp. n.: **a** dorsal view **b** frontal view **c** lateral view **d** abdomen **e** penis **f** apex of penis **g** tegmen, ventral view **h** tegmen, lateral view. Scale bars: **a–d**: 0.5 mm, **e–h**: 0.1 mm.

view (Fig. 3g). Parameres very narrow in lateral view, slightly longer than penis guide, sparsely covered with long setae at apices and inner sides (Fig. 3h).

Female externally similar to male but with black pronotum, abdominal ventrite 5 truncate and ventrite 6 rounded apically.

**Type material. Holotype:** male, No. SCAU (E) 13193, **China: Tibet:** Zhangmu Town, Nielamu County, 27°58.47'N, 85°58.15'E, ca 2200 m, 31. X. 2011, Chen XS leg. **Paratypes (5):**  $5^{\circ}$  with same data as holotype. (SCAU)

Distribution. China (Tibet).

**Etymology.** The species name is an adjective derived from Latin (*'paradoxus'* = strange), referring to its peculiar shape of penis guide.

# Scymnus (Orthoscymnus) rhododendri Canepari, 1997

Figs 4a–h, 8

Scymnus (Orthoscymnus) rhododendri Canepari, 1997: 17; Poorani 2002: 357; Kovář 2007: 584.

**Diagnosis.** This species is similar to *Scymnus* (*Orthoscymnus*) *crispatus* sp. n. in general appearance and male genitalia, but can be separated from it by having swollen apex of



**Figure 4.** *Scymnus* (*Orthoscymnus*) *rhododendri* Canepari, 1997: **a** dorsal view **b** frontal view **c** lateral view **d** abdomen **e** penis **f** apex of penis **g** tegmen, ventral view **h** tegmen, lateral view. Scale bars: **a–d**: 0.5 mm, **e–h**: 0.1 mm.

penis (Fig. 4f), extremely broad penis guide in ventral view (Fig. 4g) and the parametes distinctly constricted at base, then expanding toward apex in ventral view (Fig. 4h).

**Description.** TL: 1.60–1.67 mm, TW: 1.05–1.08 mm, TH: 0.75–0.78 mm, TL/ TW: 1.52–1.55, PL/PW: 0.49–0.53, EL/EW: 1.15–1.17, HW/PW: 0.61–0.62, PW/ EW: 0.73–0.75.

Body elongate oval, moderately convex, dorsum covered with white pubescence (Figs 4a–c). Head, antennae and mouthparts yellowish brown. Pronotum brown, sometimes with black marking at base. Scutellum black. Elytra black with apical margin narrowly brown. Prothoracic hypomeron and prosternum yellowish brown. Mesoventrite, metaventrite and elytral epipleura black. Legs yellowish brown.

Head with fine frontal punctures, as large as eye facets, 1.0–2.0 diameters apart. Eyes densely faceted, interocular distance 0.42 times head width. Pronotal punctures larger than those on frons, 1.0–2.0 diameters apart. Surface of elytra with punctures much coarser than those on pronotum, separated by 2.0–3.0 diameters. Prosternal process trapezoidal, 2 times as long as its width at base; with lateral carinae extending to anterior margin of prosternum, distinctly convergent anteriorly. Abdominal postcoxal lines extending nearly to posterior margin of abdominal ventrite 1 (Fig. 4d), area enclosed by lines finely punctate, broadly smooth along line. Abdominal ventrites 5 and 6 in male strongly emarginate apically.

Male genitalia. Penis stout (Fig. 4e); penis capsule highly sclerotized with tiny inner arm and large outer arm; apex of penis distinctly swollen with membranous appendage at apical 1/5 length (Fig. 4f). Tegmen stout (Figs 4g-h) with penis guide

wide, with sides subparallel from base to its apical 3/4 length, then tapering gradually to pointed apex in ventral view (Fig. 4g), and its apex slightly curved outwardly in lateral view (Fig. 4h). Parameres constricted at base with expanded apex, distinctly shorter than penis guide, sparsely covered with long setae at apices (Fig. 4h).

Female unknown.

**Type material. Holotype:** male, "Nepal, Sankhua Sabha Distr., above Pahakhola, (27°39.40'N, 87°16.12'E), *Quercus semecarpifolia*-Rhododendron, 2600–2800 m, 3. VI. 1988, leg Martens & Schawaller" (SMNS).

**Other material examined. China: Tibet:** 2♂, Xiayadong Village, Yadong County, 28°29.29'N, 97°1.36'E, ca 2800 m, 1. X. 2009, Chen XS leg. 5♂, Xiayadong Village, Yadong County, 28°29.29'N, 97°1.36'E, ca 2800 m, 29–30. IX. 2009, Chen XS leg.

Distribution. China (Tibet) new distribution; Nepal.

# Scymnus (Orthoscymnus) crispatus Chen & Ren, sp. n.

http://zoobank.org/CC4D9926-B36D-449E-AFB9-9FBD4CBD5F2E Figs 5a–h, 9

**Diagnosis.** This species is similar to *Scymnus* (*Orthoscymnus*) *rhododendri* in male genitalia, but can be distinguished from it by the elongate oval parameres (Fig. 5h) and the narrow, sub-triangular penis guide in ventral view (Fig. 5g).

**Description.** TL: 1.59–1.65 mm, TW: 0.90–1.01 mm, TH: 0.68–0.76 mm, TL/ TW: 1.59–1.63, PL/PW: 0.53–0.55, EL/EW: 1.27–1.32, HW/PW: 0.59–0.63, PW/ EW: 0.73–0.74.

Body elongate oval, moderately convex, dorsum covered with white pubescence (Fig. 5a–c). Head yellow. Antennae and mouthparts yellowish brown. Pronotum yellow. Scutellum black. Elytra black with apical margin narrowly brown. Prothoracic hypomeron yellow. Prosternum brown. Mesoventrite, metaventrite and elytral epipleura black. Legs yellowish brown.

Head with fine frontal punctures, as large as eye facets, 0.5–1.0 diameter apart. Eyes densely faceted, interocular distance 0.43 times head width. Pronotal punctures slightly larger than those on frons, 1.0–2.0 diameters apart. Surface of elytra with punctures much larger than those on pronotum, separated by 2.0–3.0 diameters. Prosternal process trapezoidal, 4 times as long as its width at base; with lateral carinae extending to anterior margin of prosternum, distinctly convergent anteriorly. Abdominal postcoxal lines extending nearly to posterior margin of abdominal ventrite 1 (Fig. 5d), area enclosed by lines finely punctate, broadly smooth along line. Abdominal ventrite 5 strongly emarginate and ventrite 6 weakly emarginate apically in male.

Male genitalia. Penis stout (Fig. 5e); penis capsule highly sclerotized with tiny inner arm and large outer arm; apex of penis with membranous appendage (Fig. 5f). Tegmen stout (Fig. 5g–h) with penis guide slightly constricted at base, widest at basal 1/4 length, then tapering gradually to pointed apex in ventral view (Fig. 5g) and its apex curved outwardly in lateral view (Fig. 5h). Parameres elongate oval, shorter than penis guide, sparsely setose at apices (Fig. 5h).



**Figure 5.** *Scymnus* (*Orthoscymnus*) *crispatus* Chen & Ren, sp. n.: **a** dorsal view **b** frontal view **c** lateral view **d** abdomen **e** penis **f** apex of penis **g** tegmen, ventral view **h** tegmen, lateral view. Scale bars: **a**–**d**: 0.5 mm, **e**–**h**: 0.1 mm.

Female externally similar to male but with abdominal ventrites 5 and 6 truncate apically. In some specimens, pronotum and elytra are entirely reddish brown.

**Type material. Holotype:** male, No. SCAU (E) 13195, **China: Tibet:** Jilong Town, Jilong County,  $28^{\circ}23.00$ 'N,  $85^{\circ}19.60$ 'E, ca 2900 m, 29. X. 2011, Li WJ leg. **Paratypes (71):**  $1535^{\circ}$  with same data as holotype.  $13^{\circ}$ , Lebu Village, Cuona County,  $27^{\circ}48.63$ 'N,  $91^{\circ}44.98$ 'E, ca 2400 m, 24. X. 2011, Huo LZ leg. (SCAU)

Distribution. China (Tibet).

**Etymology.** The species name is an adjective derived from Latin (*'crispatus'* = crispate), referring to its parameters with crispate surface in ventral view.

# Scymnus (Orthoscymnus) robustibasalis (Yu, 2000), comb. n.

Figs 6a–h, 9

*Scymnus (Pullus) robustibasalis* Yu in Yu et al. 2000: 180; Pang et al. 2004: 80; Kovář 2007: 587.

**Diagnosis.** This species is most similar to *Scymnus (Orthoscymnus) duomaculatus* sp. n. in having black pronotum but can be easily separated from it by the black elytra (Fig. 6a) and parameres tapering toward apex, distinctly shorter than penis guide in lateral view (Fig. 6h).



**Figure 6.** *Scymnus* (*Orthoscymnus*) *robustibasalis* (Yu, 2000), comb. n.: **a** dorsal view **b** frontal view **c** lateral view **d** abdomen **e** penis **f** apex of penis **g** tegmen, ventral view **h** tegmen, lateral view. Scale bars: **a**-**d**: 0.5 mm, **e**-**h**: 0.1 mm.

**Description.** TL: 1.69–1.76mm, TW: 1.10–1.21mm, TH: 0.76–0.83mm, TL/ TW: 1.45–1.54, PL/PW: 0.47–0.52, EL/EW: 1.24–1.26, HW/PW: 0.56–0.57, PW/ EW: 0.73–0.75.

Body elongate oval, moderately convex, dorsum covered with white pubescence (Figs 6a–c). Head, antennae and mouthparts dark brown. Pronotum black with anterior angles dark brown. Scutellum black. Elytra black with apical margin narrowly reddish brown. Prothoracic hypomeron dark brown. Prosternum, mesoventrite, metaventrite and elytral epipleura black. Legs yellowish brown.

Head with dense frontal punctures, slightly smaller than eye facets, 0.5–1.0 diameter apart. Eyes densely faceted, interocular distance 0.50 times head width. Pronotal punctures as large as those on frons, 1.0–1.5 diameters apart. Surface of elytra with punctures much larger than those on pronotum, separated by 1.0–2.0 diameters. Prosternal process trapezoidal, 2 times as long as its width at base; with lateral carinae extending to anterior margin of prosternum, slightly convergent anteriorly. Abdominal postcoxal lines reaching 3/4 length of abdominal ventrite 1 (Fig. 6d), area enclosed by lines finely punctate, broadly smooth along line. Abdominal ventrites 5 and 6 in male strongly emarginate apically.

Male genitalia. Penis robust and short, unevenly curved (Fig. 6e); penis capsule sclerotized with both arms well developed; apex of penis simple (Fig. 6f). Tegmen stout with tegminal strut black, highly sclerotized (Fig. 6g-h). Penis guide slightly

constricted at base, parallel-sided at middle part, then tapering gradually to blunt apex in ventral view (Fig. 6g). Parameres stout, tapering toward apex, distinctly shorter than penis guide, densely covered with long setae at apices and inner sides (Fig. 6h).

Female unknown.

Type material. Holotype: male, "Wenfeng Temple, Lijiang, Yunnan, (26°48.64'N, 100°12.15'E), 20. IV. 1997, Yao DF et al. leg (handwritten) / Scymnus (Pullus) robustibasalis Yu, sp. n. (printed, red label)" (BAAF). Paratype: 13, "Wenfeng Temple, Wenbishan, Lijiang, Yunnan, (26°48.64'N, 100°12.15'E), 20. IV. 1997, Yao DF et al. leg (handwritten) / 970512-2 (handwritten) / Paratype (printed, yellow label), Scymnus (Pullus) robustibasalis Yu, sp. n. (printed)" (BAAF).

**Other material examined. Sichuan:** 1*A*, Laba River National Nature Reserve, Tianquan, 30°0.58'N, 102°27.59'E, ca 1100 m, 4. X. 2007, Chen XS leg. Yunnan: 1Å, Hutiaoxia, Lijiang, 27°10.97'N, 100°3.16'E, ca 1100 m, 3. IX. 2005, Qin ZQ leg.

Distribution. China (Sichuan, Yunnan).

Scymnus (Orthoscymnus) duomaculatus Chen & Ren, sp. n. http://zoobank.org/D56A3761-3318-4CC9-BBC3-FE4C77B2FFA1

Figs 7a-h, 9

Diagnosis. This species closely resembles Scymnus (Orthoscymnus) robustibasalis in having black pronotum but can be distinguished from it by the black elytra with two brown spots (Fig. 7a) and parameres expanding toward their rounded apices, slightly longer than penis guide in lateral view (Fig. 7h). It is also similar to Scymnus (Pullus) rufomaculatus Canepari, 2012 in dorsal colour pattern, but can be separated from it by the stout penis guide in lateral view (Fig. 7h) and the different shape of penis capsule (Fig. 7e).

Description. TL: 1.62–1.83 mm, TW: 1.12–1.24 mm, TH: 0.71–0.81 mm, TL/ TW: 1.44–1.47, PL/PW: 0.51–0.53, EL/EW: 1.24–1.25, HW/PW: 0.57–0.60, PW/ EW: 0.71-0.74.

Body oval, moderately convex, dorsum covered with white pubescence (Fig. 7a-c). Head black. Antennae and mouthparts dark brown. Pronotum and scutellum black. Elytra black with two kidney-shaped brown spots near suture. Underside entirely black. Legs dark brown.

Head with fine frontal punctures, as large as eye facets, 0.5-1.0 diameter apart. Eyes densely faceted, interocular distance 0.5 times head width. Pronotal punctures larger than those on frons, 1.0-2.0 diameters apart. Surface of elytra with punctures larger than those on pronotum, separated by 1.0-2.0 diameters. Prosternal process trapezoidal, 2 times as long as its width at base; with lateral carinae extending to anterior margin of prosternum, distinctly convergent anteriorly. Abdominal postcoxal lines extending nearly to posterior margins of abdominal ventrite 1 (Fig. 7d), area enclosed by lines finely punctate, broadly smooth along line. Abdominal ventrite 5 truncate and ventrite 6 strongly emarginated apically in male.



**Figure 7.** *Scymnus (Orthoscymnus) duomaculatus* Chen & Ren, sp. n.: **a** dorsal view **b** frontal view **c** lateral view **d** abdomen; **e** penis **f** apex of penis; **g** tegmen, ventral view **h** tegmen, lateral view. Scale bars: **a–d**: 0.5 mm, **e–h**: 0.1 mm.

Male genitalia. Penis slender (Fig. 7e); penis capsule sclerotized with small inner arm and large outer arm; apex of penis slightly sinuated with membranous appendage (Fig. 7f). Tegmen stout (Fig. 7g–h) with penis guide parallel-sided from base to 3/4 length, then tapering gradually to blunt apex in ventral view (Fig. 7g). Parameres curved at base, expanded toward apex, slightly longer than penis guide, sparsely covered with long setae at apices (Fig. 7h).

Female externally similar to male but with abdominal ventrites 5 and 6 rounded apically.

Type material. Holotype: male, No. SCAU (E) 13197, China: Tibet: Jilong Town, Jilong County, 28°23.00'N, 85°19.60'E, ca 2900 m, 29. X. 2011, Li WJ leg. **Paratypes (9): Tibet:**  $2^{\circ}$  with same data as holotype.  $1^{\circ}_{\circ}5^{\circ}_{\circ}$ , Zhangmu Town, Nielamu County, Rikaze, 27°58.47'N, 85°58.15'E, ca 2500 m, 27. IX. 2009, Chen XS leg.  $1^{\circ}_{\circ}$ , Zhangmu Port, Rikaze, 27°58.47'N, 85°58.15'E, ca 3000 m, 28. IX. 2009, Chen XS leg. (SCAU).

# Distribution. China (Tibet).

**Etymology.** The species name is derived from Latin ('*duo-*' = two and '*macula-tus*' = maculate), referring to two brown spots on the elytra.



**Figure 8.** Distribution map. S. (O.) smetanai Canepari ( $\bullet$ ); S. (O.) jilongicus Chen & Ren, sp. n. ( $\blacktriangle$ ); S. (O.) paradoxus Chen & Ren, sp. n. ( $\blacksquare$ ); S. (O.) rhododendri Canepari ( $\bigstar$ ).



**Figure 9.** Distribution map. S. (O.) *crispatus* Chen & Ren, sp. n. ( $\bullet$ ); S. (O.) *robustibasalis* (Yu), comb. n. ( $\bigstar$ ); S. (O.) *duomaculatus* Chen & Ren, sp. n. ( $\blacktriangle$ ).

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RESEARCH ARTICLE



# Further contributions to the longhorn beetle (Coleoptera, Cerambycidae) fauna of New Brunswick and Nova Scotia, Canada

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### Abstract

Sixteen species of Cerambycidae are newly recorded for New Brunswick, Canada; Arhopalus obsoletus (Randall), Atimia confusa confusa (Say), Callidium frigidum Casey, Phymatodes amoenus (Say), P. testaceus (Linnaeus), Neoclytus mucronatus mucronatus (Fabricius), Xylotrechus aceris Fisher, X. sagittatus sagittatus (Germar), Tylonotus bimaculatus Haldeman, Lepturges angulatus (LeConte), L. symmetricus (Haldeman), Urgleptes querci (Fitch), Oplosia nubila (LeConte), Eupogonius subarmatus (LeConte), Monochamus carolinensis (Olivier), and Pogonocherus parvulus LeConte. Urgleptes signatus (LeConte) and U. querci are newly recorded from Nova Scotia. All but two specimens were collected in 12-funnel Lindgren traps. Xylotrechus aceris, T. bimaculatus, L. symmetricus, U. signatus (NS), and P. parvulus were detected exclusively in traps deployed in the forest canopy, and most individuals of O. nubila and M. carolinensis were captured almost exclusively in traps near (1 m above) the forest floor. These results highlight the importance of sampling both the understory and upper canopy when using traps for surveying diversity of Cerambycidae.

### Keywords

Cerambycidae, new records, Canada, New Brunswick, Nova Scotia

# Introduction

The Cerambycidae (longhorn beetles) fauna of New Brunswick was first reviewed by Webster et al. (2009). In that review, 48 species were reported as new to the province. Majka et al. (2010) added two more species to the faunal list. Most recently, Webster et al. (2012a) added six more species and removed *Phymatodes testaceus* (Linnaeus) from the faunal list. Additional species of Cerambycidae were newly recorded from New Brunswick and Nova Scotia during a study to develop tools for enhanced detection of invasive species of Cerambycidae. The purpose of this paper is to report these new records.

# Methods and conventions

Collection methods. All specimens but two (which were hand collected) were collected from Lindgren 12-funnel trap samples during studies to develop improved tools for detection of invasive species of Cerambycidae. Lindgren funnel traps are visually similar to tree trunks and are often effective for sampling species of Coleoptera that live in microhabitats associated with standing trees (Lindgren 1983). The species records come from samples collected in more than 800 funnel traps deployed at 17 sites (24-64 traps per site) between 2012 and 2015. At most sites, equal numbers of traps were deployed in the upper canopy as well as in the understory, but three sites were sampled only with canopy traps, and five sites were sampled only with understory traps. Overall, understory traps outnumbered canopy traps by a factor of 1.3. Canopy traps were 10-20 m above the ground, whereas understory traps were 1-1.5 m above the ground (i.e., 30-50 cm from the bottom of the collecting cup to the ground). In both cases, traps were suspended from rope such that the trap was at least 1 m from the main stem of trees and at least 30 m from another trap. For details of the methods used to deploy Lindgren traps and for sample collection, please see Webster et al. (2012b) and Hughes et al. (2014).

Traps were baited with various multi-lure combinations of plant volatiles and longhorn beetle aggregation/sex pheromones that varied among sites and years. These included high release-rate lures of ethanol and alpha-pinene, as well as hydroxyketones, hexanediols, 2-undecyloxy-1-ethanol (commonly known as monochamol), ipsenol, (E,Z)-6,10-dimethyl-5,9-undecadien-2-ol [(E,Z)-fuscumol] and (E,Z)-6,10dimethyl-5, 9-undecadien-2-yl acetate [(E,Z)-fuscumol acetate]. The fuscumol and fuscumol acetate lures were purchased from Sylvar Technologies (Fredericton, NB). The hexanediols were synthesized at Atlantic Forestry Centre, and the hydroxyketones were purchased from Bedoukian Research (Danbury, CT), and both were loaded into release devices at Contech Enterprises Inc. (Delta, BC). All other lures were purchased directly from Contech Enterprises Inc. (Delta, BC). Traps baited with these pheromones and plant volatiles have been shown to increase trap catches of many species of longhorn beetles (Lacey et al. 2004, 2009, Hanks et al. 2007, Hanks and Millar 2013, Silk et al. 2007, Pajares et al. 2010, Allison et al. 2012, Ryall et al. 2014, Sweeney et al. 2014).

A description of the habitat was recorded for all specimens collected during this survey. Locality and habitat data are presented as on labels for each record. Two labels were used on many specimens, one that included the locality, collection date, and collector, and one with macro- and micro-habitat data and collection method. Information from the two labels is separated by a // in the data presented from each specimen. This information, as well as additional published data, is summarized and discussed in the collection and habitat data section for each species.

**Distribution.** Every species is cited with current distribution in Canada and Alaska, using abbreviations for the state, provinces, and territories. New records for New Brunswick are indicated in **bold** under **Distribution in Canada and Alaska**. The following abbreviations are used in the text:

AK	Alaska	MB	Manitoba
YT	Yukon Territory	ON	Ontario
NT	Northwest Territories	QC	Quebec
NU	Nunavut	NB	New Brunswick
BC	British Columbia	PE	Prince Edward Island
AB	Alberta	NS	Nova Scotia
SK	Saskatchewan	NF & LB	Newfoundland and Labrador*

\*Newfoundland and Labrador are each treated separately under the current distribution in Canada and Alaska.

Acronyms of collections examined or where specimens reside referred to in this study are as follows:

AFC	Atlantic Forestry Centre, Fredericton, New Brunswick, Canada
CNC	Canadian National Collection of Insects, Arachnids and Nematodes, Ot-
	tawa, Ontario, Canada
KNPC	Kouchibouguac National Park Collection, New Brunswick, Canada
NBM	New Brunswick Museum, Saint John, New Brunswick, Canada
RWC	Reginald P. Webster Collection, Charters Settlement, New Brunswick,
	Canada

# Results

# Species accounts

All records below are species newly recorded for New Brunswick or Nova Scotia, Canada. The determination that a species was a new record was based on information in the print version of Bousquet et al. (2013). Species designated with a † are adventive to Canada.

# Family Cerambycidae Latreille, 1802 Subfamily Spondylidinae Audinet-Serville, 1832 Tribe Asemini J. Thomson, 1860

# Arhopalus obsoletus (Randall, 1838)

**Material examined. New Brunswick, Northumberland Co.**, ca. 2.5 km W of Sevogle, 47.0876°N, 65.8613°W, 8–22.VII.2013, 22.VII-6.VIII.2013, 9–23.VII.2014, C. Alderson & V. Webster // Old *Pinus banksiana* stand, Lindgren funnel traps (3, AFC; 2, RWC).

**Collection and habitat data.** Adults were captured in Lindgren funnel traps in an old jack pine (*Pinus banksiana* Lamb.) forest during July and August. Larvae feed at the base and in roots of dead pines (Yanega 1996).

Distribution in Canada and Alaska. ON, NB (Bousquet et al. 2013).

# Tribe Atimiini LeConte, 1873

# Atimia confusa confusa (Say, 1826)

**Material examined. New Brunswick, York Co.**, Canterbury, Eel River P.N.A. (Protected Natural Area), 45.8967°N, 67.6343°W, 21.V–2.VI.2014, 2–20.VI.2014, 25.VIII-2.IX.2014, C. Alderson & V. Webster // Old-growth eastern white cedar swamp & fen, Lindgren funnel traps (2, AFC; 2, RWC); Keswick Ridge, 45.9962°N, 66.8781°W, 22.V-4.VI.2014, C. Alderson & V. Webster // Mixed forest, Lindgren funnel trap in canopy (1, AFC).

**Collection and habitat data.** Specimens of *Atimia c. confusa* were caught in Lindgren traps in an old-growth eastern white cedar (*Thuja occidentalis* L.) swamp and fen during May, June, August, and September. Most individuals were caught in traps in the open part of the fen. One individual was captured in a Lindgren trap deployed in the canopy of a tree in a mixed forest with eastern white cedar. Yanega (1996) states that larvae of this species develop under bark of cedars and junipers (*Juniperus* sp.), and cypresses (*Taxodium* sp.) but does not give any details on the species.

Distribution in Canada and Alaska. ON, QC, NB (Bousquet et al. 2013).

Subfamily Cerambycinae Latreille, 1802 Tribe Callidiini Kirby, 1837

# Callidium frigidum Casey, 1912

**Material examined. New Brunswick, York Co.**, Douglas, Currie Mountain, 45.9832°N, 66.7564°W, 27.V-10.VI.2013, C. Alderson & V. Webster // Old *Pinus strobus* stand, Lindgren funnel trap in canopy of *P. strobus* (1, AFC); Canterbury, Eel River P.N.A.,

45.8967°N, 67.6343°W, 2–20.VI.2014, C. Alderson & V. Webster // Old-growth eastern white cedar swamp & fen, Lindgren funnel traps (6, AFC; 1, NBM; 5, RWC).

**Collection and habitat data.** Specimens of *Callidium frigidum* were captured in Lindgren traps in an old-growth eastern white cedar swamp and fen during June. One individual was caught in a Lindgren funnel trap in the canopy of a stand of white pine (*Pinus strobus* L.) with scattered eastern white cedar. Larvae develop under bark of juniper and cedar (Yanega 1996).

Distribution in Canada and Alaska. ON, QC, NB, NF (Bousquet et al. 2013).

#### Phymatodes amoenus (Say, 1824)

**Material examined. New Brunswick, York Co.**, Keswick Ridge, 45.9962°N, 66.8781°W, 3–18.VI.2015, 20.VI-16.VII.2015, C. Alderson & V. Webster // Mixed forest, Lindgren funnel trap in canopy (4), 1 m high under trees (2) (3, AFC; 3, RWC); same locality and collectors but 3–18.VI.2015, 18–30.VI.2015 // Hardwood forest, green Lindgren funnel trap in canopy (2), purple Lindgren trap in canopy (1), green Lindgren trap 1 m high under trees (2) (2, AFC; 3, RWC).

**Collection and habitat data.** *Phymatodes amoenus* was captured in Lindgren traps on the edge of a mixed forest and edge of nearby hardwood stand adjacent to a field. Seven of the 11 individuals were captured in traps in the canopy of trees. Larvae of this species mine under bark of dead grapevines (Yanega 1996). Our only native grape, *Vitis labrusca* L. occurred at several areas along the margin of the mixed and hardwood forest where traps were deployed and is the presumed host in New Brunswick.

Distribution in Canada and Alaska. ON, QC, NB (Bousquet et al. 2013).

# Phymatodes testaceus (Linnaeus, 1758)†

**Material examined. New Brunswick, York Co.**, Fredericton, Odell Park, 45.9571°N, 66.6650°W, 1–15.VI.2012, 15–28.VI.2012, 10–26.VII.2012, C. Alderson & V. Webster // Old-growth eastern hemlock forest, Lindgren funnel traps 1 m high under *Betula alleghaniensis* (2, AFC; 2, RWC); same locality and collectors but 45.9484°N, 66.6802°W, 17.VI-3.VII.2014 // Old mixed forest, Lindgren funnel trap 1 m high under trees (1, AFC; 1, RWC).

**Collection and habitat data.** Adults of this introduced species were caught during June and July in Lindgren funnel traps in an urban park with sections of old-growth eastern hemlock (*Tsuga canadensis* (L.) Carr.) and mixed forest. All adults were caught in traps in the understory. The immature stages of this species develop under bark of various hardwoods and pine (Yanega 1996).

Distribution in Canada and Alaska. BC, ON, QC, NB, NS (Bousquet et al. 2013).

**Comments.** Webster et al. (2009) reported *Phymatodes testaceus* from New Brunswick based on a series of specimens from Pleasantfield. It was determined that these specimens were mislabeled and were from Pleasantfield, Nova Scotia. Webster et al. (2012a) accordingly removed the species from the faunal list of New Brunswick. This species is reinstated to the faunal list of New Brunswick based on the above records.

#### Tribe Clytini Mulsant, 1839

# Neoclytus mucronatus mucronatus (Fabricius, 1775)

**Material examined. New Brunswick, York Co.**, 16 km W of Tracy off Rt. 645, 45.6854°N, 66.8839°W, 11–25.VII.2014, C. Alderson & V. Webster // Old red pine forest, Lindgren funnel trap (1, AFC: 1, RWC).

**Collection and habitat data.** Two specimens of *Neoclytus m. mucronatus* were captured during July in a Lindgren funnel trap baited with a multi-lure combination that included its aggregation pheromone, 3-hydroxyhexan-2-one, placed in the understory of an old red pine (*Pinus resinosa* Ait.) forest. According to Yanega (1996), larvae of this species develop under bark of dead and dying hickory (*Carya* sp.) (which does not occur in New Brunswick) and rarely pine. Presence of the hydroxyketone lure is likely responsible for detecting *N. m. mucronatus* because it contains the aggregation pheromone identified for this species (Lacey et al. 2007). Failure to detect *N. m. mucronatus* in traps baited with its aggregation pheromone at 13 other sites in New Brunswick from 2012–2014 suggests its occurrence in New Brunswick is rare or localized.

Distribution in Canada and Alaska. ON, NB (Bousquet et al. 2013).

# Xylotrechus aceris Fisher, 1917

**Material examined. New Brunswick, Carleton Co.**, Jackson Falls, "Bell Forest", 46.2200°N, 67.7231°W, 31.VII-14.VIII.2012, C. Alderson & V. Webster // Rich Appalachian hardwood forest, Lindgren funnel traps in canopy of *Acer saccharum* (1, AFC; 1, RWC).

**Collection and habitat data.** Both adults were caught in Lindgren funnel traps in the canopy of sugar maples (*Acer saccharum* Marsh.) in a hardwood forest during August. The larvae develop in branches of live maple (*Acer* sp.) (Yanega 1996).

Distribution in Canada and Alaska. ON, QC, NB (Bousquet et al. 2013).

#### *Xylotrechus sagittatus sagittatus* (Germar, 1821)

**Material examined. New Brunswick, Kent Co.**, Kouchibouguac National Park, 46.816821°N, 64.915475°W, 23.VIII.2012 // Salt marsh, flight intercept trap baited with spruce blend, ethanol, fuscumol (1, KNPC); same locality but 46.8072°N, 64.9100°W, 4–20.VIII.2015, 20–31.VIII.2015, C. Alderson & V. Webster // Jackpine

forest, Lindgren funnel traps, 1 m high (5, AFC; 2, RWC). **Northumberland Co.**, ca. 2.5 km W of Sevogle, 47.0876°N, 65.8613°W, 8–21.VIII.2013, 23.VII-6.VIII.2014, 6–20.VIII.2014, 20.VIII-3.IX.2014, C. Alderson & V. Webster // Old *Pinus banksiana* stand, Lindgren funnel traps (5, AFC; 1, NBM; 5, RWC). **Queens Co.**, C.F.B. Gagetown, 45.7516°N, 66.1866°W, 15–31.VII.2013, C. Alderson & V. Webster // Old mixed forest with *Quercus rubra*, Lindgren funnel trap in canopy of *Q. rubra* (1, AFC).

**Collection and habitat data.** Most individuals in New Brunswick were caught in Lindgren funnel traps in old jack pine forests. One adult was captured in a Lindgren funnel trap in the canopy of a red oak (*Quercus rubra* L.) adjacent to a white pine stand; another from a flight intercept trap in a salt marsh next to a jack pine stand. Yanega (1996) reports *Pinus* as the main larval host of this species. Adults were captured during July, August, and September.

Distribution in Canada and Alaska. MB, ON, QC, NB, NS, PE (Bousquet et al. 2013).

#### Tribe Hesperophanini Mulsant, 1839

## Tylonotus bimaculatus Haldeman, 1847

**Material examined. New Brunswick, Queens Co.**, C.F.B. Gagetown, 45.7516°N, 66.1866°W, 15–31.VII.2013, C. Alderson & V. Webster // Old mixed forest with *Quercus rubra*, Lindgren funnel trap in canopy of *Q. rubra* (1, AFC). **Sunbury Co.**, Gilbert Island, 45.8770°N, 66.2954°W, 25.VII-8.VIII.2012, 5–17.VII.2013, C. Alderson, C. Hughes, & V. Webster // Hardwood forest, Lindgren funnel trap in canopy of *Tilia americana* (1), and canopy of *Fraxinus pennsylvanica* (2) (1, AFC; 2, RWC).

**Collection and habitat data.** All specimens (4) of *Tylonotus bimaculatus* from New Brunswick were captured in Lindgren funnel traps in the canopy of trees (red oak, basswood (*Tilia americana* L.), green ash (*Fraxinus pennsylvanica* Marsh.)) in mixed and hardwood forests with ash (*Fraxinus* sp.). Hosts include live or dying hardwoods, especially ash (Yanega 1996). Adults were captured during July and August.

Distribution in Canada and Alaska. MB, ON, QC, NB (Bousquet et al. 2013).

Subfamily Lamiinae Latreille, 1825 Tribe Acanthocinini Blanchard, 1845

# Lepturges angulatus (LeConte, 1852)

**Material examined. New Brunswick, Northumberland Co.**, Upper Graham Plains, 47.1001°N, 66.8154°W, 24.VII-7.VIII.2014, C. Alderson & V. Webster // Old black spruce (*Picea mariana* (Mill.) B.S.P.) forest with white pine, Lindgren funnel trap in canopy of white pine (1, AFC). **York Co.**, Fredericton, Odell Park, 45.9484°N,

66.6802°W, 1–15.VIII.2014, C. Alderson & V. Webster // Old mixed forest, Lindgren funnel traps in canopy of hardwoods (1, AFC; 1, RWC).

**Collection and habitat data.** All adults (3) of *Lepturges angulatus* from New Brunswick were captured in Lindgren funnel traps in the canopy of trees; one from the canopy of a white pine in an old black spruce forest with white pine and two from the canopy of hardwoods in an old mixed forest stand. Yanega (1996) reports various hardwoods and pine as larval hosts of this species. Adults were collected during July and August in New Brunswick.

Distribution in Canada and Alaska. ON, QC, NB (Bousquet et al. 2013).

# Lepturges symmetricus (Haldeman, 1847)

**Material examined. New Brunswick, Carleton Co.**, Jackson Falls, "Bell Forest", 46.2200°N, 67.7231°W, 21.VI-3.VII.2012, C. Alderson & V. Webster // Rich Appalachian hardwood forest, Lindgren funnel trap in canopy of *Tilia americana* (1, AFC). **Sunbury Co.**, Gilbert Island, 45.8770°N, 66.2954°W, 12–29.VI.2012, C. Alderson, C. Hughes, & V. Webster // hardwood forest, Lindgren funnel trap in canopy of *Juglans cinerea* (1, RWC). **York Co.**, Fredericton, Odell Park, 45.9539°N, 66.66666°W, 9–24.VII.2013, C. Alderson & V. Webster // Hardwood stand, Lindgren funnel trap in canopy (1, AFC); Keswick Ridge, 45.9962°N, 66.8781°W, 13–27.VIII.2015, C. Alderson & V. Webster // Mixed forest, Lindgren funnel trap in canopy (1, RWC).

**Collection and habitat data.** All adults (4) of *Lepturges symmetricus* from New Brunswick were captured in Lindgren funnel traps in the canopy of trees (American beech (*Fagus grandifolia* Ehrh.), butternut (*Juglans cinerea* L.)) in hardwood and mixed forests. Larval hosts include branches of various hardwoods (Yanega 1996). Adults were captured during June, July, and August.

Distribution in Canada and Alaska. ON, QC, NB (Bousquet et al. 2013).

### Urgleptes querci (Fitch, 1858)

Material examined. New Brunswick, Carleton Co., Jackson Falls, "Bell Forest", 46.2200°N, 67.7231°W, 3–17.VII.2012, 31.VII-14.VIII.2012, C. Alderson & V. Webster // Rich Appalachian hardwood forest, Lindgren funnel traps in canopy of *Acer saccharum* (1), *Fagus grandifolia* (1), and *Juglans cinerea* (1) (1, AFC; 2, RWC). Restigouche Co., Jacquet River Gorge P.N.A., 47.8257°N, 66.0764°W, 5–19. VIII.2014, C. Alderson & V. Webster // Old *Populus balsamifera* stand near river, Lindgren funnel trap 1 m high under trees (1, NBM); ca. 3 km SE of Simpsons Field, 47.5277°N, 66.5142°W, 23.VI-5.VIII.2015, C. Alderson & V. Webster // Old cedar & spruce forest with *Populus balsamifera* & *P. tremuloides*, Lindgren funnel trap (1, AFC). Sunbury Co., Gilbert Island, 45.8770°N, 66.2954°W, 29.VI-11.VII.2012, 25.VII-8.VIII.2012, 8–21.VIII.2012, C. Alderson, C. Hughes, & V. Webster // hard-

wood forest, Lindgren funnel traps 1 m high under Juglans cinerea (8), in canopy of Juglans cinerea (3), and 1 m high under Tilia americana (5) (9, AFC; 1, NBM; 6, RWC): same data as previous record, but 5-17.VII.2013, Lindgren funnel trap in canopy of Ulmus americana (1, AFC). Victoria Co., Saint Leonard, mesotrophic sugar maple forest, 16.VII.2014, John Klymko (1, NBM). York Co., Douglas, Currie Mountain, 45.9844°N, 66.7592°W, 24.VII-7.VIII.2013, 6-17.IX.2013, C. Alderson & V. Webster // Mixed forest with Quercus rubra, Lindgren funnel traps 1 m high under Q. rubra (2 AFC); Fredericton, Odell Park, 45.9539°N, 66.66666°W, 24.VI-9.VII.2013, 7-19.VIII.2013, C. Alderson & V. Webster // Hardwood stand, Lindgren funnel traps in canopy (2), Lindgren funnel trap 1 m under trees (1) (3, AFC); Keswick Ridge, 45.9962°N, 66.8781°W, 3-18.VII.2014, C. Alderson & V. Webster // Mixed forest, Lindgren funnel trap in canopy (1, RWC); Canterbury, Eel River P.N.A., 45.8966°N, 67.6345°W, 15-28.VII.2014, C. Alderson & V. Webster // Oldgrowth eastern white cedar swamp & fen, Lindgren funnel trap (1, NBM). Nova Scotia, Halifax Co., Magazine Hill, 44°42'19.1"N, 63°37"19.89"W, 11.VIII.2014, Sweeney Lab, coll. // High-Low Experiment, Ketols Lure, High Traps (2, AFC).

**Collection and habitat data.** In New Brunswick, most *Urgleptes querci* adults were captured in Lindgren funnel traps in hardwood and mixed forests; one individual was caught in a Lindgren trap in an old-growth eastern white cedar swamp, and another was hand-collected in a sugar maple forest. The two adults from Nova Scotia were captured in the canopy of trees in a mixed forest. Larvae of this species develop in branches of many hardwoods, especially maple, shrubs, and vines (Yanega 1996). This species was collected from June into September.

Distribution in Canada and Alaska. ON, QC, NB, NS (Bousquet et al. 2013).

# Urgleptes signatus (LeConte, 1852)

**Material examined. Nova Scotia, Halifax Co.**, Magazine Hill, 44°, 42', 19.1"N, 63°, 37", 19.89"W, 21.VII.2014, 28.VII.2014, 4.VIII.2014, Sweeney Lab, coll. // High-Low Experiment, Mono Lure, High Trap (1), Mono Lure, Low Trap (1), Ketols Lure, High Trap (1) (3, AFC).

**Collection and habitat data.** Two of the three specimens from Nova Scotia were captured in Lindgren funnel traps in the canopy of trees in a mixed forest.

Distribution in Canada and Alaska. ON, QC, NB, NS (Bousquet et al. 2013).

### Tribe Acanthoderini J. Thomson, 1860

Oplosia nubila (LeConte, 1862)

Material examined. New Brunswick, Carleton Co., Jackson Falls, "Bell Forest", 46.2200°N, 67.7231°W, 21.VI-3.VII.2012, C. Alderson & V. Webster // Rich Appa-

lachian hardwood forest, Lindgren funnel trap in canopy of *Tilia americana* (1, RWC). **Sunbury Co.**, Gilbert Island, 45.8770°N, 66.2954°W, 12–29.VI.2012, 29.VI-11. VII.2012, 11–25.VII.2012, C. Alderson, C. Hughes, & V. Webster // hardwood forest, Lindgren funnel traps 1 m high under *Tilia americana* (9) and in canopy of *Tilia americana* (13) (11, AFC; 1, CNC; 1, NBM; 9, RWC); same data as previous record but 5–17.VII.2013, Lindgren funnel trap in canopy of *Ulmus americana* (1, AFC). **York Co.**, Fredericton, Odell Park, 45.9539°N, 66.66666°W, 10–24.VI.2013, 9–24. VII.2013, C. Alderson & V. Webster // Hardwood stand, Lindgren funnel traps in canopy of *Fraxinus americana* L. and *Fagus grandifolia* Ehrh. (2, AFC); Keswick Ridge, 45.9962°N, 66.8781°W, 3–18.VII.2014, C. Alderson & V. Webster // Mixed forest, Lindgren funnel trap in canopy (1, AFC).

**Collection and habitat data.** Most (17 out of 27) individuals of *Oplosia nubila* from New Brunswick were captured in Lindgren funnel traps in the canopy of trees. Larvae of this species develop under bark of decaying basswood, hickory (which does not occur in New Brunswick), and beech (Yanega 1996). In New Brunswick, nearly all adults were captured in traps that were either in the canopy or understory of basswood trees at sites where other tree species were also sampled.

Distribution in Canada and Alaska. MB, ON, QC, NB (Bousquet et al. 2013).

#### Eupogonius subarmatus (LeConte, 1859)

**Material examined. New Brunswick, Carleton Co.**, Jackson Falls, "Bell Forest", 46.2200°N, 67.7231°W, 17.VII.2012, R.P. Webster // Rich Appalachian hardwood forest, on foliage (1, RWC). **York Co.**, Keswick Ridge, 45.9962°N, 66.8781°W, 29.VII-13.VIII.2015, C. Alderson & V. Webster // Mixed forest, Lindgren funnel trap in canopy (1, AFC).

Distribution in Canada and Alaska. ON, QC, NB (Bousquet et al. 2013).

#### Monochamus carolinensis (Olivier, 1795)

**Material examined. New Brunswick, Kent Co.**, Kouchibouguac National Park, 46.8072°N, 64.9100°W, 7–22.VII.2015, 27.VII-4.VIII.2015, C. Alderson & V. Webster // Jackpine forest, Lindgren funnel traps, 1 m high (5, AFC). **Northumberland Co.**, ca. 2.5 km W of Sevogle, 47.0876°N, 65.8613°W, 8–22.VII.2013, 22.VII-6.VIII.2013, 6–21.VIII.2013, 21.VIII-4.IX.2013, 17.IX-1.X.2013, 1–17.X.2013, C. Alderson & V. Webster // Old *Pinus banksiana* stand, Lindgren funnel traps (10, AFC: 6, CNC; 6, NBM; 3, RWC); Upper Graham Plains, 47.1001°N, 66.8154°W, 9–24. VII.2014, C. Alderson & V. Webster // Old black spruce forest, Lindgren funnel trap (1, AFC). **Queens Co.**, C.F.B. Gagetown, 45.7516°N, 66.1866°W, 2–17.VII.2015, 30.VII-14.VIII.2015, 14–28.VIII.2015, 28.VIII-10.IX.2015, C. Alderson & V. Webster // Old mixed forest with *Quercus rubra*, Lindgren funnel traps in canopy (8, AFC). **Sunbury Co.**, Acadia Research Forest, 45.9990°N, 66.2623°W, 26.VII-7.VIII.2012, 22.VIII-10.IX.2012, C. Hughes & K. Van Rooyen // Mature balsam fir forest with scattered red spruce & red maple (and white pine), Lindgren funnel traps (1, AFC; 1, RWC). **York Co.**, Douglas, Currie Mountain, 45.9832°N, 66.7564°W, 24.VI-9.VII.2013, 9–24.VII.2013, 24.VII-7.VIII.2013, 7–19.VIII.2013, 17.IX-3.X.2013, 3–15.X.2013, C. Alderson & V. Webster // Old *Pinus strobus* stand, Lindgren funnel traps in canopy of *P. strobus* (18, AFC; 6, CNC; 17, NBM; 7, RWC); Fredericton, Odell Park, 45.9484°N, 66.6802°W, 3–17.VII.2014, 17.VII-1.VIII.2014, C. Alderson & V. Webster // Old mixed forest, Lindgren funnel trap in canopy of conifer (2), 1 m high under trees (1) (1, AFC; 2, NBM); 16 km W of Tracy, off Rt. 645, 45.6854°N, 66.8839°W, 11–25.VII.2014, 25.VI-8.VII.2014, 18.VIII-5.IX.2014, C. Alderson & V. Webster // Old red pine forest, Lindgren funnel trap in canopy of red pine (3, AFC; 3, NBM).

**Collection and habitat data.** *Monochamus carolinensis* were captured in Lindgren traps baited with a multi-lure combination that included monochamol, ipsenol, alpha-pinene, and ethanol in a jack pine forest, an old black spruce stand with white pine, a mature balsam fir forest with white pine, an old white pine stand, an old red pine forest, and a mixed forest with red oak and white pine. Hosts include various *Pinus* species according to Yanega (1996). In New Brunswick, large numbers (many specimens were not vouchered) of adults were captured in a white pine stand, mostly in the canopy. This species was also common in a jack pine stand but uncommon in a red pine forest. These data suggest that white pine may be the preferred host in New Brunswick. This species has a long flight season in New Brunswick from early July to mid-October. Ryall et al (2014) showed that catch of *M. carolinensis* was significantly increased by baiting traps with monochamol, ipsenol, alpha-pinene and ethanol.

# Distribution in Canada and Alaska. ON, QC, NB (Bousquet et al., 2013).

**Comments.** *Monochamus carolinensis* was listed for New Brunswick by McNamara (1991). Webster et al. (2012a) could not locate any specimens to support its occurrence in the province but included it in the fauna of the province. Bousquet et al. (2013), however, did not list it as occurring in New Brunswick. The above records support reinstatement of the species to the faunal list of New Brunswick.

#### Tribe Pogonocherini Mulsant, 1839

# Pogonocherus parvulus LeConte, 1852

**Material examined. New Brunswick, Gloucester Co.**, Bathurst, Daly Point Nature Preserve, 47.6392°N, 65.6098°W, 25.VI-9.VII.2015, C. Alderson & V. Webster // Mixed forest, black Lindgren trap in canopy (*Populus*)(1, AFC). **Restigouche Co.**, ca. 3 km SE of Simpsons Field, 47.5277°N, 66.5142°W, 25.VI-10.VII.2015, C. Alderson & V. Webster // Old cedar & spruce forest with *Populus balsamifera & P. tremuloides*, Lindgren funnel trap in canopy of *P. balsamifera* (1, RWC). **Sunbury Co.**, Gilbert

Island, 45.8770°N, 66.2954°W, 20.VI-5.VII.2013, C. Alderson, C. Hughes, & V. Webster // hardwood forest, Lindgren funnel traps in canopy of *Acer saccharinum* and *Populus tremuloides* (1, AFC; 1, RWC).

**Collection and habitat data.** One individual each was captured in Lindgren funnel traps in the canopy of silver maple and trembling aspen (*Populus tremuloides* Michx.) in a hardwood forest on Gilbert Island. At Daly Point and Simpsons Field, *P. parvulus* was captured in the canopy of *Populus* sp.. Willow (*Salix*), a common species at the above sites, is listed by Yanega (1996) as a host of this species.

Distribution in Canada and Alaska. AB, SK, MB, ON, QC, NB (Bousquet et al. 2013).

# Discussion

These new species records of Cerambycidae for the provinces of New Brunswick and Nova Scotia enrich our knowledge of the region's fauna and species diversity. With the exception of one specimen of *E. subarmatus* and one specimen of *U. querci*, all long-horn beetle specimens were collected in Lindgren multi-funnel traps placed in either the understory or upper canopy. Of the 16 species collected in traps, three species were collected exclusively in understory traps (*A. obsoletus, A. c. confusa, N. m. mucronatus*), and six species were collected exclusively in canopy traps (*L. angulatus, L. symmetricus, P. parvulus, T. bimaculatus, U. signatus, X. aceris*). These results highlight the need to sample both the canopy and understory when using traps to survey for beetle species. Differences in insect species composition between traps placed in the upper canopy and understory and the importance of sampling both strata have been shown in several forest habitats (Su and Woods 2001; Vance et al. 2003; Graham et al. 2012; Dodds 2014).

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RESEARCH ARTICLE



# Two new species of spotted *Hypancistrus* from the Rio Negro drainage (Loricariidae, Hypostominae)

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### Abstract

Two new species, *Hypancistrus phantasma* and *Hypancistrus margaritatus*, are described based on material from the Rio Negro drainage. Both species are distinguished from congeners by unique color patterns. *Hypancistrus phantasma* is described from the Rio Uaupes and differs from congeners by having a tan body with small dark spots (vs. dark with light spots or with saddles or stripes). *Hypancistrus margaritatus* is described from the Takutu River and differs from congeners by having densely-packed light spots on a dark brown background, with spots about the size of the nasal aperture (vs. sparse light spots either smaller or larger than the nasal aperture, or brown to black spots, saddles, or stripes).

# Keywords

Siluriformes, Guyana, Brazil, taxonomy, suckermouth armored catfish, Neotropics

# Introduction

*Hypancistrus* is a small genus comprising six species of loricariid catfishes in the tribe Ancistrini of the subfamily Hypostominae: *H. zebra* Isbrücker and Nijssen (1991), the type species from the Rio Xingu; *H. inspector* Armbruster (2002) from the Rio Negro; and *H. contradens* Armbruster et al. (2007), *H. debilittera* Armbruster et al. (2007), *H. furunculus* Armbruster et al. (2007), and *H. lunaorum* Armbruster et al. (2007), all from the Rio Orinoco. *Hypancistrus* can be distinguished externally from most other hypostomines by having larger and fewer teeth on the dentary relative to the teeth on the premaxilla. Different numbers of teeth on the dentary and premaxilla are found in many loricariids, so this character is not always diagnostic (Armbruster 2002). The genus is diagnosed by the unique presence of a wide anterior separation between the metapterygoid and the lateral ethmoid, and a sharply angled adductor palatini crest. It also lacks the lateral wall of the metapterygoid channel (Armbruster 2002).

Species of *Hypancistrus* are best distinguished from each other by their color pattern and cannot be separated by traditional morphometrics used in loricariids (Armbruster et al. 2007). Numerous undescribed forms remain, and there is considerable variation in color patterns (Armbruster et al. 2007). Undescribed forms of *Hypancistrus* (and other loricariids) are assigned L-numbers by the aquarium fish magazine DATZ that are widely used by aquarists, and some of these forms are discussed. Here we describe two new species of *Hypancistrus* with spotted color patterns.

# Methods

Measurements and counts follow Armbruster (2003) with additional counts for lateral plate series from Armbruster et al. (2007). Anatomical nomenclature follows Schaefer (1987) and Geerinckx et al. (2007) for skeletal characteristics, Schaefer (1997) for names of plate rows, Douglas et al. (2002) for the term 'iris operculum,' and Armbruster et al. (2007) for the term 'nasal aperture.' We define minimum interspot distance as the minimum distance between spots measured. Midlateral spots were selected from behind the head to the base of the caudal peduncle for measurement, and minimum interspot distance is given as a ratio over spot diameter. Institutional abbreviations are as listed in Sabaj Pérez (2014).

# **Systematics**

#### Hypancistrus phantasma sp. n.

http://zoobank.org/D20CFAAD-CE01-4F2F-99D9-7E36B1D6C0F3 Figure 1

Holotype. MZUSP 116531, 123.3 mm SL, Amazon Basin, Rio Negro drainage: Rio Uaupes, Taracua, 0.1°N, 68.46667°W, 14 Feb 1924, D. Melin and A. Vilars.

**Paratypes.** NRM 16880, 3, 92.5–105.46 mm SL, same data as holotype; NRM 39344, 1, 101.3 mm SL, same locality as holotype, 19 Feb 1924, same collectors as holotype.

**Diagnosis.** *Hypancistrus phantasma* can be distinguished from congeners by a color pattern consisting of a tan base coloration with black spots vs. a color pattern consisting of a dark base coloration and light spots (as in *H. contradens, H. inspector, H. lunaorum* and *H. margaritatus*) or a color pattern consisting of saddles, vermiculations, bands, or stripes (as in *H. furunculus, H. debilittera*, and *H. zebra*).



Figure 1. *Hypancistrus phantasma* sp. n., holotype, 123.3 mm SL, dorsal, lateral, and ventral views, MZUSP 116531, Rio Uaupes. Photographs by M Tan.

**Description.** Morphometric data given in Table 1. Counts are variation observed in paratypes. Largest specimen examined 123.3 mm SL. Ventral surface from anus to head largely lacking plates in adults. Small plates present in skin ventral to pectoral girdle, anteromesially to gill opening, and on ventrolateral margins of thorax extending posteriorly from insertion of pectoral-fin spine towards insertion of pelvic-fin spine.

		Н. р	hantasm	a		H. margaritatus
	Holotype	Avg	SD	Min	Max	Holotype
SL	123.3	103.3	12.4	92.5	123.3	45.6
Predorsal Length	42.3	42.8	0.4	42.3	43.4	45.5
Head Length	35.0	35.8	0.5	35.0	36.5	38.4
Head-dorsal Length	7.3	7.1	0.4	6.6	7.6	7.5
Cleithral Width	30.6	31.4	0.8	30.6	32.7	31.2
Head-pectoral Length	26.7	25.8	0.8	24.8	26.7	26.6
Thorax Length	23.4	23.0	0.5	22.4	23.6	25.6
Pectoral-spine Length	32.8	34.3	1.6	32.8	36.8	35.7
Abdominal Length	24.6	25.0	0.2	24.6	25.2	24.2
Pelvic-spine Length	26.5	27.3	0.9	26.3	28.5	33.3
Postanal Length	32.4	32.6	0.7	32.1	33.8	34.1
Anal-fin spine Length	10.3	11.7	0.9	10.3	12.6	14.6
Dorsal-pectoral Distance	28.3	28.9	0.5	28.3	29.6	29.5
Dorsal spine Length	32.3	33.8	2.1	32.1	36.7	36.6
Dorsal-pelvic Distance	26.1	25.2	0.8	24.3	26.1	24.1
Dorsal-fin base Length	28.3	27.7	0.6	26.7	28.3	29.0
Dorsal-adipose Distance	16.9	16.5	0.7	15.2	17.1	16.1
Adipose-spine Length	7.1	8.5	0.9	7.1	9.0	8.5
Adipose-upper caudal Distance	13.4	14.3	1.1	13.4	15.8	11.9
Caudal peduncle Depth	11.2	11.0	0.8	9.6	11.7	13.0
Adipose-lower caudal Distance	21.2	22.4	0.8	21.2	23.1	21.0
Adipose-anal Distance	19.4	19.2	0.5	18.3	19.6	19.5
Dorsal-anal Distance	17.4	17.3	0.7	16.5	18.2	15.9
Pelvic-dorsal Distance	28.2	28.1	0.7	27.0	28.9	26.0
Head-eye Length	11.7	12.0	0.3	11.7	12.4	13.8
Orbit Diameter	8.3	8.9	0.5	8.3	9.4	10.0
Snout Length	19.7	19.7	0.3	19.3	20.0	21.0
Internares Width	4.9	5.1	0.5	4.7	5.9	5.5
Interorbital Width	15.1	16.1	0.7	15.1	16.8	17.9
Head Depth	24.8	25.3	0.4	24.8	25.8	26.3
Mouth Length	14.6	15.2	0.4	14.6	15.5	17.4
Mouth Width	12.2	13.3	1.8	11.2	16.1	17.7
Barbel Length	4.0	4.2	0.6	3.7	5.2	3.2
Dentary tooth cup Length	4.0	3.9	0.4	3.4	4.5	2.3
Premaxillary tooth cup Length	2.0	1.8	0.2	1.4	2.0	2.8

**Table 1.** Morphometric data of new *Hypancistrus* species. Morphometric data of *Hypancistrus phantasma* (n = 5) and *Hypancistrus margaritatus* (n = 1). Morphometric data except standard length are given as percentages of standard length.

Extent of small ventral plates correlated with body size, with larger specimens having larger ventral plated areas with plates ventral to pectoral girdle joining medially, and ventrolateral abdominal plates extending further posteriorly. Lateral plates unkeeled except ventral plate row with moderately elongate odontodes forming one or two keel-like

rows on caudal peduncle, and mid-ventral plate row bent above pectoral girdle forming ridge continuous with cleithrum. Cheek plates with 23–49 hypertrophied odontodes. Frontal, infraorbitals, nasal, preopercle, compound pterotic, and suprapreopercle supporting odontodes. Small ridge of opercle covered in smallest paratype (92.5 mm SL), exposed in remaining specimens; if exposed, zero to six odontodes present.

Caudal fin emarginate, lower lobe longer than upper. Ventral surface flat. Head tall. Snout short. Vertical through anterior margin of orbit about half-way between vertical through anterior margin of snout and vertical through posteromedial tip of supraoccipital. Head with steep angle in profile, roughly 45° from tip of snout to anterior margin of eye. Body depth increases gradually from anterior margin of eye to dorsal-fin origin, then decreases gradually from dorsal-fin origin to posterior insertion of adipose fin; caudal-peduncle depth increases slightly from insertion of adipose fin to origin of caudal fin.

Supraorbital crest low. Orbital opening oriented at less than 45° from sagittal plane. Interorbital isthmus between supraorbital crests flat. Supraoccipital crest low. Eye large with iris operculum. Gill opening restricted in *L*-conformation, with half of opening vertical and opening laterally and half of opening horizontal and opening ventrally.

Dorsal-fin spine short; depressed dorsal fin reaching anterior edge of or slightly beyond preadipose plate. Depressed pectoral-fin spine reaching beyond base of pelvic-fin rays; depressed pelvic-fin spine reaching beyond posterior insertion of anal fin. Dorsal fin II,7; caudal fin I,14,I; dorsal procurrent caudal-fin spines four to five, four in holotype; ventral procurrent caudal-fin spines four to five, four in holotype; anal fin i3–4 (one paratype examined with 3 anal-fin rays); pectoral fin I,6; pelvic fin i,5. Fin spines and rays supporting odontodes. Odontodes more elongate distally on pectoral-fin spine and ventrally on pelvic-fin spine than at base of pectoral- and pelvic-fin spines.

Lips papillose, forming oral disk less than half width of head. Maxillary barbels long (reaching past posterior edge of lower lip when extended posteriorly), thin, and pointed; barbel rugose proximally, almost smooth distally.

Median plates 24; mid-dorsal plates 22–24 (24 in holotype, mode 23); mid-ventral plates 24; rows of plates on caudal peduncle five. Dentary teeth two to three (two in holotype), teeth long and wide; premaxillary teeth four to seven (six in holotype), thinner and shorter than dentary teeth. In new teeth, medial cusps longer and wider than lateral cusps; in worn teeth, medial and lateral cusps of approximately the same length and width. Central buccal papilla absent.

**Color.** Specimens preserved in 70% alcohol with tan base color and small brown spots. Tan base coloration largely uniform, with paler region between orbits, posterior to orbit, and extending posterior to cleithrum. Naked areas white, including ventral surface and areas surrounding origins of pectoral- and pelvic-fin spines. Small brown spots evenly spaced on head. Brown spots on body larger than spots on head, increasing slightly and gradually in size posteriorly. Brown spots on body more closely spaced anteriorly and more distantly spaced posteriorly; on imaginary vertical-oblique lines through the spots, four to five spots occurring per line anteriorly diminishing to two spots per line posteriorly. No spots ventral to an imaginary line between origin



**Figure 2.** Map of South America, with known localities for *H. phantasma* sp. n. (●) and *H. margaritatus* sp. n. (■).

of pelvic-fin spine and origin of dorsal caudal-fin spine. Fin rays tan, fin membranes of paired fins and anal fins hyaline. Dorsal-fin rays tan; dorsal-fin membrane tan at base, gradually fading to dark brown band at the distal edge. Caudal-fin membrane on lower lobe transitioning to brown posteriorly. Dark spots present on pectoral-fin rays, pelvic-fin rays, and dorsal-fin rays. Faint white, round spots on dorsal and caudal fins; on dorsal fin, white color more apparent on brown fin membranes than on rays. Odontodes on cheek and fin spines straw-colored with dark brown tips.

**Range.** Only known from Taracuá of the Rio Uaupes, a tributary of the Rio Negro drainage (Fig. 2).

**Etymology.** The specific epithet *phantasma* is Latin for "phantom," and refers to its elusiveness (the described specimens represent the only known specimens, despite nearly a century passing since their collection) and its pale body coloration. It is treated as a noun in apposition.

### Hypancistrus margaritatus sp. n.

http://zoobank.org/03E1C489-F788-4E9A-A749-DAFD65D42530 Figures 3, 4

Holotype. CSBD F1701/AUM 35610 (dual-accessioned), 45.6 mm SL, Amazon Basin, Rio Negro drainage: Rio Branco, Takutu River. Takutu River ca. 2.75 km W Saint Ignatius. Rupununi (Region 9), Guyana, South America. 3.35500°N, 59.83077°W, 5-6 Nov 2002, J.W. Ambruster, M.H. Sabaj, D.C. Werneke, C.L. Allison, M.R. Thomas, C.J. Chin, D. Arjoon, L. Atkinson.

**Diagnosis.** Hypancistrus margaritatus is distinguished from all congeners by its color pattern of dense, small, light-colored spots on a dark base color. Three other described species have a color pattern of light spots on a dark base color: *H. inspector*, *H. lunaorum*, and *H. contradens. Hypancistrus margaritatus* has consistently-sized spots on head and trunk about the size of the nasal aperture (vs. smaller spots on head than trunk in *H. inspector*, spots usually smaller than half the nasal diameter in *H. lunaorum*, and spots ranging in size from equal to or larger in diameter of nasal aperture in *H. contradens*). Hypancistrus margaritatus also has more spots, 23 in a lateral, horizontal series from snout tip to base of caudal peduncle 23 in holotype (vs. 8–20 spots in *H. contradens*; 8–16 in *H. lunaorum*). Hypancistrus margaritatus has more densely-packed spots relative to *H. lunaorum*, with spots on lateral surface of the body having a minimum interspot to spot diameter ratio ranging from 1.0–1.6 (vs. 1.9–4.4 in *H. lunaorum*).

**Description.** Morphometric data given in Table 1. Holotype 45.6 mm SL. Ventral surface from anus to head lacking plates. Lateral plates unkeeled. Cheek plates with 14 hypertrophied odontodes on one side and 18 on other. Frontal, infraorbitals, nasal, preopercle, compound pterotic, and suprapreopercle supporting odontodes. Small ridge of opercle exposed with four odontodes.

Caudal fin emarginate, lower lobe longer than upper. Ventral surface flat. Head tall. Snout short. Distance between verticals through tip of snout and anterior margin of orbit greater than distance between verticals through anterior margin of orbit and posteromedial tip of supraoccipital. Head with steep angle in profile, roughly 45°, from tip of snout to anterior margin of eye. Body depth increases gradually from anterior margin of the eye to dorsal-fin origin, then decreases gradually from dorsal-fin origin to insertion of adipose fin, then caudal peduncle depth increases slightly from insertion of adipose fin to caudal-fin origin.

Supraorbital crest pronounced. Orbital opening oriented at less than 45° from sagittal plane. Interorbital isthmus between supraorbital crests flat. Supraoccipital crest low. Eye large with iris operculum. Gill opening restricted in *L*-conformation, with half of opening vertical and opening laterally and half of opening horizontal and opening ventrally.

Dorsal-fin spine short; depressed dorsal fin reaching slightly beyond pre-adipose plate to origin of adipose fin. Depressed pectoral-fin spine reaching beyond base of pelvic-fin rays; depressed pelvic-fin spine reaching beyond posterior insertion of anal fin. Dorsal fin II,7; caudal fin I,14,I; four dorsal procurrent caudal-fin spines; four ventral procurrent caudal-fin spines; anal fin i4; pectoral fin I,6; pelvic fin i,5. Fin spines and rays supporting odontodes.

Lips papillose, forming oral disk approximately half the width of the head. Maxillary barbels long, not reaching past the posterior edge of the lower lip when extended posteriorly, thin, and pointed; barbel rugose proximally, almost smooth distally.



**Figure 3.** *Hypancistrus margaritatus* sp. n., holotype, 45.6 mm SL, dorsal, lateral, and ventral views, AUM 35610, Takutu River. Photographs by M Tan.



**Figure 4.** Photograph of live *H. margaritatus* holotype, AUM 35610, Takutu River. Image flipped horizontally. Photograph by MH Sabaj Pérez.

Median plates 24; mid-dorsal plates 23; mid-ventral plates 24; rows of plates on caudal peduncle five. Dentary teeth five on one side and six on other, long and wide. Premaxillary teeth eight, smaller than dentary teeth. Medial cusps longer and wider than lateral cusps, with cusps separate and angled away from one another (vs. parallel and adjacent). Central buccal papilla absent.

Color. Light yellow spots on dark brown base color in life (Figure 3). Brownishgray base color with small white spots in 70% ethanol. Gray base color mostly uniform, with slightly paler saddle areas at origin of dorsal fin, in middle area of dorsal fin, between dorsal fin and adipose fin, and posterior to adipose fin extending onto dorsal procurrent caudal fin rays. Light spots evenly-sized across body, approximately size of nasal aperture, and smaller in diameter than the length of lateral plates. Light spots relatively evenly spaced and present on all plated regions of body, usually with minimum interspot distance 1.0-1.6 times spot diameter. 21 spots in horizontal series from snout tip to end of caudal peduncle, 23 spots in series along sagittal plane from snout tip to dorsal procurrent caudal fin rays. Dark background color and evenly spaced small white spots also on fin spines and rays; fin-ray membranes hyaline but dusky with sparse melanophores. Six white spots on pectoral-fin spine, decreasing gradually in number to two to three on shortest fin rays. Four to five white spots on pelvic-fin spine, decreasing in number to three spots on shortest fin rays. Spots on dorsal-fin spine and rays in rows roughly parallel to slope of dorsal surface of body between dorsal-fin origin and insertion. Five to six spots on dorsal-fin spine and anterior rays, decreasing in number to three on last dorsal-fin rays. Posterior margin of dorsal fin darker gray than rest of the dorsal fin. Adipose-fin spine with a single spot. Adiposefin membrane with two small spots. Adipose-fin membrane hyaline, more transparent

posteriorly. Ventral naked area posterior to pectoral fin insertion and anterior to anus pale yellow. Mouth and ventral area anterior to pectoral fin insertion yellowish. Eye color dark dorsally with dense melanophores and small white spots, white ventrally with dark shaded spots of sparse melanophores. Odontodes present on fin spines and cheeks straw-colored with dark brown tips.

**Range.** *Hypancistrus margaritatus* is described from a single specimen collected in the Takutu River, a tributary of the Rio Branco of the Rio Negro drainage.

**Etymology.** The specific epithet is Latin for "adorned with pearls," referring to the dense white spots on the body.

**Remarks.** The holotype and only known specimen of the species was dual-accessioned at AUM and CSBD because the specimen will be kept at AUM for the near term, but will eventually be repatriated to Guyana.

A Hypancistrus from the Takutu River that may represent H. margaritatus has been designated as L404 in the aquarium pet trade (Stawikowski 2006) and is uncommonly sold (MT pers. obs.). L404 appears to be conspecific with Hypancistrus margaritatus. In designating the L-number L404, Stawikowski (2006) noted the largest imported specimens were 11 cm in length. The pictured invidual may be larger than the holotype of H. margaritatus. It also has many more spots (~35 spots from snout tip to caudal peduncle vs. 21 in the holotype of H. margaritatus). An image of L404 was also provided in Seidel (2008). The image shows approximately 28 spots from snout tip to caudal peduncle, intermediate between that of the holotype of H. margaritatus and the Stawikowski (2006) image. If L404 is H. margaritatus, spot number may increase with body size in this species, while the relative distance between spots does not increase.

*Hypancistrus margaritatus* appears to be rare, as only one specimen was collected during four expeditions that yielded 55,156 fish specimens (de Souza et al. 2012). The specimen was collected from within a hole in a lateritic boulder in a run of the mainstem Takutu River. This species is listed as *Hypancistrus* sp. in de Souza et al. (2012).

# Discussion

Of the described species, *Hypancistrus phantasma* appears most similar to *H. inspector*, as both species have large maximum sizes relative to other *Hypancistrus* species and share the presence of dark distal edges on the dorsal and caudal fins. *Hypancistrus inspector* is found in the upper Rio Negro, and *H. phantasma* is found in the Rio Uaupes, a tributary to the Rio Negro. Because of their morphological similarity and close geographical proximity, *H. inspector* and *H. phantasma* may be closely related. They can be separated by the light base color and presence of dark spots in *H. phantasma* vs. dark base color with light spots in *H. inspector*. Although *H. inspector* is distinguished from *H. contradens* in part by having a dorsal fin that does not reach the adipose fin when depressed (Armbruster et al. 2007), the dorsal fin of *H. phantasma* does usually reach the preadipose plate. Also, *H. phantasma* has significantly fewer dentary teeth, two to three vs. five to 10 in *H. inspector*; however, gaps between the dentary teeth in *H.* 

*phantasma* specimens examined suggest that they may have lost teeth. A color pattern of a pale base color with black spots is found in an undescribed species of *Hypancistrus* from the Rio Xingu referred to as L174 (Seidel 2008). Based on photographs and reported information, this species differs from *H. phantasma* in its smaller maximum body size, absence of a black edge on the dorsal and caudal fins, and black spots being large and sometimes near enough to coalesce, particularly behind the head where they may form a collar.

The specimens of *Hypancistrus phantasma* were collected in 1924, and it is likely their coloration has been affected by age since preservation. Nevertheless, the distal edge of the dorsal fin is relatively dark. Faded specimens of *H. inspector* do not have dark spots like those in *H. phantasma*, and merely show a reduction in intensity of coloration. Thus, even if the preserved color pattern in *H. phantasma* may not be representative of the live coloration, the presence of small dark spots on the body is diagnostic.

Hypancistrus margaritatus is most similar to the other small-bodied, spotted Hypancistrus: H. contradens and H. lunaorum. It differs from these species in having more body spots. In H. contradens and H. lunaorum, the spots increase in number allometrically (Armbruster et al. 2007), but the spots never reach the number present in H. margaritatus. It appears there is an allometric relationship with spot number and body size in H. margaritatus as well, based on images of specimens identified as L404 in aquarium literature presumed to be conspecific. Specimens of H. contradens and H. lunaorum at equivalent body sizes to the H. margaritatus holotype have far fewer spots, so a larger number of spots in H. margaritatus likely distinguishes this species from H. contradens and H. lunaorum across their size ranges. In addition, the distance between spots in H. lunaorum relative to spot size is much greater than in H. margaritatus, H. contradens, and H. inspector.

Hypancistrus margaritatus is also similar to some undescribed forms of Hypancistrus. A specimen of Hypancistrus with small spots from the Rio Madeira was identified as Hypancistrus cf. inspector (de Queiroz et al. 2013). The photograph shows a specimen that is heavily damaged, but has many small spots like Hypancistrus margaritatus. The spots are more densely packed (minimum interspot distance < spot diameter) than in H. margaritatus. There do not appear to be spots on the dorsal and caudal fins, which differs from the presence of spots on these fins in H. margaritatus, H. contradens, H. inspector, and H. lunaorum. The specimen likely represents another undescribed species. In the aquarium literature, H. margaritatus (as L404) has been described as similar to another Hypancistrus form called L136, which also has a color pattern of dense, lightcolored spots on a dark base color (Stawikowski 2006). The identity of these forms and their possible conspecificity with *H. margaritatus* should be assessed. Another spotted L-number, L004 (and putative conspecific L-numbers L005, L028, L073), appears similar to *H. lunaorum*, possessing small spots (smaller in diameter than nasal aperture) with a larger interspot distance-spot diameter ratio (Seidel 2008). The spotted L262 appears to have smaller spots and in higher numbers than *H. margaritatus* (Seidel 2008).

Both new species of *Hypancistrus* may be extremely rare. *Hypancistrus margaritatus* was only collected once, as a single specimen, in four collecting trips to the Takutu

River region (de Souza et al. 2012). However, this species has apparently been collected occasionally by aquarium hobbyists and designated as L404 (Stawikowski 2006). To the knowledge of the authors, *H. phantasma* has not been collected since 1924. There are insufficient data to assess the conservation statuses of these species.

# Other materials examined

Locality data listed in Armbruster (2002), Armbruster et al. (2007). *H. contradens*: AUM 37978, AUM 42097, AUM 42170, AUM 42190, AUM 54471 *H. inspector*: AUM 31019, AUM 39234, AUM 42198, MCNG 12133, MCNG 37040 *H. lunaorum*: AUM 39247, AUM 39277, AUM 39590, AUM 39837, AUM 42120, AUM 42142, AUM 44315

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DATA PAPER



# Dataset of Passerine bird communities in a Mediterranean high mountain (Sierra Nevada, Spain)

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#### Abstract

In this data paper, a dataset of passerine bird communities is described in Sierra Nevada, a Mediterranean high mountain located in southern Spain. The dataset includes occurrence data from bird surveys conducted in four representative ecosystem types of Sierra Nevada from 2008 to 2015. For each visit, bird species numbers as well as distance to the transect line were recorded. A total of 27847 occurrence records were compiled with accompanying measurements on distance to the transect and animal counts. All records are of species in the order Passeriformes. Records of 16 different families and 44 genera were collected. Some of the taxa in the dataset are included in the European Red List. This dataset belongs to the Sierra Nevada Global-Change Observatory (OBSNEV), a long-term research project designed to compile socio-ecological information on the major ecosystem types in order to identify the impacts of global change in this area.

#### **Keywords**

Passerines, Sierra Nevada (Spain), global-change monitoring, Mediterranean high mountain, species composition, abundance

# Introduction

Birds are among the most suitable groups of organisms for assessing species vulnerability to climate change (Pacifi et al. 2015). There is scientific evidence of the impact of climate change on bird communities (Crick 2004, Pearce-Higgins and Green 2014, Pearce-Higgins et al. 2015). Most studies supporting such impacts are based on longterm datasets (e.g. Gregory et al. 2009). Long-term datasets have been recognized as a key component for monitoring biodiversity (Magurran et al. 2010), and are considered one of the major requirements to identify changes in phenology (Sanz 2002). However, long-term monitoring programs are often difficult to develop. In this sense, reviewing old studies can help to integrate short-term studies into long-term datasets, providing a potential source of data to assess changes in ecological communities (Sanz 2002, Müller et al. 2010). This is relevant for the Mediterranean region, where more bird studies as well as available long-term datasets (Sanz 2002) are needed, especially considering that predicted levels in species richness have shown a sharp decrease in the southern regions of Europe (Barbet-Massin et al. 2012).

In this paper, a dataset of passerine bird communities is described from Sierra Nevada, a Mediterranean high mountain region in southern Spain. The dataset comes from Sierra Nevada Global Change Observatory (OBSNEV), a monitoring programme designed to evaluate the potential impacts of global change in this mountain area. Monitoring methodologies of the OBSNEV include revisiting old plots to assess long-term population trends, changes in phenology, and shifts in community composition, among other parameters.

Studies of bird communities in the Sierra Nevada mountain region go back to the 1850s, with the first published records of field observations recorded by ornithologists (Pleguezuelos 1991, Garzón 2012). A recent review of the birds in the Sierra Nevada was made by Garzón and Henares (2012). All these works include passerines, but specific studies focusing specifically on passerine bird communities on this mountain region were conducted during the 1980s (Zamora and Camacho 1984, Zamora 1987a, 1987b, 1988a, 1988b, 1990). The dataset presented here contributes knowledge about the passerines in this area, enabling assessments of population trends (e.g. Zamora and Barea-Azcón 2015).

Project title: Sierra Nevada Global-Change Observatory (OBSNEV)

**Personnel:** Regino Jesús Zamora Rodríguez (Scientific Coordinator, Principal Investigator, University of Granada); Francisco Javier Sánchez Gutiérrez (Director of the Sierra Nevada National Park and Natural Park).

**Funding:** Sierra Nevada Global Change Observatory is funded by the Consejería de Medio Ambiente y Ordenación del Territorio (Junta de Andalucía) through the European Union (FEDER project) and by the Spanish Government (via "Fundación Biodiversidad", which is a Public Foundation). Some activities undertaken by the OBSNEV (data analysis, quantification of ecosystem services, harmonization of monitoring methods, integration in major cyberinfrastructures, etc.) are funded by the European Commission under different projects (FP7: EU BON; H2020: eLTER, ECOPOTENTIAL; Life: ADAPTAMED).

**Study area description:** Sierra Nevada (Andalusia, SE Spain), is a mountainous region covering more than 2000 km<sup>2</sup> with an altitudinal range of between 860 m and 3482 m a.s.l. (Figure 1). The climate is Mediterranean, characterized by cold winters and hot summers, with pronounced summer drought (July-August). The annual average temperature decreases in altitude from 12–16°C below 1500 m to 0°C above 3000 m a.s.l., and the annual average precipitation is about 600 mm. Additionally, the complex orography of the mountains causes sharp climatic contrasts between the sunny, dry south-facing slopes and the shaded, wetter north-facing slopes. Annual precipitation ranges from less than 250 mm in the lowest parts of the mountain range to more than 700 mm in the summit areas. Winter precipitation is mainly in the form of snow above 2000 m a.s.l.

This mountain area harbours 27 habitat types from the Habitat Directive. Sierra Nevada protected area contains at least 78 animal species (48 breeding birds, 17 mammals, 7 invertebrates, 2 amphibians and 4 reptiles) and 13 plant species listed in the Annex II and/or in the Annex IV of Habitat Directive or Annex I or Annex II of Bird Directive. It is thus considered one of the most important biodiversity hotspots in the Mediterranean region (Blanca 1996, Blanca et al. 1998, Cañadas et al. 2014).

Sierra Nevada receives legal protection in multiple ways, including Biosphere Reserve MAB Committee UNESCO; Special Area of conservation (Natura 2000 network); Natural Park and National Park; and IBA (Important Bird Area). The area includes 61 municipalities with more than 90, 000 inhabitants. The main economic activities are agriculture, tourism, livestock raising, beekeeping, mining, and skiing (Bonet et al. 2010).

**Design description:** Sierra Nevada Global Change Observatory (OBSNEV) (Bonet et al. 2011) is a long-term research project that is being undertaken at Sierra Nevada Biosphere Reserve (SE Spain). It is intended to compile the information necessary for identifying as early as possible the impacts of global change, in order to design adequate management mechanisms to minimize these impacts and enable the system to adapt to new environmental conditions (Aspizua et al. 2010, Bonet et al. 2010). The general objectives are to:



**Figure 1. a** Location of Sierra Nevada (southern Spain) and **b** distribution of transects in the Protected Natural Area of Sierra Nevada. Transect colour according to habitat type (see Methods section). A Landsat 5 Image (2001) was used as background.

- Evaluate the functioning of ecosystems in the Sierra Nevada Nature Reserve, their natural processes and dynamics over a medium-term timescale.
- Identify population dynamics, phenological changes, and conservation issues regarding key species that could be considered indicators of ecological processes.
- Identify the impact of global change on monitored species, ecosystems, and natural resources, providing an overview of trends of change that could help foster ecosystem resilience.
- Design mechanisms to assess the effectiveness and efficiency of management activities performed in the Sierra Nevada in order to implement an adaptive management framework.
- Help to disseminate information of general interest concerning the values and importance of Sierra Nevada.

The Sierra Nevada Global Change Observatory has four cornerstones:

- A monitoring programme with 40 methodologies that collect information on ecosystem functioning (Aspizua et al. 2012, 2014).
- An information system to store and manage all the information gathered (http://obsnev.es/linaria.html Pérez-Pérez et al. 2012; Free access upon registration).
- A plan to promote adaptive management of natural resources using the data amassed through the monitoring programme.
- An outreach programme to disseminate all the available information to potential users (see News Portal of the project at http://obsnev.es and the wiki of the project at http://wiki.obsnev.es, Pérez-Luque et al. 2012)

The Sierra Nevada Global Change Observatory is linked to other national (Zamora and Bonet 2011) and international monitoring networks: GLOCHAMORE (Global Change in Mountain Regions) (Björnsen 2005), GLOCHAMOST (Global Change in Mountain Sites) (Schaaf 2009), LTER-Spain (Long-Term Ecological Research), Life-Watch (Basset and Los 2012), etc. This project is also involved in several European projects such as MS-MONINA (FP7 project. www.ms-monina.eu), EU BON (Hoffmann et al. 2014), eLTER (H2020 project. www.lter-europe.net/projects/eLTER), ECOPOTEN-TIAL (H2020 project. www.ecopotential-project.eu/) and ADAPTAMED (Life project).

# Taxonomic coverage

This dataset includes a total of 27847 records of the order Passeriformes with 16 families represented (Figure 2). Nearly one third of the specimens belong to the family Fringillidae. A total of 44 genera are represented in this collection, with *Emberiza*, *Cyanistes, Turdus, Fringilla* and *Parus* having the highest number of records (Figure 3). Of this dataset 70 species appear in the European Red List (BirdLife International 2015): 67 are categorized as Least Concern, 2 is considered Near Threatened, and 1 is considered as Vulnerable (Table 1). According to the Spanish Red List (Madroño et al. 2004), 3 species in this dataset are placed in the Near Threatened category, 1 is listed as Vulnerable and 1 as Least Concern (Table 1).

# Taxonomic ranks

Kingdom: Animalia Phylum: Chordata Subphylum: Craniata Class: Aves Order: Passeriformes Family: Aegithalidae, Alaudidae, Certhiidae, Cinclidae, Corvidae, Fringillidae, Laniidae, Motacillidae, Muscicapidae, Paridae, Passeridae, Phylloscopidae, Sittidae, Sturnidae, Sylviidae, Turdidae



**Figure 2.** Taxonomic families included in the dataset. The bars show the percentage of records belonging to each family.



Figure 3. Distribution of records in the dataset according to genus.

Scientific name	European	Spanish	Birds	Spanish Name <sup>d</sup>	English Name <sup>e</sup>
	Red List <sup>a</sup>	Red List <sup>b</sup>	Directive <sup>c</sup>		
Aegithalos caudatus (Linnaeus, 1758)	LC	NE		Mito común	Long-tailed Tit
Alauda arvensis Linnaeus, 1758	LC	NE	IIB	Alondra común	Eurasian Skylark
Anthus campestris (Linnaeus, 1758)	LC	NE	I	Bisbita campestre	Tawny Pipit
Anthus spinoletta (Linnaeus, 1758)	LC	NE		Bisbita alpino	Water Pipit
Carduelis cannabina (Linnaeus, 1758)	LC	NE	II	Pardillo común	Common Linnet
Carduelis carduelis (Linnaeus, 1758)	LC	NE		Jilguero europeo	European Goldfinch
Carduelis chloris (Linnaeus, 1758)	LC	NE		Verderón común	European Greenfinch
Carduelis spinus (Linnaeus, 1758)	LC	NE		Jilguero lúgano	Eurasian Siskin
Certhia brachydactyla CL Brehm, 1820	LC	NE	I	Agateador europeo	Short-toed Treecreeper
Cinclus cinclus (Linnaeus, 1758)	LC	NE		Mirlo acuático europeo	White-throated Dipper
Coccothraustes coccothraustes (Linnaeus, 1758)	LC	NE		Picogordo común	Hawfinch
Corvus corax Linnaeus, 1758	LC	NE		Cuervo grande	Northern Raven
Corvus monedula Linnaeus, 1758	LC	NE	IIB	Grajilla occidental	Western Jackdaw
Cyanistes caeruleus (Linnaeus, 1758)	LC	NE		Herrerillo común	Eurasian Blue Tit
Emberiza cia Linnaeus, 1766	LC	NE		Escribano montesino	Rock Bunting
Emberiza cirlus Linnaeus, 1766	LC	NE		Escribano soteño	Cirl Bunting
Emberiza hortulana (Linnaeus, 1758)	LC	NE	Ι	Escribano hortelano	Ortolan Bunting
Erithacus rubecula Linnaeus, 1758	LC	NE		Petirrojo europeo	European Robin
Fringilla coelebs Linnaeus, 1758	LC	NE	I	Pinzón vulgar	Common Chaffinch
Fringilla montifringilla Linnaeus, 1758	LC	NE		Pinzón real	Brambling
Galerida cristata Linnaeus, 1758	LC	NE		Cogujada común	Crested Lark
Galerida theklae (CL Brehm,1858)	LC	NE	Ι	Cogujada montesina	Thekla Lark
Garrulus glandarius (Linnaeus, 1758)	LC	NE	IIB	Arrendajo euroasiático	Eurasian Jay
<i>Hippolais polyglotta</i> (Vieillot, 1817)	LC	NE		Zarcero políglota	Melodious Warbler
Lanius meridionalis Temminck, 1820	VU			Alcaudón norteño	Great Grey Shrike

Table 1. Conservation status of the species included in this dataset.v

Scientific name	Furonean	Snanich	Rirde	Snanich Name <sup>d</sup>	Fnglish Name <sup>e</sup>
	Red List <sup>a</sup>	Red List <sup>b</sup>	Directive <sup>c</sup>		
Lanius senator Linnacus, 1758	LC	NT		Alcaudón común	Woodchat Shrike
Lophophanes cristatus (Linnaeus, 1758)	LC			Herrerillo capuchino	European Crested Tit
Loxia curvirostra Linnaeus, 1758	LC	NE		Piquituerto común	Red Crossbill
Lullula arborea (Linnaeus, 1758)	LC	NE	I	Alondra Totovía	Woodlark
Luscinia megarhynchos CL Brehm, 1831	LC	NE		Ruiseñor común	Common Nightingale
Miliaria calandra (Linnaeus, 1758)	LC	NE		Escribano triguero	Corn Bunting
Monticola saxatilis (Linnaeus, 1766)	LC	NE		Roquero rojo	Common Rock Thrush
Motacilla alba Linnaeus, 1758	LC	NE		Lavandera blanca	White Wagtail
Motacilla cinerea Tunstall, 1771	LC	NE		Lavandera cascadeña	Grey Wagtail
Muscicapa striata (Pallas, 1764)	LC	NE		Papamoscas gris	Spotted Flycatcher
Oenanthe hispanica (Linnaeus, 1758)	LC	NT		Collalba rubia	Black-eared Wheatear
<i>Oenanthe oenanthe</i> (Linnaeus, 1758)	LC	NE		Collalba gris	Northern Wheatear
Oriolus oriolus (Linnaeus, 1758)	LC	NE		Oropéndola europea	Eurasian Golden Oriole
Parus major Linnaeus, 1758	LC	NE		Carbonero común	Great Tit
Passer domesticus (Linnaeus, 1758)	LC	NE		Gorrión común	House Sparrow
Periparus ater (Linnacus, 1758)	LC	NE	I	Carbonero garrapinos	Coal Tit
Petronia petronia (Linnaeus, 1766)	LC	NE		Gorrión chillón	Rock Sparrow
Phoenicurus ochruros (SG Gmelin, 1774)	LC	NE		Colirrojo tizón	Black Redstart
Phoenicurus phoenicurus (Linnaeus, 1758)	LC	VU		Colirrojo real	Common Redstart
Phylloscopus bonelli (Vieillot, 1819)	LC	NE		Mosquitero papialbo	Western Bonelli's Warbler
Phylloscopus collybita (Vieillot, 1817)	LC	NE		Mosquitero común	Common Chiffchaff
Pica pica (Linnaeus, 1758)	LC	NE	IIB	Urraca común	Eurasian Magpie
Prunella collaris (Scopoli, 1769)	LC	NE		Acentor alpino	Alpine Accentor
Prunella modularis (Linnaeus, 1758)	LC	NE		Acentor común	Dunnock
Pyrrhocorax pyrrhocorax (Linnaeus, 1758)	LC	NT	I	Chova piquirroja	Red-billed Chough
Regulus ignicapillus (Temminck, 1820)	LC	NE		Reyezuelo listado	Common Firecrest
	F	-	-	;	
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Scientific name	European Red List <sup>a</sup>	Spanish Red List <sup>b</sup>	Birds Directive <sup>c</sup>	Spanish Name "	English Name
Saxicola rubetra (Linnaeus, 1758)	LC	NE		Tarabilla norteña	Whinchat
Saxicola rubicola (Linnaeus, 1766)	LC	NE		Tarabilla común	African Stonechat
Serinus citrinella (Pallas, 1764)	LC	NE		Verderón serrano	Citril Finch
Serinus serinus (Linnaeus, 1766)	LC	NE		Serín Verdecillo	European Serin
Sitta europaea Linnaeus, 1758	LC	NE		Trepador azul	Eurasian Nuthatch
Sturnus unicolor Temminck, 1820	LC	NE		Estornino negro	Spotless Starling
Sylvia atricapilla (Linnaeus, 1758)	LC	NE		Curruca capirotada	Eurasian Blackcap
Sylvia cantillans (Pallas, 1764)	LC	NE		Curruca carrasqueña	Subalpine Warbler
Sylvia communis Latham, 1787	LC	NE		Curruca zarcera	Common Whitethroat
Sylvia conspicillata Temminck, 1820	LC	LC		Curruca tomillera	Spectacled Warbler
Sylvia melanocephala (Gmelin, 1789)	LC	NE		Curruca cabecinegra	Sardinian Warbler
Sylvia undata (Boddaert, 1783)	NT	NE	I	Curruca rabilarga	Dartford Warbler
Troglodytes troglodytes (Linnaeus, 1758)	LC	NE	I	Chochín común	Eurasian Wren
Turdus iliacus Linnaeus, 1758	NT	NE	IIB	Zorzal alirrojo	Redwing
Turdus merula Linnaeus, 1758	LC	NE	IIB	Mirlo común	Common Blackbird
Turdus philomelos CL Brehm, 1831	LC	NE	IIB	Zorzal común	Song Thrush
Turdus pilaris Linnaeus, 1758	LC	NE	IIB	Zorzal real	Fieldfare
Turdus torquatus Linnaeus, 1758	LC	NE		Mirlo capiblanco	Ring Ouzel
Turdus viscivorus Linnaeus, 1758	LC	NE	IIB	Zorzal charlo	Mistle Thrush

<sup>a</sup> European Red List of Birds (BirdLife International 2015).

<sup>c</sup> Species included in the Birds Directive Annexes (EC 1979) <sup>b</sup> Red Book of the birds of Spain (Madroño et al. 2004).

<sup>d</sup> Spanish common names (Gutiérrez et al. 2012, De Juana et al. 2004, 2005, 2007, 2009a, 2009b, 2010a, 2010b).

<sup>e</sup> English common names (Gill and Donsker 2015).

LC: Least Concern; NE: Not Evaluated; NT: Near Threatened; VU: Vulnerable.

Genus: Aegithalos, Alauda, Anthus, Carduelis, Certhia, Cinclus, Coccothraustes, Corvus, Cyanistes, Emberiza, Erithacus, Fringilla, Galerida, Garrulus, Hippolais, Lanius, Lophophanes, Loxia, Lullula, Luscinia, Miliaria, Monticola, Motacilla, Muscicapa, Oenanthe, Oriolus, Parus, Passer, Periparus, Petronia, Phoenicurus, Phylloscopus, Pica, Prunella, Pyrrhocorax, Regulus, Saxicola, Serinus, Sitta, Spinus, Sturnus, Sylvia, Troglodytes, Turdus

#### Spatial coverage

**Bounding box for covered area:** 36°52'12"N and 37°15'36"N Latitude; 3°41'24"W and 2°33'36"W Longitude

**Temporal coverage:** Observations in the collection included in this data paper date from March 2008 to April 2015 (Figure 4).

**Collection name:** Dataset of Passerine bird communities in a Mediterranean high mountain (Sierra Nevada, Spain)

Collection identifier: http://www.gbif.es/ipt/resourcve?r=passerine

# Methods

**Study extent description:** This dataset covers four representative habitats within the Sierra Nevada mountain range: Pyrenean oak forest, thorny thickets on the edge of the forest, common juniper and Spanish juniper scrublands, and high-summit ecosystems. These ecosystems were selected based on criteria of singularity and ecological functionality in the context of Sierra Nevada (Barea-Azcón et al. 2012, 2014) and can be described as follows:

- Pyrenean oak forest: Mediterranean woodland composed mainly of relict *Quercus pyrenaica* and some dominant scrubland species (i.e. *Berberis hispanica, Prunus ramburii, Rosa canina, Crataegus monogyna and Adenocarpus decorticans*). These forests show strong evidence of past management that has determined their current structure and diversity. This management is based on mainly charcoal production, pastureland creation, and wood harvesting until the 1950s, so that the current trees are mostly resprouts of individuals 60 to 70 years old. The target localities (*n*=4) are located at an average elevation of 1650 m a.s.l. (1600-1750 m a.s.l.) and are distributed in the southern, western, northern, and eastern slopes of Sierra Nevada, reflecting all the ecological conditions of the Pyrenean oak forests in the study area (Pérez-Luque et al. 2013).
- Thorny scrubs: Typical areas dominated by thorny thickets on the edge of the forest or as result of recent colonization of abandoned arable lands. *Berberis hispanica*, *Prunus ramburii*, *Rosa canina*, *Crataegus monogyna* are dominant but accompanied by other species such as *Lonicera arborea* or even *Sorbus* spp. This open habitat is very important for breeding birds in the study area and



**Figure 4.** Temporal coverage of the dataset. For each taxon (y-axis) the temporal coverage is shown including a point. Point size is proportional to monthly records of each taxon.

also for winter-visiting species due to a great production of fruits from the end of the summer to the beginning of winter. Transects (n=4) in this habitat are located between 1450 and 2060 m a.s.l. (average: 1790 m a.s.l.).

• Common juniper and Spanish juniper scrublands: vegetation in these localities is composed mainly of common juniper (*Juniperus communis*), Spanish juniper (*Juniperus sabina*). Cytisus galianoi and Genista baetica are also important species in these ecosystems. These scrublands rarely exceed 60 cm in height and appear intermingled with rocks and stony ground. Transects (n=4) located in this ecosystems cover an elevational range from 2000 to 2300 m a.s.l. (average: 2150 m a.s.l.).

• High-summit ecosystems: composed by typical Alpine landscape. These ecosystems are characterized by rocky outcrops that originated from glacial activity, pastureland, small snow beds, and glacial lagoons. The four transects representing this Mediterranean high-mountain habitat span an elevational gradient from 2280 to 3100 m a.s.l., with an average elevation of 2580 m a.s.l.

**Sampling description:** The sampling procedure was the line-transect method (Verner 1985), with a bandwidth of 100 m, with 50 m on each side of the line (Barea-Azcón et al. 2014). Each 50 m band was divided into five ranges parallel to the line transect (comprising a 10 m width each one). A total of 16 transects were sampled with lengths of 1.9 to 3 km (Table 2). Sight and sound records within the sample area were considered contacts. All transects were sampled in the early morning, under appropriate climatic conditions. The observer walked at a constant speed of 2 to 4 km/h. Transects are repeated at least once per month, snow cover permitting. This implies that the sites located at the higher elevations were sampled only from late spring to early autumn.

**Method step description:** All data were stored in a normalized database (PostgreSQL) and incorporated into the Information System of Sierra Nevada Global-Change Observatory. Taxonomic and spatial validations were made on this database (see *Quality-control description*). A custom-made SQL view of the database was performed to gather occurrence data and other variables associated with occurrence data, specifically:

- Bird Count: number of individuals recorded by the observer within transect (see Sampling description)
- Distance: distance of the contact (bird) from transect line. The distance was estimated by eye.

The occurrence and measurement data were accommodated to fulfil the Darwin Core Standard (Wieczorek et al. 2009, 2012). We used Darwin Core Archive Validator tool (http://tools.gbif.org/dwca-validator/) to check whether the dataset met Darwin Core specifications. The Integrated Publishing Toolkit (IPT v2.0.5) (Robertson et al. 2014) of the Spanish node of the Global Biodiversity Information Facility (GBIF) (http://www.gbif.es/ipt) was used both to upload the Darwin Core Archive and to fill out the metadata.

The Darwin Core elements for the occurrence data included in the dataset were: occurrenceId, modified, language, basisOfRecord, institutionCode, collectionCode, catalogNumber, scientificName, kingdom, phylum, class, order, family, genus, specificEpithet, scientificNameAuthorship, continent, country, countryCode, stateProvince, county, locality, minimumElevationInMeters, maximumElevationInMeters, decimal-Longitude, decimalLatitude, coordinateUncertaintyinMeters, geodeticDatum, recordedBy, day, month, year, EventDate.

For the measurement data, the Darwin Core elements included were: occurrenceId, measurementID, measurementType, measurementValue, measurementAccuracy,

Transect name	Length (m)	Habitat type	Longitude	Latitude	Province	Municipality	Elevation (m asl)
Robledal de Cáñar	2556		-3.4292	36.9532	Granada	Cáñar	1736
Robledal de Dílar	2553	Pyrenean	-3.4779	37.0582	Granada	Dílar	1605
Cortijo del Hornillo	3044	oak Forest	-3.3680	37.1246	Granada	Güejar Sierra	1585
Dehesa del Camarate	2805	-	-3.2537	37.1797	Granada	Lugros	1575
Dehesa del Río Dúrcal	3292		-3.4825	37.0255	Granada	Dúrcal	2033
Collado de Matas Verdes	2237	Thorny	-3.4470	37.0909	Granada	Monachil	1918
El Purche	1944	thickets	-3.4780	37.1311	Granada	Monachil	1453
Lanteira	2515		-3.1725	37.1409	Granada	Lanteira	1794
Collado del Sabinar	2745		-3.4184	37.1199	Granada	Güejar Sierra	2036
Campos de Otero	2264	Juniper	-3.3930	37.1100	Granada	Güejar Sierra	2143
Loma Papeles	2539	scrublands	-3.3401	37.1434	Granada	Güejar Sierra	2113
Dehesa de las Hoyas	2436	-	-3.3173	37.1724	Granada	Güejar Sierra	2074
Laguna Seca	2530	High-	-2.9615	37.0992	Granada	Huéneja	2295
Aguas Verdes	2431		-3.3589	37.0540	Granada	Capileira	3149
Hoya Mora	2046	summit	-3.3771	37.0896	Granada	Güejar Sierra	2407
Papeles alto	2309	ecosystems	-3.3098	37.1357	Granada	Güejar Sierra	2420

Table 2. Information about transects sampled to collect data included in this dataset.

measurementUnit, measurementDeterminedDate, measurementDeterminedBy, measurementMethod.

**Quality control description:** The sampling transects were georeferenced using a hand held GPS device (WGS 84 Datum) with an accuracy of ±5 m. We also used colour digital orthophotographs provided by the Andalusian Cartography Institute and GIS (ArcGIS 9.2; ESRI, Redlands, California, USA) to verify that the geographical coordinates of the transects were correct (Chapman and Wieczorek 2006).

For field identification, several field guides were used (De Juana and Varela 2000, Jonsson 2001). The scientific names were checked with database of the IOC World Bird List (v 5.52) (Gill and Donsker 2015). We also used the R package taxize (Chamberlain and Szocs 2013, Chamberlain et al. 2014) to verify the taxonomical classification.

In addition, we performed validation procedures (Chapman 2005a, 2005b) (geopraphic coordinate format, coordinates within country/provincial boundaries, absence of ASCII anomalous characters in the dataset) with DARWIN\_TEST (v3.2) software (Ortega-Maqueda and Pando 2008).

# **Dataset description**

Object name: Darwin Core Archive Dataset of Passerine bird communities in a Mediterranean high mountain (Sierra Nevada, Spain) Character encoding: UTF-8 Format name: Darwin Core Archive format Format version: 1.0 Distribution: http://www.gbif.es/ipt/resource?r=passerine Publication date of data: 2015-10-08 Language: English Licenses of use: This "Dataset of Passerine bird communities in a Mediterranean high mountain (Sierra Nevada, Spain)" is licensed under and made available under the Creative Commons Attribution Non Commercial (CC-BY-NC) 4.0 License http://creativecommons.org/licenses/by-nc/4.0/legalcode Metadata language: English Date of metadata creation: 2015-10-08 Hierarchy level: Dataset

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