RESEARCH ARTICLE



A butterfly with olive green eyes discovered in the United States and the Neotropics (Lepidoptera, Lycaenidae, Eumaeini)

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Abstract

We describe *Ministrymon janevicroy* Glassberg, **sp. n.**, from the United States (Texas). Its wing pattern closely resembles that of the widespread and well-known lycaenid, *Ministrymon azia* (Hewitson). The new species is distinguished by the structure of its male and female genitalia, by the patterning of the ground color on the basal half of the ventral hindwing surface, and by the color of its eyes. Adults of *Ministrymon janevicroy* in nature have olive green eyes in contrast to the dark brown/black eyes of *M. azia. Ministrymon janevicroy* occurs in dry deciduous forest and scrub from the United States (Texas) to Costa Rica (Guanacaste) with disjunct populations on Curaçao and Isla Margarita (Venezuela). In contrast, *M. azia* occurs from the United States to southern Brazil and Chile in both dry and wet lowland habitats. Nomenclaturally, we remove the name *Electrostrymon grumus* K. Johnson & Kroenlein, 1993, from the synonymy of *M. azia* (where it had been listed as a synonym of *Ministrymon hernandezi* Schwartz & K. Johnson, 1992). We accord priority to *Angulopis hernandezi* K. Johnson & Kroenlein, 1993, over *Electrostrymon grumus* K. Johnson & Kroenlein, 1993, syn. n., which currently is placed in *Ziegleria* K. Johnson, 1993. The English name Vicroy's Ministreak is proposed for *M. janevicroy*. We update biological records of dispersal and caterpillar food plants, previously attributed to *M. azia*, in light of the new taxonomy.

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Keywords

Butterfly Eye Color, Curaçao, Isla Margarita, Ministrymon azia, Ministrymon janevicroy, Vicroy's Ministreak

Introduction

Ministrymon azia (Hewitson) (Fig. 1) is widely cited in faunal lists and occurs from the southern United States to southern Brazil, Paraguay, and Argentina in virtually all lowland habitats, ranging from desert in coastal Peru and Chile to rainforest in the Amazon Basin (Godman and Salvin 1887-1901, Draudt 1919-1920, Kaye 1921, Talbot 1928, Holland 1931, Stallings and Turner 1946, Hayward 1958, Brown and Mielke 1967, Ebert 1970, Lamas 1977, Robbins et al. 1996, 2012a, Gareca et al. 2009, Duarte et al. 2010). Adults of *M. azia* appear to be highly dispersive, having been recorded migrating through Portachuelo Pass in northern Venezuela and being dispersed by dry season trade winds in Panama (Beebe 1951, Robbins and Small 1981). Caterpillars of M. azia eat the flowers of a wide variety of Fabaceae and are discussed in the biological control and agriculture literature (e.g., Cock 1985, Harley et al. 1995, Fernández and Rodríguez 1997, Vargas and Parra 2009). The ventral wing pattern of *M. azia* west of the Andes is slightly different from that in other parts of its range, but genitalic variation is negligible (Johnson and Miller 1991). The nomenclature and taxonomy of M. azia are stable (Robbins and Lamas 2002, ICZN 2006). This species lacks a common name in the agricultural literature (Bosik 1997) but has been called Gray Ministreak in recent works dealing with North American butterflies (Cassie et al. 1995, Wauer 2004, Allen et al. 2005, Cech and Tudor 2005).

The generic placement of *M. azia* is a bit of an historical puzzle. Clench (1961: 196) described *Ministrymon* based on the presence of "two small erect ventral teeth near the tip" of the penis, but placed *azia* in *Tmolus* Hübner, a genus that lacks these teeth (as noted by Clench 1961). *Ministrymon azia* has four small erect teeth (Figs 5–6, first illustrated by Johnson and Miller 1991). It is puzzling that Clench did not observe the teeth because they are reasonably conspicuous. Robbins (2004a) listed 22 species in *Ministrymon* primarily based upon the presence of teeth on the ventral side of the penis near the tip. These teeth are otherwise unreported in the Eumaeini.

We recently discovered that the traditional species concept of *M. azia* includes a cryptic species that occurs sympatrically and synchronically with *M. azia* from the United States (Texas) south into the Neotropics. The cryptic species was discovered in Texas and Mexico (Glassberg 2005, 2012) because its adults have olive green eyes instead of the dark brown/black eyes of *M. azia* (Fig. 1). So far as we are aware, this is the first time that an undescribed butterfly species has been recognized on the basis of eye color, a point that is amplified in the discussion. We subsequently found that the genitalia and ventral wing patterns of these species differ substantially and consistently. It is the purpose of this paper to give the undescribed species a scientific name, to present data that support the hypothesis that it is biologically distinct, and to update information on the biology of these species using the new taxonomy.

Materials and methods

Standard methods were used to dissect genitalia and to prepare them for examination with an SEM (Robbins 1991). Genitalic terminology follows that in Clench (1961) and Klots (1970), as modified for the Eumaeini (Robbins 1991). Forewing length was measured with a digital vernier caliper. Wing vein names follow Comstock (1918), and terminology for male secondary sexual characters follows Robbins (1991) and Robbins et al. (2012b). Museum specimens of *M. janevicroy* studied are deposited (unless otherwise noted) in the USNM (see below for repository acronyms). Thirty images of *M. janevicroy* in nature from Texas, Mexico, and Venezuela were assembled (most taken without a flash). For this study, specimens and images of *M. janevicroy* were compared with a study series of 550+ specimens of *M. azia* from 20 countries deposited in the USNM and with 44 images of individuals of *M. azia* in nature.

We list genitalic dissections in Supplementary file 1 *Ministrymon* Genitalia Examined, images in nature in Supplementary file 2 Images of Live Butterflies, and data on forewing length and frequency of eye-color in Supplementary file 3 *M. janevicroy* Datasets.

Museum specimens cited in this study are deposited in the following collections – museum acronyms from Evenhuis (1993).

AMNH	American Museum of Natural History, New York, USA
BMNH	The Natural History Museum [formerly British Museum (Natural History)],
	London, United Kingdom
DZUP	Museu de Entomología Pe. Jesus Santiago Moure, Universidade Federal do
	Paraná, Curitiba, Paraná, Brazil
FSMC	Florida Museum of Natural History (Allyn Museum/McGuire Center),
	University of Florida, Gainesville, Florida, USA
MC	Personal collection of Alfred Moser, Sao Leopoldo, RS, Brazil
TAMU	Texas A & M University, College Station, USA
UCRC	Entomology Research Museum, University of California, Riverside, Cali-
	fornia, USA
USNM	National Museum of Natural History, Smithsonian Institution, Washington,
	DC, USA

Taxonomy

Ministrymon janevicroy Glassberg, sp. n. urn:lsid:zoobank.org:act:10ED3009-21F8-4B7C-B9B4-A93A5D867972 http://species-id.net/wiki/Ministrymon_janevicroy Figs 1–4, 6–9

Type material. Holotype: (Fig 3). [hand written in black India Ink on white paper] July 12, 1969/Santa Ana Ref.[uge]/Hidalgo Co[unty]/Texas/J.B. Sullivan. [printed



Figure 1. Olive green eyes of *Ministrymon janevicroy* (left, Orizaba, Veracruz, Mexico) and the dark brown/black eyes of *M. azia* (Chavarrillo, Veracruz, Mexico).

red label] Holotype/*Ministrymon janevicroy*/Glassberg. [printed green label] Genitalia No./2013: 10/R. K. Robbins. Deposited USNM. **Paratypes** (9/, 4). Uvalde County. 1/, Concan[,] Tex[as]/7[July]-6-[19]36/W.D. Field. Hidalgo County. 8/, same data as holotype. 1/, June 12, 1976/Sullivan City/Hidalgo Co./Texas/J.B. Sullivan. 1/ (Fig. 3), Pharr, Texas/20 April 1948/H.A. Freeman (via Nicolay collection). Kerr County. 2/, Kerrville/Jun[e] 1917/Texas (via Barnes Collection). Paratypes have a blue printed paratype label and are deposited USNM. Five paratypes have been dissected and labeled as such (cf. supplementary file).

Other specimens examined (excluded from the type series). Mexico: 3333, 399. El Salvador: 19. Nicaragua: 433, 699. Costa Rica: 433, 19. Curaçao 233, 599 (FSMC). Venezuela: 29.

Images in nature examined (excluded from the type series, specifics listed in a supplementary file). United States (Texas): 19, Mexico 10, Venezuela 1.

Etymology. This species is named for my wife, Jane Vicroy Scott, whose love and patient forbearance have sustained me, and made me a more effective advocate for butterflies. Her tireless work in support of the North American Butterfly Association, especially with the National Butterfly Center in the Rio Grande Valley (less than 40km from the type locality of *M. janevicroy*), has helped make the world a little bit more friendly for butterflies and thus for people. The name is a non-latinized noun in apposition. I have proposed the English name Vicroy's Ministreak for this species (Glassberg 2012).

Diagnosis and description. *Ministrymon janevicroy* is placed in *Ministrymon* because there are small erect teeth on the ventral surface of the penis near the distal end (Fig. 6). Clench (1961) originally noted this generic distinguishing trait, albeit limited



Figure 2. *M. janevicroy* (left, close-up on bottom) with variegated "pebbly-textured" ground color and *M. azia* (right) with "smooth-textured" gray appearance. Both specimens from Managua, Nicaragua.

to two teeth. In museum collections, specimens of *M. janevicroy* are routinely curated with *M. azia* because of the similarity in ventral wing patterns (Fig. 1). For this reason, we differentiate *M. janevicroy* from *M. azia*. However, *Ministrymon* has not been revised, so it would be premature to suggest that these species are phylogenetic sisters, even if it is likely.

Adults of *M. janevicroy* are differentiated from those of *M. azia* by (1) the male and female genitalia, (2) the ventral wing pattern, and (3) the color of the eyes.

The male genitalia of *M. janevicroy* (7 dissections, listed in supplementary information) differ consistently from those of *M. azia* (11 dissections), primarily by structures of the posterior penis (Fig. 6). The four—as illustrated—or five small erect teeth on the ventral surface of the penis tip of *M. janevicroy* are clustered anterior of the posterior penis tip while in *M. azia* two teeth are located near the posterior penis edge, well posterior of two other teeth. Inside the penis shaft, there is a single slender cornutus in



Figure 3. Male holotype (top) and female paratype of *M. janevicroy*. Eye color in the male appears to have darkened more post mortem than that of the female.

M. janevicroy while the vesica on either side of the cornutus in *M. azia* is sclerotized. Depending upon the amount of sclerotization and the extent to which the vesica is everted, these sclerotizations may appear as a double prong (as in Fig. 6) or as a pair of lateral sclerotized triangular teeth. The shorter and squatter valvae in ventral aspect and the shallower and wider notch between the labides in dorsal aspect of *M. janevicroy* (illustrated in Fig. 6) represent individual variation and do not distinguish the species. The illustrated longer saccus of *M. janevicroy* (Fig. 6) may differentiate the species statistically, but this length in the study series was overlapping.

The female genitalia of M. *janevicroy* (6 dissections) differ substantially and consistently from those of M. *azia* (5 dissections). The female genitalia of M. *janevicroy* are distinguished from those of M. *azia* by a membranous "neck" just posterior of the cervix (arrow on the left of Fig. 7) and the lack of a well-formed posterior pouch from which the ductus seminalis arises (arrow on the right of Fig. 7). These differences are conspicuous and immediately distinguish the species. The illustrated ductus bursae



Figure 4. Distribution of *M. janevicroy* (hearts) based on museum specimens.

of *M. janevicroy* is longer than that of *M. azia* (Fig. 7), but this difference represents individual variation.

Glassberg (2012) distinguished the variegated "pebbly-textured" appearance on the basal half of the ventral hindwing surfaces of *M. janevicroy* from the more "smoothtextured" appearance in *M. azia* (Fig. 2). In the study series, the variegated "pebblytextured" appearance on the hindwing (but not always the forewing) correlates without exception with genitalic structures for the 29 dissected specimens of *M. janevicroy* and *M. azia*. The wing scales that are responsible for the variegated "pebbly-textured" appearance in *M. janevicroy* are gray basally and whitish at their tips and do not lie flat against the wing. In contrast, the wing scales that are responsible for the gray "smooth -textured" appearance in *M. azia* are almost uniformly gray and lie flat against the wings. The scales in *M. janevicroy* are also wider than those of *M. azia*, and have a jagged terminal edge, but it is unclear how these shape differences affect wing appearance.

Adults of *M. janevicroy* have olive green eyes in nature while those of *M. azia* have dark brown/black eyes (Fig. 1). The 30 images of adults in nature with a varie-gated "pebbly-textured" basal hindwing have olive green eyes, and the 44 images of those with a smooth-textured gray basal hindwing have dark brown/black eyes. In the museum study series, all *M. azia* adults had dark brown/black eyes while 9.5% of *M. janevicroy* adults had eyes as dark as those of *M. azia* (data in a supplementary file).



Figure 5. SEM of *M. azia* penis tip showing small erect teeth in lateral (top) and ventral aspect.

The remaining adults of *M. janevicroy* had lighter eyes, ranging from yellow-brown to brown (this variation is shown in Fig. 3). It would appear that eye color darkens a variable amount post mortem in *M. janevicroy*. A survey of eye color in other *Ministrymon* species is presented in the discussion.

The wing venation of male and female *M. janevicroy* is illustrated (Fig. 8). In *M. janevicroy* forewing vein M_2 arises closer to M_1 than to M_3 in both sexes, but is otherwise typical of the Eumaeini (Eliot 1973). Males of *M. janevicroy* have a scent patch at the distal end of the forewing discal cell in which the tan androconia are partially or wholly (in some individuals) covered by dark brown wing scales (Fig. 9). This scent patch structure is the same as that in *M. azia*. There is no evident sexual dimorphism in size (\Im mean forewing length = 9.1 mm, s=0.62, N=10, \Im mean forewing length = 9.1 mm, s=0.33, N=4, data in supplementary file).

Distribution, habitat, and phenology. *Ministrymon janevicroy* occurs from southern Texas (there is also an image of an individual of this species from Big Bend National Park in western Texas, cf. supplementary information) to Guanacaste Province, Costa Rica and in South America on the islands of Curaçao and Margarita (Ven-



Figure 6. Male genitalia of *Ministrymon janevicroy* (top) and *M. azia*, posterior of butterfly at right, both from Yucatan, Mexico. Ventral aspect with penis removed (top left), lateral aspect with penis removed (left middle), lateral aspect of penis (bottom), penis tip in ventral aspect (right middle), and dorsal aspect of tegumen (top right). Scale 1 mm.



Figure 7. Bursa copulatrix of the female genitalia of *Ministrymon janevicroy* (left, Venezuela) and *M. azia* (Mexico) in dorso-lateral aspect, posterior of butterfly at top. Arrow on left points to the membranous "neck" of the anterior ductus bursae. Arrow on right points to the well-formed posterior pouch from which the ductus seminalis arises. Scale 1 mm.

ezuela) (Fig. 4). It is a relatively common species in Central America, where it is as well represented in museum collections as *M. azia. Ministrymon janevicroy* appears to be absent from the Antilles (including Florida and the Lesser Antilles) and from South America, except for Curaçao and Venezuela's Isla Margarita. It may also occur on Aruba, where *M. azia* was recorded (Miller et al. 2003), but we have not seen specimens. *Ministrymon janevicroy* inhabits dry deciduous forest and scrub. It and *M. azia* occur at the same localities. For example, both have been collected at the type locality for *M. janevicroy* (Santa Ana Wildlife Refuge) in Hidalgo County, and both were photographed on the same day at the same locality (Rio Blanco Canyon) near Orizaba, Veracruz, Mexico. In Texas, adults of *M. janevicroy* have been found from January to August. Elsewhere, there is no evidence for seasonality.



Figure 8. Male (left, Yucatan, Mexico) and female (Santa Tecla, El Salvador) venation of *M. janevicroy*.



Figure 9. Male dorsal forewing scent patch showing dark brown wing scales covering tan-colored androconia.

Discussion

Generic Placement and Identification. *Ministrymon janevicroy* is placed in *Ministrymon* because it possesses small erect teeth on the ventral surface of the penis near the distal end (Fig. 6). This synapomorphy for *Ministrymon* was proposed by Clench (1961) and has not been reported in other eumaeine genera. Other characters accord with this placement (Robbins unpubl.). Forewing vein M_2 arises closer to M_1 than to M_3 in the male (Fig. 8) and the corpus bursae of the female genitalia is posteriorly constricted (Fig. 7). These traits are widespread (but not universal) in the *Tmolus* Section of Eumaeini, to which *Ministrymon* belongs (Robbins 2004a). A male dorsal scent patch is situated at the distal end of forewing discal cell and is partially covered by dark brown wing scales (Fig. 9). Within the *Tmolus* Section, this type of scent patch occurs in all *Ministrymon*, all *Tmolus*, and some *Nicolaea* K. Johnson.

The hypothesis that *M. janevicroy* is reproductively isolated from the sympatric *M. azia* is well-supported. The male and female genitalic differences between the two are distinct and distinguishing (Figs 6–7). The variegated "pebbly-textured" ground color appearance of the basal part of the ventral hindwing (Fig. 2) is also distinguishing. The eye color difference is distinct and distinguishing in live individuals (Fig. 1) and in the majority of museum specimens. *Ministrymon janevicroy* is unrecorded from tropical wet lowland forest (>200 cm annual precipitation, Holdridge 1967) while *M. azia* occurs in both wet and dry habitats. *Ministrymon janevicroy* occurs from Texas to Costa Rica and on Curaçao and Isla Margarita. In contrast, *M. azia* occurs commonly in wet and dry habitats from Texas and Florida to southern Brazil and Argentina. In sum, the two species differ morphologically and biologically in many respects, supporting a hypothesis of reproductive isolation between *M. janevicroy* and *M. azia*.

The substantive differences in the genitalic structures of *M. azia* and *M. janevicroy* (Figs 6–7) could be interpreted to mean that these two taxa are not closely related within *Ministrymon*. However, these species are sympatric in the same habitats, have very similar wing patterns, and the same androconial structures. If reproductive isolation between these species evolved by sexual selection acting on the genitalia (e.g., Eberhard 1985, Arnqvist 1998, Hosken and Stockley 2004), then the genitalic differences observed could be a consequence of this evolutionary process, and is not an indication of a lack of relationship.

In the diagnosis and previous paragraphs, we distinguished *M. janevicroy* from *M. azia* because both share a similar ventral wing pattern. If *M. janevicroy* were more closely related to another described *Ministrymon* species, its ventral wing pattern would distinguish it immediately from that species.

Eye Color. The "hairiness" of adult eyes has been widely used in lycaenid taxonomy for more than a century (cf. Eliot 1973 and included references), but adult eyecolor has not been used traditionally (e.g., Godman and Salvin 1887-1901, Scudder 1889, Draudt 1919-1920, Eliot 1973). More recently, Glassberg (2001, 2005) used eye color in live individuals to differentiate the lycaenid *Cyanophrys goodsoni* (Clench) from other *Cyanophrys* species and to distinguish between the lycaenids *Strymon ba*- *zochii* (Godart) and *Strymon cestri* (Reakirt). *Ministrymon janevicroy* was originally discovered in Texas and Mexico (Glassberg 2005) because its adults have olive green eyes in nature instead of the dark brown/black eyes of *M. azia*. Eye color in *M. janevicroy* appears to darken after death, but most museum specimens of *M. janevicroy* have lighter eyes than those of *M. azia*.

To provide context for the eye color difference between *M. azia* and *M. janevicroy*, we surveyed other *Ministrymon* species by recording eye color in museum specimens and in images of live adults. *Ministrymon zilda* (Hewitson) has a deep black eye color (an apparent autapomorphy), both in museum specimens and in live individuals. *Ministrymon cleon* (Fabricius) (cf. Duarte and Robbins 2010 for a note on identification of this name) has the same dark brown/black eyes as *M. azia* in museum specimens and in one image of a live adult. Museum specimens of all other described *Ministrymon* species are variable with most having lighter-colored eyes than those of *M. azia*—similar in color to those of *M. janevicroy*—and with a minority of individuals in each species having the dark brown/black-colored eyes of *M. azia*. Of these, we have examined images of live adults for nine species, all of which have olive green eyes.

This survey of *Ministrymon* adult eye colors leads to three conclusions. First, although similarity in wing pattern suggests that *M. azia* is the phylogenetic sister of *M. janevicroy*, adult eye color suggests that *M. azia* might be the phylogenetic sister of *M. cleon*. Clearly, a phylogenetic analysis of the genus is needed. Second, adult eye color is a useful taxonomic character in the field, but its use in the museum is more limited. In this case, all museum specimens in the "*M. azia*" complex with yellow-brown to brown eyes are *M. janevicroy*, but the converse is untrue. Third, the biological significance of adult eye color is yet unknown. There is no evident correlation with gender, habitat, or other biological traits.

Variation. While there was no discernible geographic variation in the morphology of *M. janevicroy*, three morphological aspects vary in single populations. First, when Hewitson (1873) described *M. azia*, he noted that the discal spot (= scent patch) was "indistinctly marked" in one male and was more conspicuous in another male. The same variation occurs in *M. janevicroy*. It is caused by variation in the color of the dark brown scales covering the scent patch (Fig. 9), not by variation in the presence of androconia. Second, there may be four or five small erect teeth on the penis, and in one dissection, there was an indication of yet another tooth. Third, as previously noted, eye color varies in museum specimens depending upon postmortem darkening, but this variation is not reflected in live individuals, so far as we are aware.

Biogeography. A number of Central American eumaeine species occur in deciduous dry forest from the southern United States (Texas) or Mexico to Costa Rica (Guanacaste), but are unrecorded further south and east in Panama and northern Colombia. This species list includes *Arawacus sito* (Boisduval), *Cyanophrys goodsoni* (Clench), *Cyanophrys miserabilis* (Clench), *Michaelus hecate* (Godman & Salvin), *Ministrymon clytie* (W.H. Edwards), *Rekoa zebina* (Hewitson), *Strymon alea* (Godman & Salvin), *Strymon bebrycia* (Hewitson), and *Ziegleria hoffmani* (K. Johnson). *Ministrymon janevicroy* is now added to this list. Of these, only *S. alea* (Isla Margarita) and *M. janevicroy* are also recorded on islands just off the north coast of South America, but not from the dry continental forests of northern Venezuela and northern Colombia. It is possible that remnant populations of species that were once more widespread persist only on these islands, but alternately, the mainland Guajira peninsula of Colombia/Venezuela is yet poorly documented.

There is one female in the *M. azia* species group in the USNM from the Brazilian state of Minas Gerais that has the olive green eye color and variegated "pebblytextured" wing pattern of *M. janevicroy*, but a different postmedian line on the ventral surface of the hindwing. Additionally, two males of the same species in MC are genitalically distinct from *M. janevicroy* (genitalic images sent to us by A. Moser). This species is a potential phylogenetic sister species of *M. janevicroy*. We are collaborating with Moser to find more specimens with the intention of describing it.

Nomenclature. Seven names have been applied to the species now called *M. azia* (Robbins 2004a), and it is the purpose of this section to explain why these names do not apply to *M. janevicroy*. The name *Thecla guacanagari* Wallengren, 1860 (Ecuador), which has a ventral wing pattern that appears to be transitional between that of Thecla azia and Thecla brocela, was suppressed by ICZN Opinion 2144 (ICZN 2006). We examined the lectotype of Thecla azia Hewitson, 1873 (Mexico) in the BMNH and received images of its male genitalia (courtesy R.I. Vane-Wright and B. Huertas). It is the basis for our identification of this name. We examined the holotype of Thecla nipona Hewitson, 1877 (Brazil). It has the smooth-textured gray appearance on the basal half of the ventral wing surface. Also, *M. janevicroy* does not occur in Brazil. We examined the holotype of Thecla brocela Dyar, 1913 (USNM). Its ventral wing pattern is typical of those populations of *M. azia* that occur west of the Andes from southern Ecuador to Chile. The genitalia, gray smooth-textured appearance on the basal half of the ventral wing surface, and uniform dark brown/black eyes are the same as those of M. azia from elsewhere. We examined an image of the holotype of Ministrymon quebradivaga K. Johnson & L.D. Miller, 1991 (Chile). As with M. brocela, its wing pattern is typical of those populations of *M. azia* that occur west of the Andes from southern Ecuador to Chile. The genitalia illustrated in the original description are those of M. azia, not of M. janevicroy. We know Ministrymon hernandezi Schwartz & K. Johnson, 1992 (Cuba) from the original publication. The male genitalia illustrations are stylized renderings, but the placement of the teeth on the ventral penis tip and the shape of the cornuti place this name in the synonymy with M. azia. Further, M. janevicroy does not occur in the Antilles. Finally, we accord nomenclatural priority to Angulopis hernandezi K. Johnson & Kroenlein, 1993 (a male holotype) over Electrostrymon grumus K. Johnson & Kroenlein, 1993 (a female holotype), new synonym, and remove the latter name from the synonymy of M. azia. Robbins (2004a) had erroneously listed grumus as a synonym of hernandezi Schwartz & K. Johnson rather than as a synonym of hernandezi K. Johnson & Kroenlein. The name Angulopis hernandezi is currently placed in genus Ziegleria K. Johnson (Robbins 2004a, Duarte and Robbins 2010).

Faunal documentation. The Eumaeini fauna of the United States is well-documented, and most species described in the past 75 years have arguably been cryptic

species that had been overlooked because of wing pattern similarity with known species. Specific examples are *Satyrium caryaevorus* (McDunnough), *Satyrium kingi* (Klots & Clench), *Callophrys hesseli* (Rawson & Ziegler), and *Strymon solitario* Grishin & Durden. To this list, we add *Ministrymon janevicroy*. In sharp contrast, slightly more than 20% of the Central and South American eumaeine fauna is undescribed (Robbins 2004b), but the vast majority of these undescribed species are exceedingly rare in museum collections, unlike *M. janevicroy*. Assessing variation of these rare species remains an obstacle to documentation.

Biology and updated taxonomy. The purpose of this section is to assess previously published biological information about *M. azia* in the context of the updated taxonomy. As noted in the introduction to this paper, *M. azia* occurs from the United States (Texas and Florida) to Chile in virtually all lowland habitats, ranging from desert in coastal Peru and Chile to rainforest in the Amazon Basin. The information in this paper is consistent with this statement, and we note that there are specimens of *M. azia* in the USNM from Hidalgo, Cameron, and Edwards County in Texas. *Ministrymon janevicroy* is restricted to dry deciduous forest and scrub, and its range is a subset of that of *M. azia*. These species appear to be sympatric wherever *M. janevicroy* occurs.

Ministrymon azia was the most common lycaenid migrating through Portachuelo Pass in northern Venezuela (Beebe 1951), and it was one of the species being dispersed by dry season trade winds on the Pacific slope of Panama (Robbins and Small 1981). There are 34 vouchers of *M. azia* and none of *M. janevicroy* in the USNM that were caught migrating through Portachuelo Pass. There are 12 vouchers of *M. azia* and none of *M. janevicroy* in the USNM that were being dispersed by dry season trade winds at the Cerro Campana ridge in Panama. The records of migration and dispersal would appear to refer to *M. azia*, not to *M. janevicroy*.

Published larval food plant records (all Fabaceae, one exception) for *M. azia* from areas where *M. janevicroy* does not occur are the plant genera *Acacia* Willd. in the United States (Florida) and Chile, *Mimosa* L. in Cuba, and Trinidad, and *Leucaena* Benth. in the United States (Florida) (Boscoe 1982, Cock 1985, Fernández and Rodríguez 1997, Vargas and Parra 2009, Glassberg 2012, images of the immatures of *M. azia* on *Leucaena* available from Chin-Lee, http://bugguide.net/node/view/133700, accessed April 22, 2013). Miller et al. (1997) wrote that caterpillars of *M. azia* in Florida will eat *Schinus terebinthifolius* Raddi (Anacardiaceae), but this anomalous record needs confirmation.

Reared museum specimens that we have seen have all been *M. azia*. We examined individuals of *M. azia* in the USNM that were reared from *Leucaena* in Florida (2°) , 2°) and from *Mimosa* in Guerrero and Veracruz, Mexico (1°) , 1°) and in Trinidad (2°) . In DZUP, there are reared specimens from *Mimosa* in Pernambuco and Rio Grande do Sul, Brazil (2°) . Finally, we identified an adult female that was reared from *Prosopis* L. in Tarapacá, Chile, but deposition of this specimen is unknown.

Other caterpillar food plant records are currently ambiguous and may refer to *M. azia* or to *M. janevicroy*. Harley et al. (1995) reared "*M. azia*" in Mexico and Venezuela from *Mimosa*, but the deposition of the vouchers is not known. In TAMU, there are reared adults from *Leucaena* $(3 \circlearrowright, 3 \heartsuit)$ and from *Mimosa* $(4 \circlearrowright, 3 \heartsuit)$ in the United States (Texas). In UCR, there are two reared individuals from *Leucaena* in Sonora, Mexico. These reared individuals need to be re-examined to determine their specific identify.

Acknowledgments

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Appendix I

List of genitalic dissections. (doi: 10.3897/zookeys.301.5081.app1) File format: Adobe PDF file (pdf).

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Appendix 2

Images of live butterflies examined. (doi: 10.3897/zookeys.301.5081.app2) File format: Adobe PDF file (pdf).

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Appendix 3

Data on forewing length and frequency of eye-color. (doi: 10.3897/zookeys.301.5081. app3) File format: Adobe PDF file (pdf).

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RESEARCH ARTICLE



Seladonia (Pachyceble) henanensis sp. n. (Hymenoptera, Halictidae) from China

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Abstract

Seladonia (Pachyceble) henanensis **sp. n.**, is described from Henan Province, the eastern-central part of China. This species is separated from its allied species by a combination of the following morphological characters: head broad in female, inner hind tibial spur of female with 7–8 slender teeth, T1 basolaterally with appressed hair tuft in both sexes, and genitalia with long and large lower gonostylus in male. Important taxonomic characters are illustrated with photographs, scanning electron micrographs, and line drawings.

Keywords

Apoidea, Henan Province, taxonomy, new species, Seladonia

Introduction

The halictine bee genus Seladonia Robertson (Halictidae, Halictinae) is a nearly cosmopolitan group, with 107 recognized species (Ascher and Pickering 2012). According to both morphological and molecularphylogenetic analyses (Pesenko 2004, Danforth et al. 1999, Gibbs et al. 2012), this genus is sister group to the genus Halictus Latreille. Seladonia differs from Halictus by the body having a metallic green or blue-green luster, posterior margin of fourth metasomal sternum straight, and male genitalia with medial lobe on upper gonostylus. In addition, Seladonia is divided into six subgenera (Pesenko, 2004): Mucoreohalictus Pesenko, 2004, Pachyceble Moure, 1940, Paraseladonia Pauly, 1997, Placidohalictus Pesenko, 2004, Seladonia s. str. Robertson, 1918, and Vestitohalictus Blüthgen, 1961. On the other hand, Seladonia is often regarded as a subgeneric rank of the genus Halictus (e.g., Michener 2007). Three subgenera (Mucoreohalictus, Placidohalictus, and Vestitohalictus) of the genus Seladonia sensu Pesenko (2004) corresponds to Halictus (Vestitohalictus) sensu Michener (2007), but the rest subgenera of it share with Michener's classification (Michener 2007). We treat *Seladonia* at the generic level in this study, in accordance with Pesenko (2004).

Second and third authors, Tadauchi and Xu, visited Henan Province in the eastern-central part of China in 2011 for a collaborative project, and then they collected various wild bees in the area. First author, Murao had an opportunity to examine the specimens, one of which is a new *Seladonia* species belonging to the subgenus *Pachyceble*. In the present paper, we describe this new species and illustrate diagnostically important characters with drawings, photographs, and scanning electron micrographs.

Material and methods

This study is based on the specimens deposited in the Entomological Laboratory, Faculty of Agriculture, Kyushu University, Fukuoka, Japan (ELKU), the late Dr. Shoichi F. Sakagami's collection, deposited in the Museum of Nature and Human Activities, Sanda, Hyogo, Japan (MNHAH), and the first author's private collection (without abbreviation). Terminology used in the description follows Sakagami and Ebmer (1987), and partly Pesenko (2006). Abbreviations used in the text are as follows:

BL = body length; WL = wing length; HL = head length; HW = head width; IOD = interocellar distance; OOD = ocellocular distance; OCD = ocelloccipital distance; UOD = upper interorbital distance; MOD = maximum interorbital distance; LOD = lower interorbital distance; CAL = clypealveolar distance; CPL = clypeal length; EL = eye length; EW = eye width; GW = genal width; Fn = nth antennal flagellomere; FnL = nth flagellomere length; FnW = nth flagellomere width; MsW = mesosomal width; SCL = mesoscutellar length; MNL = metanotal length; PDL = propodeal dorsum length; MtW = metasomal width; IS = interspace between punctures (IS 0.5 = means 1/2 of the diameter of punctures); PP= punctures. Body measurements are given in ranges followed by the average and standard deviation.

Comparative material examined. *Seladonia (Pachyceble) tumulorum tumulorum* (Linnaeus, 1758). [SWITZERLAND] 2♀, Schweitz 450m Delémont Fangzeit, 23. vii. 1972 (E. Hüttinger, MNHAH). [AUSTRIA] 2♀, Umgeb. Linz, O. Öst., 31. vii. 1928 (H. Priesner, MNHAH); 1♀, Tirol, Innsbruck Weiherburg, 25. v. 1965 (A.W. Ebmer, MNHAH); 2♀, Oberöst., Linz-Koglerau, 8. vi. 1965 (A.W. Ebmer, MNHAH); 2♀1♂, Biologiezentrum, Linz, N48°20'13.86", E14°18'44.78", 8. vii. 2012 (R. Murao, 1♂ illustrated in Figs 19, 22); 1♀, Nickelsdorf-Kleylehof, Bulgenland, 12. vi. 1973 (A.W. Ebmer, MNHAH). [JUGO-SLAVIA] 1♀, Istrien Ucka 1000m, 13. vii. 1971 (A.W. Ebmer, MNHAH).

- Seladonia (Pachyceble) tumulorum ferripennis (Cockerell, 1929): [JAPAN] 7♀, Jozankei N. Sapporo, Hokkaido, 22. v. 1960 (M. Shiokawa, MNHAH), 19. vii. 1960 (M. Shiokawa, MNHAH), 3. vii. 1960 (M. Shiokawa, MNHAH), 3. vii. 1960 (M. Shiokawa, MNHAH); 3♀, University Campus, Sapporo, Hokkaido, 23. v. 1959 (S.F. Sakagami, MNHAH, paratype), 11. vi. 1959 (S. F. Sakagami, MNHAH), 20. viii. 1959 (S. F. Sakagami, MNHAH), 9. ix. 1959 (S.F. Sakagami, MNHAH).
- Seladonia (Pachyceble) leucahenea leucahenea (Ebmer, 1972): [KAZAKHSTAN] 2♀, Aksu Valley, alt. 130–560m, S. Kazakhstan Prov., 16. vi. 2003 (O. Tadauchi, ELKU); 1♀, Karaalma, alt. 1210m, near Jabagly, S. Kazakhstan Prov., 17. vi. 2003 (O. Tadauchi, ELKU); 1♀, Achisai, alt. 670–700m, Mts. Karatau, S. Kazakhstan Prov., 4. vi. 2003 (O. Tadauchi, ELKU); 1♀, near Sternjak, Kokchetav District, N. Kazakhstan Prov., 19. vi. 2002 (V. Kazenas, A. Jdanko, and V. Rascheev, ELKU).
- Seladonia (Pachyceble) confusa confusa (Smith, 1853): [U.S.A] 1♀, Lapeer Co., MICH., Deerfield twp., 30. v. 1937 (G. Steyskal, MNHAH); 1♂, IND. Hendricks Co. Pittsboro, 9. viii. 1964 (E. R. Jaycox, MNHAH, illustrated in Figs 20, 23).
- Seladonia (Pachyceble) confusa arapahonum (Cockerell, 1906): [U.S.A] 2^Q, Newton, Ut., 16. iv. 1948 (G. E. Bohart, MNHAH).
- *Seladonia (Pachyceble) confusa alpina* (Alfken, 1907): [AUSTRIA] 1♀, Tirol, 4. v. 1965 (A. W. Ebmer, on *Salix* sp., MNHAH).
- Seladonia (Pachyceble) confusa perkinsi (Blüthgen, 1926): [AUSTRIA] 5¢, Mt. Georgen/G, 9. iv. 1971 (A. W. Ebmer, MNHAH).
- Seladonia (Pachyceble) confusa pelagia (Ebmer, 1996): [MONGOLIA] 5^Q, Central aimak Songino, 24km SW von Ulan-Baator, alt. 1300m, 7. vi. 1966 (Z. Kaszab, ELKU).

Taxonomy

The subgenus Pachyceble Moure, 1940

Pachyceble Moure, 1940: 54. Type species: *Pachyceble lanei* Moure, 1940, by original designation.

Diagnosis. This subgenus is similar to the subgenus *Seladonia* s. str. in having the following characters: basitibial plate of female usually well developed; propodeal dorsum about as long as metanotum; propodeum usually not densely hairly from lateral to

dorsal surfaces; metasomal terga usually with apical and basal bands of pale plumose hairs. But it is separated from them by male antenna long reaching metasoma, male F2 1.7–2.0 times as long as wide, and male S6 with deep depression behind gradulus.

Seladonia (Pachyceble) henanensis Murao, sp. n.

urn:lsid:zoobank.org:act:11562BA6-82CD-4547-932D-DD01DF764DEB http://species-id.net/wiki/Seladonia_henanensis Figs 1–18, 21

Type material. Holotype: \Diamond , CHINA, Henan Prov., Xinxiang, Mt. Guanshan, Dongling Village, N35°33'34.709", E113°31'43.703", alt. 942m, 8. vii. 2011 (O. Tadauchi leg., ELKU: Code No. BeeFTadauchi01022, illustrated in Figs 1, 3, 5, 7, 9, 13–18, 21). Paratypes: [CHINA] 5 \Diamond 1 \Diamond , same locality as the holotype, 9. vii. 2011 (O. Tadauchi, ELKU: Code Nos. BeeFTadauchi01015–01019 (\Diamond), BeeFTadauchi01020 (\Diamond); No. 01015 illustrated in Fig. 10, No. 01016 in Figs 11, 12, No. 01019 in Figs 2, 4, 6, No. 01020 in Fig. 8); 1 \Diamond , same locality as the holotype, 7. vii. 2011 (O. Tadauchi, ELKU: Code No. BeeFTadauchi01021).

Type depository. The holotype and one female paratype (Code No. BeeFTadauchi01019) are deposited in the Department of Entomology, College of Agriculture and Biotechnology, China Agricultural University (Beijing, China), and the remaining paratypes are in ELKU.

Etymology. The specific name is derived from the type locality, Henan Province of China.

Collecting sites. All specimens were collected from along a sightseeing road at Guanshang National Geopark (Fig. 24).

Distribution. China (Henan Province).

Diagnosis. This species seems most closely related to the Trans-Palaearctic species *Seladonia (Pachyceble) tumulorum* and the Holarctic species *S. (P.) confusa* in having similar body sculptures and male genitalia. However, it differs these allied species by the following key:

1	<u>٩</u> ٩2
_	Å ³
2	T1 without appressed hair tuft
_	T1 basolaterally with appressed hair tuft as in Fig. 10
3	HL/HW ratio= 0.93–1.00; inner hind tibial spur with 5–6 teeth
_	HL/HW ratio= 0.88–0.90; inner hind tibial spur with 7–8 teeth
	S. (P.) henanensis
4	Male genitalia with short and small lower gonostylus (Fig. 22)
	S. (P.) tumulorum
_	Male genitalia with long or broad lower gonostylus (Figs 21, 23)5



Figures 1–6. *Seladonia (Pachyceble) henanensis* sp. n. 1–2 lateral habitus 3–4 head in frontal view 5 mesoscutum 6 propodeal dorsum. 1, 3, 5 male, holotype. 2, 4, 6 female paratype.

Lower gonostylus broad and truncate apically (Fig. 23) S. (P.) confusa
Lower gonostylus rounded apically (Fig. 21)....... S. (P.) henanensis

Based on the published works of Dawut and Tadauchi (2003), Ebmer (2005), Pesenko (2006), Pesenko and Wu (1997), and the specimens examined for this study, this species is also separated from the other Chinese species by the combination of



Figures 7–12. *Seladonia (Pachyceble) henanensis* sp. n. 7–8 propodeal dorsum 9–10 1st and 2nd metasomal terga 11 labrum 12 inner hind tibial spur 7, 9 male, holotype 8 male, paratype 10–12 female, paratype.

following characters: HL/HW ratio= 0.88–0.90 in female; inner hind tibial spur of female with slender 7–8 teeth; upper gonostylus of male genitalia with slender medial lobe; and lower gonostylus of it long and large.

Description. Male. Coloration. Head and mesosoma dark metallic green, metasoma black. Clypeus on lower half, and labrum yellow. Mandible outer surface dark yellow on basal 2/3, reddish brown apically. Scape and pedicel blackish brown; flagellomere dark yellowish brown on lower side, blackish brown on upper side. Tegula yellowish translucent. All coxae and trochanters black; fore and middle femora mostly yellow; hind femur mostly black except for apical 1/4; all tibiae and tarsi yellow. Wings transparent, veins and stigma pale yellowish. Metasomal terga narrowly yellowish brown translucent apically.

Pilosity. Body hairs whitish to pale yellowish. Head and mesosoma covered with elect fine branched hairs. Lateral surface of pronotum covered with thin tomentum. T1 basolaterally with dense, whitish appressed hairs, remaining areas with fine erect branched hairs. Disc of T2–T5 with sparse simple hairs. Apical bands on metasomal terga interrupted on all segments. Metasomal sterna without special hair tufts. Disc of S1–S4 with simple and short hairs which gradually dense toward the apical parts.

Measurements (n = 3, unit mm): BL = 6.43-8.29 (7.57±1.00), WL = 5.86-7.29 (6.38±0.79); HL = 2.10-2.25 (2.15±0.09), HW = 1.95-2.13 (2.04±0.09), IOD = 0.35-0.39 (0.37±0.02), OOD = 0.39-0.40 (0.39±0.01), OCD = 0.32-0.35 (0.33±0.02), UOD = 1.23-1.32 (1.27 ± 0.05), MOD = 1.27-1.39 (1.33 ± 0.06), LOD = 0.97-1.06 (1.02 ± 0.05), CAL = 0.88-1.00 (0.95 ± 0.07), CPL = 0.45-0.58 (0.51 ± 0.06), EL = 1.35-1.45 (1.38 ± 0.06), EW = 0.60-0.65 (0.63 ± 0.03), GW = 0.30-0.45 (0.38 ± 0.08), F1L = 0.19-0.21 (0.20 ± 0.01), F2L = 0.32-0.34 (0.33 ± 0.01), F3L = 0.34-0.37 (0.35 ± 0.02), F10L = 0.34-0.35 (0.34 ± 0.01), F2W = 0.19-0.21 (0.20 ± 0.01); MsW = 2.05-2.25 (2.13 ± 0.10), SCL = 0.50 (0.50 ± 0.00), MNL = 0.30-0.33 (0.32 ± 0.01), PDL = 0.35-0.40 (0.38 ± 0.03); MtW = 1.85-2.15 (1.98 ± 0.15).

Structure. Head nearly as long as wide; HW:HL = 1:1.05. Vertex rounded in frontal view. MOD:UOD:LOD = 1:0.96:0.77. IOD:OOD:OCD = 1:1.07:0.91. Ocellocular area and frons flat, dull, with reticulate PP. Paraocular area similar sculptures with ocellocular area and frons. Supraclypeus slightly convex with dense PP, IS smooth (IS = 0.2). CPL:CAL = 1:1.87. Clypeus gently elevated from middle to lower area, with dense PP, IS smooth (IS = 0.2–0.5). EW:GW = 1:0.61. Malar space short, 0.3 times as wide as mandible at base. Hypostoma distinctly striated. Mandible edentate. Labrum without basal elevation and distal process. Antenna long, reaching metasoma. F1–F3L:F10L:F2W = 1:1.70:1.81:1.75:1.04; flagellomere nearly flattened on lower side.

Pronotal lateral ridge rounded, rather indistinct; lateral surface weakly rugulose below; lateral lobe apically rounded. Mesoscutum (Fig. 5) and mesoscutellum shiny, with dense PP over entire surface, IS smooth (IS = 0.2-0.8). Metanotum and mesepisternum dull and rugulose. SCL:MNL:PDL= 1:0.63:0.77. Propodeal dorsum (Fig. 7) slightly inclined, with distinct irregular sinuate ridges over entire surface. Propodeal side and shield densely punctured over entire surface, IS smooth (IS = 0.3-0.5). Hind tibia without basitibial plate. Inner hind tibial spur without distinct teeth. Hind tarsus slender.

Discs of T1–T3 with dense PP over entire surface, IS smooth (IS = 0.5-1.0). S1–S4 distinctly tessellate over entire surface. S1–S4 apically nearly straight, S5 increasingly incurved. S6 (Fig. 13) with a distinct longitudinal median depression. S7–S8 (Fig. 14): S7 medially triangular, apex not exceeding S8; S8 medially slightly projecting, apex rounded with a few hairs as long as S8 itself.



Figures 13–17. Male of *Seladonia (Pachyceble) henanensis* sp. n., holotype. 13 6th metasomal sternum 14 7th and 8th metasomal sterna 15 genitalia in ventral view 16 genitalia in dorsal view 17 genitalia in lateral view. Scale bars: 13, 0.5 mm; 14–17, 0.2 mm.

Genitalia (Figs 15–18, 21): gonobase short, ventral arm connected with each other in upper ends; gonocoxite nearly parallel-sided on inner and outer margins in dorsal view, with longitudinal striation in dorsal view, with fingerprint striation in lateral view; upper gonostylus with dense tuft of short hairs and another tuft of several long filament-like modified hairs ventrally, medial lobe slender with a few short hairs apically; lower gonostylus 2.3 times as long as wide, nearly as high as upper gonostylus, spatulate in lateral view, and with dense short hairs on inner surface; penis valve broad medially, with relatively long hairs along median line in dorsal view.

Female. As in male except as indicated.

Coloration. Clypeus and all legs without yellow maculatons. Mandible dark reddish, remainder black. All segments of antenna dark brown.



Figures 18–24. 18, 21 Male of *Seladonia (Pachyceble) henanensis* sp. n., holotype 19, 22 Male of *S. (P.) tumulorum tumulorum* (Linnaeus) 20, 23 Male of *S. (P.) confusa confusa* (Smith) 24 Collecting site of *S. (P.) henanensis* sp. n., photograph by Dr. Satoshi Kamitani 18–20 gonostylus of male genitalia in dorsal view 21–23 lower gonostylus of male genitalia in lateral view. Scale bars: 0.2 mm.

Pilosity. Scopa well developed on hind femur to tibia, and S1–S3. Apical bands on metasomal terga interrupted on T1–T2, completed but narrow on T3–T4.

Measurements (n = 5): BL = 7.71–9.29 (8.60±0.60), WL = 6.43–7.86 (7.37±0.60); HL = 2.15–2.30 (2.25±0.06), HW = 2.40–2.60 (2.53±0.08), IOD = 0.35–0.42 (0.41±0.03), OOD = 0.45–0.52 (0.49±0.03), OCD = 0.35–0.42 (0.41±0.03), UOD = 1.52–1.65 (1.57±0.05), MOD = 1.66–1.81 (1.75±0.06), LOD = 1.42–1.55 (1.48±0.06), CAL = 0.85–0.90 (0.88±0.03), CPL = 0.45–0.50 (0.47±0.02), EL = 1.50–1.55 (1.53±0.03), EW = 0.65–0.75 (0.71±0.04), GW = 0.45–0.65 (0.54±0.08), MsW = 2.40–2.60 (2.53±0.08), SCL = 0.50–0.55 (0.54±0.02), MNL = 0.30–0.35 (0.34±0.02), PDL = 0.35–0.40 (0.39±0.02); MtW = 2.50–2.85 (2.75±0.15).

Structure. Head wider than long; HW:HL = 1:0.89. Vertex flat medially in frontal view. MOD:UOD:LOD = 1:0.90:0.85. IOD:OOD:OCD = 1:1.21:1.00. PP on supraclypeal area gradually becoming sparse to apically, IS = 0.5–1.0. CPL:CAL = 1:1.89. Clypeus nearly flat, its punctures sparser than in male, IS = 0.5–2.0. EW:GW = 1:0.76. Malar space linear. Hypostoma distinctly tessellate. Mandible bidentate. Labrum (Fig. 11): basal area of labrum 1.7 times as wide as long; basal elevation developed, triangle-shaped; distal process slender, slightly shorter than basal area (0.9 times), and without lateral projection; keel of distal process obtuse apically; labral fimbria acutely pointed at apex. Antenna short, its apically not reaching mesoscutellum as well as the other congeners.

Lateral surface of pronotum finely punctuated, IS smooth. SCL:MNL:PDL = 1:0.62:0.72. Propodeal dorsum (Fig. 6) without smooth area. Propodeal side with dense PP on lateral slope, with weak rugulae on rest parts. Propodeal shield weakly tessellate, with sparse PP. Inner hind tibial spur (Fig. 12) with 7–8 slender teeth.

Luster on T3–T4 duller than T1–T2. PP on T1 sparser than T2–T4; IS = 1–2.5 on T1, IS= 0.5 on T2–T4. Metasomal sterna flat, weakly tessellated over entire surface, and nearly straight apically.

Variation. Male hypostoma striate in holotype, but nearly smooth in one paratype. In addition, male propodeal dorsum without smooth area (Fig. 7) in holotype, but with narrow and smooth area along posterior margin (Fig. 8) in two paratypes.

List of Chinese species of Seladonia (Pachyceble)

- 1. Seladonia (Pachyceble) argilos (Ebmer, 2005)
- 2. Seladonia (Pachyceble) confusa pelagia (Ebmer, 1996)
- 3. Seladonia (Pachyceble) henanensis Murao, sp. n.
- 4. Seladonia (Pachyceble) leucahenea leucahenea (Ebmer, 1972)
- 5. Seladonia (Pachyceble) opacoviridis (Ebmer, 2005)
- 6. Seladonia (Pachyceble) tibetana (Blüthgen, 1926)
- 7. Seladonia (Pachyceble) tumulorum ferripennis (Cockerell, 1929)
- 8. Seladonia (Pachyceble) yunnanica (Pesenko & Wu, 1997)

Seladonia (Pachyceble) confusa alpina (Alfken, 1907) and *S. (P.) dorni* (Ebmer, 1982) are recorded from China (Fan 1991, Niu et al. 2004). However, these records not include in above list, in accordance with Ebmer (2005) and Pesenko (2006).

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RESEARCH ARTICLE



Synopsis of Acanthocerini (Hemiptera, Coreidae) from Argentina

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Abstract

Eight genera and 13 species of the tribe Acanthocerini are recorded in Argentina, i.e., Athaumastus haematicus (Stål), A. macer Brailovsky, A. subcarinatus (Stål), A. subterlineatus Bergroth, Beutelspacoris sanchezi Brailovsky, B. dilatata Casini, Camptischium clavipes (Fabricius), Crinocerus sanctus (Fabricius), Dersagrena flaviventris (Berg), D. lacerdae (Signoret), D. subfoveolata (Berg), Thlastocoris hernandezi Brailovsky and Zoreva dentipes Fabricius. Redescriptions are given for A. haematicus, A. subcarinatus and D. flaviventris with photographs of male and female genitalia of D. subfoveolata. Zoreva recorded from Argentina the first time. New locality records are given for Buenos Aires, Chaco, Formosa, Misiones, and Tucumán.

Keywords

Acanthocerini, genera, Argentina, key, redescription, distribution

Introduction

The Coreidae, commonly called "leaf-footed, pod- or squash-bugs", are heavy bodied insects usually strongly elongate or broadly elliptical. This family includes some of the largest living heteropterans, as well as species that are delicate or slender (Schuh & Slater 1995). The family contains about 267 genera and more than 1884 species worldwide (Henry 2009). The basic suprageneric classification was established by Stål (1867, 1870) and Schaefer (1964, 1965), who provided the most comprehensive treatment. Packauskas (1994) gave keys to the subfamilies and tribes of the New World Coreidae and a checklist of published keys to genera and species, and Packauskas (2010) cataloged the New World Coreidae and provided a comprehensive introduction to the literature.

The most comprehensive treatment of the Coreidae for Argentina are by Pennington (1920, 1921) and Kormilev (1954), but only Pennington (1921) dealt with the Acanthocerini.

Many coreids are of great economic importance. As mentioned by Mitchell (2000), grains legumes, rice, cassava, cucurbits, tomatoes, garden vegetables, and various fruit and nut trees are among the crops attacked by coreids worldwide. According to Mitchell (2000), the Acanthocerini includes species of minor economic importance, i.e., *Athaumastus haematicus* (Stål) that attacks potatoes, cotton, sunflower, oranges and eggplant, *Dersagrena flaviventris* (Berg) on cotton, and *Camptischium clavipes* (F.) on castor bean and guaco (Bosq 1937, 1940; Mitchell 2000).

Knowledge of the South American fauna is poor; this is especially true in regard to economically important taxa. Comprehensive keys for identification of the species in the region have not been published.

Most of Argentina lies in the Neotropical faunal region. The country covers an area of 2,791,810 km² and is bordered by Uruguay, Brazil, Paraguay, Bolivia, and Chile. Approximately 75% of the country is occupied by arid and semiarid areas, but rainforests are also present in the northeast, i.e., the Yungas and Paranaense regions. Coscarón (submitted) recorded 125 species in 48 genera of Coreidae living from Argentina.

The goal of this paper is to provide an illustrated key to the genera of Acanthocerini (Coreidae) from Argentina (Fig. 38), a diagnosis and redescription of some of its species, geographical distribution, and a list of species for each genus.

Materials and methods

All specimens from this study are deposited in the collections of the Museo de Ciencias Naturales de La Plata (MLP), La Plata, Buenos Aires, Argentina (http://www.fcnym.unlp. edu.ar/abamuse.html). Photographs were compared with material of the Naturhistoriska Riksmuseet in Stockholm, Sweden (http://www.nrm.se/2.1286b10fdbe80efba80001. html) and the American Museum of Natural History in New York (http://www.amnh. org/). For the geographical distribution we used the program DIVA-GIS 7.1.7 (http:// www.diva-gis.org/) and the distribution of those specimens for which global positioning

system data were available was used for the construction of maps. Photographs were produced using a Kodak Easy Share (12 megapixels) camera and a magnifying Wild M-Stereomicroscope. The diagnoses of genera are taken from Brailovsky (1987) and O'Shea (1980), except as noted. Coreoidea Species File (Version 1.1/4.1) (http://coreoidea.speciesfile.org/HomePage.aspx) was consulted. All measurement are in millimeters.

Key to the genera of Acanthocerini for Argentina

1a	Pronotum slightly declivent (Fig. 31)2
1b	Pronotum not slightly declivent Thlastocoris Mayr
2a	Posterior femora tuberculate ventrally and smooth dorsally (Fig. 29)
2b	Posterior femora tuberculate ventrally and dorsally (Fig. 20)5
3a	First antennal segment much longer than third segment, humeral angles not sharp (Fig. 30)
3b	First antennal segment much shorter than third segment, humeral angles sharp but hardly produced laterally (Fig. 26)6
4a	Humeral angles of pronotum pointed Zoreva Amyot & Serville (Fig. 29)
4b	Humeral angles of pronotum roundedBeutelspacoris Brailovsky
5a	Dorsal surface of pronotum markedly tuberculate
5b	Dorsal surface of pronotum punctate but not tuberculate
6a	Antennifers narrowly but distinctly separated
6b	Antennifers meeting mesially

Taxonomy

Genus Athaumastus Mayr

http://species-id.net/wiki/Athaumastus http://coreoidea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=759 Figs 1, 6

Athaumastus Mayr 1865: 431. Type species: Crinocerus lugens Stål 1855: 184; monotypic.

Diagnosis. (After O'Shea 1980) Body medium-sized, robust, postocular tubercles well developed; antennifers large, placed close together, projecting anteriorly of tylus, with well developed spine on lateral surface; pronotum not very steeply declivent, lateral margins slightly nodulose, humeral angles rounded-angulate, posthumeral, posterior margins relatively smooth; anterior femora with or without distal spines on ventral surface, intermediate and posterior femora armed at least with small apical spines, posterior



Figures 1–10. Athaumastus haematicus (Stål). **1–5** \mathcal{J} , **1** dorsal view **2** ventral view **3** pronotum **4** hind leg **5** male genital capsule, ventral view **6–10** \mathcal{G} **6** dorsal view **7** ventral view **8** pronotum leg **9** hind leg **10** female genital segment, ventral view.

femora markedly curved, incrassate, especially in male; posterior tibiae flattened, armed with teeth along ventral margin, with large tooth halfway along ventral margin in male.

Athaumastus haematicus (Stål)

http://species-id.net/wiki/Athaumastus_haematicus http://coreoidea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=779 Figs 1–5, 6–10, 39

Crinocerus haematicus Stål 1859: 455.

Athaumastus haematicus Berg 1878: 85.– Pennington 1920: 13.– Pennington 1921: 36.– Bosq 1937: 113.– Hayward 1942: 72.– Hayward 1960: 30.– Quintanilla et al. 1968: 31.– Viana and Williner 1972: 27.– Quintanilla et al. 1976: 117.– Rizzo 1976: 34.– Viana and Williner 1978: 74.– Quintanilla et al. 1981: 147.

Redescription. Male. n= 8. Total body length: 12.3-14.2: head length 1.0-1.2; head width 1.4-0.18; eye width 0.2-0.3; interocular space 0.8-0.9; preocellar distance 0.4; interocellar space 0.2. Rostrum: I 0.7-0.8, II 1.2, III 1.0, IV 0.64-0.7. Antennal seg-
ments: I 1.8-2.1, II 1.3-2.2, III 2.2-2.7 and IV 1.4-2.0. Pronotum length 2.3-2.9; width 4.6-6.4. Scutellum length 2.3, width 2.2. Length of abdomen with hemelytra: 8.6-9.8; length abdomen with hemelytra: 9.0-10.0; Abdomen width: 3.9-4.6. Dorsal coloration: Head brown tinged with red except antennal segments 2-3, bases of segments with brown tonalities. Pronotum brown, tinged with red. Scutellum dark read. Corium and clavus brown, tinged with red and hemelytral membrane dark brown, veins light brown. Connexival segments dark brown, tinged with red. Ventral coloration: Ground color light brown, tinged with red, mesosternun darker and abdomen not homogeneously dark pigmented. Legs dark brown, tinged with red. Structure: Pronotum rugose. Frontal angles rugose projecting with in as acute projecting spines, humeral angles with two rounded projections. Scutellum granulate. Metafemora with two rows of spines, tibia with small teeth basally. Hemelytra shorter than the abdomen.

Female. n=8. Total body length: 12.0-13.5; head length: 10.0; head width: 1.4-1.6; eye width: 0.2-0.3; interocular space: 0.8-0.9; preocellar distance: 0.4; interocellar space: 0.3. Rostrum: I 0.6-0.8, II 1.2, III 0.9, IV 0.7. Antennal segments: I 1.1-1.7, II 1.5-1.6, III 1.9-20.0 and IV 1.2-1.5. Pronotal length: 2.2-2.7; width: 4.2-5.0. Scutellar length: 1.7; width: 1.5. Length of abdomen with hemelytra: 9.0-11.0; length of abdomen without hemelytra: 9.6-11.3; abdomen width: 4.7-5.4. Dorsally and ventrally light brown. Anterior angles granulate; humeral angles with two rounded projections.

Specimens examined. Argentina: Catamarca: 1Å Andalgalá (27°36'02"S, 66°18'56"W), 1Å Pomán (28°23'44.38"S, 66°13'06.91"W). Córdoba: 2 \bigcirc Cabaña (31°13'00.56"S, 64°22'00.32"W), 1Å Makena (31°21'52.69"S, 64°10'18.54"W), 3 \bigcirc 2Å Marull (30°59'43.72"S, 62°49'38.55"W), 1Å Mar Chiquita (30°48'35.46"S, 62°52'31.68"W), 1Å Rayo cortado (30°04'26.09"S, 63°49'25.99"W). 2 \bigcirc 3Å Corrientes. Chaco: 1 \bigcirc Charata (27°13'06.31"S, 61°11'15.89"W), 1 \bigcirc El zapallar (26°32'17.85"S, 59°20'42.57"W), 8 \bigcirc 7Å Gancedo (27°29'21.89"S, 61°40'31.52"W), 1 \bigcirc Resistencia (27°27'05"S, 58°59'10"W). Formosa: 2Å Ingeniero Juárez (23°53'46.85"S, 61°51'37.88"W). 1Å La Rioja. 1 \bigcirc San Luis. Santiago del Estero: 1Å Río Salado (27°44'32.51"S, 64°21'16.97"W).

Distribution. Argentina: Buenos Aires; Catamarca; Córdoba: Carlos Paz, El Sauce, San Javier; Corrientes: Alvear Department, Bella Vista Department, Berón de Astrada Department, Capital Department, Colón Department, Concepción Department, Concordia Department, Diamante Department, Empedrado Department, Esquina Department, General Paz Department, La Paz Department, Mburucuyá Department, Paraná Department, Paso de los Libres Department, Saladas Department, San Martín Department, San Miguel Department, San Roque Department, Santo Tomé Department, Victoria Department; Chaco; Entre Ríos: Concordia; Formosa; Jujuy; La Pampa; La Rioja; Mendoza; Misiones: Alem Department, Apóstoles Department, Cainguás Department, Oberá Department, San Javier Department, San Martín Department, 25 de Mayo Department; Neuquén; Salta; San Juan; San Luis: San Gerónimo, Suyuque; Santa Fé; Santiago del Estero; Tucumán.

Athaumastus macer Brailovsky

http://coreoidea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=781

Athaumastus macer Brailovsky 1993:115.

Distribution. Argentina: Tucumán

Athaumastus subcarinatus (Stål)

http://species-id.net/wiki/Athaumastus_subcarinatus http://coreoidea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=783 Figs 11–14, 40

Crinocerus subcarinatus Stål 1859: 455. Athaumastus subfoveolatus Berg 1892: 66.–Coscarón 1998: 4. Athaumastus subcarinatus Pennington 1920: 13.– Pennington 1921: 38.– Quintanilla et al. 1968: 31.– Quintanilla et al. 1976: 118.Viana and Williner 1978: 74.

Redescription. Male: n=8. Total body length: 12.4-13.0; head length: 0.8-1.1; head width: 1.4-1.5; eye width: 0.2-0.3; interocular space: 0.8; preocellar distance: 0.3; interocellar space: 0.2. Rostrum: I 0.4-0.7, II 1.1, III 0.7, IV 0.4-0.6. Antennal segments: I 1.3-1.7, II 1.5-1.9, III 1.4-2.1 and IV 1.3. Pronotum length: 2.2-2.7; width: 3.4-3.9. Scutellum length: 1.4, wide 1.6. Length of abdomen with hemelytra: 8.0; length of abdomen with hemelytra: 9.0; abdomen width: 4.0-4.1. Dorsal coloration: Head including antennal segments 1-3 brown, 4 dark brown. Pronotum brown, margins light brown. Scutellum and corium brown tinged with dark red, hemelytral membrane dark brown. Connexival segments light brown. Ventral coloration: Ground color brown with following areas dark brown: mesosternun, metapleura, and abdomen not homogeneously dark brown. Fore- and middle legs light brown, hind leg dark brown. Structure: head granulate brown; antennal segment IV pilose; pronotum granulate. Frontal angles rugose, with a projecting as acute spines; humeral angles with two rounded projections. Scutellum granulate, dark brown. Metafemora with two rows of 6 spines; tibia with small teeth basally. Hemelytra granulated brown tinged with dark red, shorter than abdomen.

Specimens examined. Argentina: Buenos Aires: 1 Junín (34°35'16.37"S, 60°58'45.71"W). Córdoba: 1 Villa Nueva (32°26'08.91"S, 63°14'59.39"W). Formosa: 1 Almirante Brown (24°47'56.53"S, 60°27'58.83"W). Misiones: 1 Joreto (27°18'59.85"S, 55°32'00.04"W).

Distribution. Argentina: Córdoba: Carlos Paz, San Javier; Corrientes: Capital Department, Lavalle Department; Entre Ríos: Concordia Department, Federación Department, Gualeguachú Department, Paraná Department, Villaguay Department; Salta.

Remarks. These are the first records of this species from Buenos Aires, Formosa, and Misiones.



Figures 11–14. *Athaumastus subcarinatus* (Stål) *A***. 12** dorsal view **12** ventral view **13** hind leg **14** male genital capsule, ventral view.

Athaumastus subterlineatus Bergroth

http://coreoidea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=785

Athaumastus subterlineatus Bergroth 1912: 85

Distribution. Argentina: Santiago del Estero, Río Salado.

Genus Beutelspacoris Brailovsky

http://species-id.net/wiki/Beutelspacoris http://coreoidea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=760

Beutelspacoris Brailovsky 1987: 523. Type species: Beutelspacoris sanchezi Brailovsky 1987: 524.
Moreyacoris Casini 1989: 25. Type species: Moreyacoris dilatata Casini 1989 : 26.

Diagnosis. (After Brailovsky 1987) Body relatively small, robust, postocular tubercles prominent; antenniferous tubercles large. Pronotum slightly declivent, wider than long; callar region distinct; collar narrow; humeral angles rounded. All femora at least slightly incrassate; posterior femora more incrassate; all femora with subdistal spines on ventral surface and dorsally smooth; anterior and intermediate tibiae terete, sulcate, and unarmed; posterior tibiae slightly flattened, armed with small teeth along internal margin.

Beutelspacoris sanchezi Brailovsky

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http://coreoidea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=788

Beutelpacioris sanchezi Brailovsky 1987: 524.

Distribution. Argentina: Santiago del Estero: Lago Muyo.

Beutelspacoris dilatata Casini

http://coreoidea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=787

Moreyacoris dilatata Casini 1989: 26.– Bachmann 1999: 221. Beutelspacoris dilatata Brailovsky and Barrera 2003: 888.

Distribution. Argentina: Jujuy; La Rioja: Nanogasta.

Genus Camptischium Amyot & Serville

http://species-id.net/wiki/Camptischium http://coreoidea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=761 Fig. 15

Camptischium Amyot and Serville 1843: 213. Type species: *Camptischium spinosum* Amyot and Serville 1843: 213; monotypic.

Diagnosis. (After O'Shea 1980) Body-medium sized, robust, stout, elliptical or obovate; postocular tubercles relatively small, antennifers large with marked external spine; pronotum steeply declivent, humeral angles produced laterally into a sharp spine, posthumeral margins nodulose; all femora somewhat incrassate, armed with spines at least distally on ventral surface, posterior femora markedly curved, incrassate, especially in male, with tubercles ventrally and dorsally; posterior tibiae flattened, with spines situated about equidistant from anterior and lateral margins.

Camptischium clavipes (Fabricius)

http://species-id.net/wiki/Camptischium_clavipes http://coreoidea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=1490 Figs 15–17, 41

Coreus clavipes Fabricius 1803:196. Acanthocerus (Camptischium) clavipes Berg 1878: 83.– Pennington 1921: 35. Camptischium clavipes Pennington 1920: 13.– Viana and Williner 1978: 75.



Figures 15–17. *Camptischium clavipes* (Fabricius) *3*. 15 dorsal view 16 pronotum 17 hind leg.

Acanthocoris clavipes Blöte 1935: 220.

Acanthocerus clavipes Bosq 1940: 401.– Hayward 1960: 30.– Quintanilla et al. 1981: 147. *Captischium clavipes* Viana and Williner 1972: 27.

Specimens examined. Argentina: Buenos Aires: $2\ \ La$ Plata ($34^{\circ}55'16''S$, $57^{\circ}57'17''W$), $1\ \ Pereyra Iraola (<math>34^{\circ}50'44.08''S$, $58^{\circ}10'42.94''W$). $1\ \ 2\ \ Catamarca.$ Córdoba: $1\ \ Bella$ vista ($29^{\circ}32'07.71''S$, $64^{\circ}10'02.87''W$), $1\ \ Villa$ María ($32^{\circ}24'37.66''S$, $63^{\circ}14'37.12''W$). $1\ \ 1\ \ Formosa.$ Jujuy: $1\ \ 4\ \ \ Yala$ ($24^{\circ}07'10.78''S$, $65^{\circ}24'06.78''W$), $1\ \ Ledesma$ ($23^{\circ}48'48.79''S$, $64^{\circ}47'41.47''W$), $1\ \ \ Reyes$ ($24^{\circ}09'49.08''S$, $65^{\circ}22'42.99''W$). Salta: $2\ \ 1\ \ San$ Lorenzo ($26^{\circ}06'34''S$, $64^{\circ}38'34''W$). $3\ \ \ 4\ \ \ Tucumán$.

Distribution. Argentina: Catamarca; Córdoba: Carlos Paz, Río San José; Chaco; Formosa; Jujuy; La Rioja; Mendoza; Misiones: Corpus, Department Cainguás, Department Montecarlo; Neuquén; Salta; San Juan; Tucumán.

Remarks. This is the first record of this species from Buenos Aires.

Genus Crinocerus Burmeister

http://species-id.net/wiki/Crinocerus http://coreoidea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=763 Fig. 18

Crinocerus Burmeister 1835: 318. Type species: *Cimex sanctus* Fabricius 1775: 709, by designation (O'Shea 1973).

Diagnosis. (After O'Shea, 1980) Body medium-sized, robust, oblong; postocular tubercles well developed; antennifers large, pronounced, situated close together with distinct external spine; pronotum steeply declivent, posterior angles rounded; all femora armed at least with subdistal spines on ventral surface, posterior femora curved, incrassate especially in male, armed with tubercles on all surfaces, becoming spines on ventral surface; posterior tibiae flattened, straight in female, curved in male.

Crinocerus sanctus (Fabricius)

http://species-id.net/wiki/Crinocerus_sanctus http://coreoidea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=792 Figs 18–20, 42

Cimex sanctus Fabricius 1775: 709.

Crinocerus sanctus Berg 1878: 82.– Pennington 1920: 13.– Pennington 1921: 35.– Bosq 1937: 115.– Quintanilla et al. 1981: 148.

Specimens examined. Argentina: Misiones: 2♀ 3♂ Loreto (27°18'59.85"S, 55°32'00.04"W), 3♀ 1♂ San Ignacio (27°15'34.49"S, 55°32'19.23"W). Tucumán: 1♀.

Distribution. Argentina: Buenos Aires; Misiones: Corpus, DepartmentAlem, Department Cainguás, Department El dorado, Department Guaraní, Department Iguazú, Department San Ignacio, Department San Javier, Santa Ana.

Remarks. This is the first record of this species from Tucumán.

Genus Dersagrena Kirkaldy

http://species-id.net/wiki/Dersagrena http://coreoidea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=764 Figs 21–26

Dalcera Signoret 1863: 556. Type species: *Dalcera lacerdae* Signoret 1863, monotypic. *Dersagrena* Kirkaldy 1904: 280. New name for *Dalcera* Signoret, takes the type for that genus.

Diagnosis. (After O'Shea 1980) Body relatively small, narrow; postocular tubercles prominent, antennifers large, situated close together, pronotum relatively shallowly



Figures 18–20. Crinocerus sanctus (Fabricius) 3. 18 dorsal view 19 pronotum, 20 hind leg.

declivent, lateral margins slightly nodulose, humeral angles sharp, posthumeral, posterior margins smooth; anterior femora unarmed, intermediate femora armed distally on ventral surface with small spines, at least in male, posterior femora incrassate, armed with spines on ventral surface, especially in male, posterior tibiae flattened with small teeth on ventral margin, more in the male.

Dersagrena flaviventris (Berg)

http://species-id.net/wiki/Dersagrena_flaviventris http://coreoidea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=793 Figs 21–25, 43

Dalcera flaviventris Berg 1879: 282.– Lethierry and Severin 1894: 22.
Athaumastus flaviventris Pennington 1920: 13.– Pennington 1921: 38.– Bosq 1937: 113.
– Coscarón 1998: 2.
Dersagrena flaviventris Mitchell 2000: 384.

Redescription. Holotype. Female. n=1. Total body length: 10.0; head length: 1.2; head width: 1.5; eye width: 0.3; interocular space: 0.7; preocellar distance: 0.2; interocellar space: 0.3. Rostrum: I 1.0, II 1.2, III 1.0, IV 0.8. Antennal segments length: I



Figures 21–25. *Dersagrena flaviventris* (Berg) \bigcirc . **21** dorsal view **22** ventral view **23** lateral view **24** pronotum **25** genital segments, ventral view.

1.1, II 1.6, 1.7 III and IV (segment missing). Pronotal length: 2.8; width: 4.1. Scutellar length: 1.4; width 1.3. Length of abdomen with male hemelytra: 9.6; length of abdomen with hemelytra: 10.0; abdomen width: 4.7. Dorsal coloration: Head dark brown, light brown interocular space. Pronotum dark brown except two stains on anterior region and lateral margins light brown. Scutellum, coria, and hemelytral membrane dark brown. Connexival segments dark brown with intersegmental line light brown. Ventral coloration: Ground color light brown, connexival segments dark brown. Legs dark brown. Structure: pronotum granulate; frontal angles granulate and projecting as acute spines reaching ocular tubercles; humeral angles with two rounded projections; scutellum granulate. Hemelytra shorter than the abdomen.

Specimen examined. Argentina: Córdoba: 1♀ Alta Gracia (31°24'53.38"S, 64°10'36.61"W).

Distribution. Argentina: Buenos Aires, Córdoba: Río Cuarto; Chaco; San Luis: Villa Mercedes; Santiago del Estero; Tucumán.

Dersagrena lacerdae (Signoret)

http://coreoidea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=794

Dalcera lacerdae Signoret 1863: 556. Dersagrena lacerdae Pennington 1920: 14.– Pennington 1921: 39.

Distribution. Argentina: Catamarca; Chaco; Formosa; Jujuy; La Rioja; Mendoza; Misiones; Neuquén; San Juan, Tucumán.



Figures 26–28. Dersagrena subfoveolata (Berg) 3. 26 dorsal view 27 pronotum 28 hind leg.

Dersagrena subfoveolata (Berg)

http://species-id.net/wiki/Dersagrena_subfoveolata http://coreoidea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=795 Figs 26–28, 34–37, 44

Athaumastus subfoveolatus Berg 1892: 66.– Bachmann 1999: 197. Dersagrena subfoveolatus Pennington 1920: 14.– Pennington 1921: 39. Desagrena subflaveolatus Viana and Williner 1978: 75.

Specimens examined. Argentina: Chaco: 1° Corzuela (26°57'21.84"S, 60°58'14.21''W), 1° Gancedo (27°29'21.89"S, 61°40'31.52"W). Formosa: 1° Ibarreta (25°12'55.21"S, 59°51'27.69"W). La Rioja: 1° Nonogasta (29°18'11.07"S, 67°30'05.67"W). Salta: 1° 4 $^{\circ}$ Talapampa (25°32'00.01"S, 65°34'00.06"W). 1° San Luis. Santiago del Estero: 1° Toboada (28°02'41.53"S, 63°47'16.89"W).

Distribution. Argentina: Catamarca; Córdoba: Capilla del Monte; Jujuy; La Pampa; La Rioja; Mendoza; Neuquén; Salta; San Juan; San Luis; Santa Fé; Santiago del Estero; Tucumán.

Remarks. These are the first records of this species from Chaco and Formosa.



Figures 29–33. *Zoreva dentipes* Fabricius 3. **29** dorsal view **30** antenna **31** head and pronotum **32** hind femur **33** abdomen dorsal view.

Genus Thlastocoris Mayr

http://species-id.net/wiki/Thlastocoris http://coreoidea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=774

Thlastocoris Mayr 1866: 88. Type species: Thlastocoris laetus Mayr, monotypic.

Diagnosis. (After O'Shea 1980) Body relatively small, postocular tubercles well developed, antennifers large, fairly widely separated, external spine present on antennifers; pronotum rather shallowly declivent; all femora at least slightly incrassate, posterior femora more incrassate, a little more in male than females, anterior, intermediate femora smooth, or with obsolete spines distally on ventral surface, posterior femora with spines on ventral surface; posterior tibiae of female straight, slightly flattened, of male more flattened with widest part at midpoint, armed with teeth along ventral margin.



Figures 34–37. *Dersagrena subfoveolata* (Berg) \mathcal{S} , \mathcal{Q} . **34–35** male genital capsule, ventral view **34** pg: pygophore **35** paramere **36–37** female genital segments, ventral view **36** 8 pt: paratergite eight, 9 pt: paratergite nine, vlf. 1: first valvifer **37** 8 pt: paratergite eight, vlf. 1: first valvifer, vlf. 2: second valvifer.

Thlastocoris hernandezi Brailovsky

http://coreoidea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=2210

Thlastocoris hernandezi Brailovsky 1990: 108.

Distribution. Argentina: Formosa: Gran Guardia.

Genus Zoreva Amyot & Serville

http://species-id.net/wiki/Zoreva http://coreoidea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=775 Fig. 29

Zoreva Amyot and Serville 1843: 216. Type species: Coreus dentipes Fabricius 1803: 196.

Diagnosis. (After O'Shea, 1980) Body narrow and elongated. Pronotum almost hexagonal, humeral angle developed into a long sharp spine of variable length and di-



Figure 38–41. Geographical distribution: 38 Argentina geographical location 39 Athaumastus haematicus (Stål) 40 Athaumastus subcarinatus (Stål) 41 Camptischium clavipes (Fabricius).

rection, posthumeral edge with small conspicuous teeth, posterior border straight or slightly concave. Leg dimorphic. Males: Femora ventrally armed with spines of variable length, femur anterior generally smooth texture; hind femur swollen and curved. Females: Femora armed with spines ventrally, length variable anterior and middle femora thinner and a little more drawn back, but never curved.



Figure 42–45. Geographical distribution: **42** *Crinocerus sanctus* (Fabricius), **43** *Dersagrena flaviventris* (Berg) **44** *Dersagrena subfoveolata* (Berg) **45** *Zoreva dentipes* Fabricius.

Zoreva dentipes Fabricius

http://species-id.net/wiki/Zoreva_dentipes http://coreoidea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=2516 Figs 29–33, 45

Coreus dentipes Fabricius 1803: 196.

Redescription. Holotype. Male. n=1. Total body length: 9.8; head length: 1.1; head width: 1.6; eye width: 0.3; interocular space: 0.7; preocellar distance: 0.2; interocellar space: 0.3. Rostrum: (missing). Antennal segments length: I 2.6, II 2.4, III 1.4, IV 1.8. Pronotal length: 1.8; width: 2.8. Scutellar length: 1.3; width 1.1. Length of abdomen with hemelytra: 8.5; length of abdomen with hemelytra: 8.4; abdomen width: 2.4. Dorsal coloration: Head light brown, except anterior region of ocelli and post ocular region dark brown, with many short hairs. Antennal segments 1-2 longer than 3-4, 4 longer than 3, segment 1-3 light brown, segment 4 dark brown except base, and segment 5 light brown. Pronotum are light brown except anterior margin dark brown. Scutellum brown except edges and posterior process dark brown. Connexival: two lateral segment light brown except lateral projection dark brown. Ventral coloration: light brown except area next to conexivum dark brown to brown, light brown not uniformy red. Legs: fore and middle femora dark brown, tarsi light brown with light brown spots. Mid femur with one spine distally. Fore femur dark brown with spines, basally very long, medially short and distally long. Structure: pronotum granulose; frontal angles granulose and projecting as acute spines reaching ocular tubercles; humeral angles with two rounded projections and shorter spines; scutellum granulose with pilosity. Hemelytra as long as the abdomen, brown with punctuations and pilosity, membrane dark brown.

Specimen examined. Argentina: Formosa: 1♂ Laguna Oca (26°13'56.25"S, 58°13'04.84"W).

Distribution. Argentina: Formosa: Laguna Oca.

Remarks. This is the first record of this species for Argentina

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CHECKLIST



Photosymbiotic ascidians in Singapore: turbid waters may reduce living space

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Abstract

The photosymbiotic ascidian fauna at Changi Beach, Pulau Semakau, Sentosa and St. John's Island, Singapore were surveyed. A total of five species, *Diplosoma simile, Lissoclinum bistratum, L. punctatum, L. timorense* and *Trididemnum cyclops*, were recorded, with *L. timorense* and *T. cyclops* being newly recorded in Singapore. However, no photosymbiotic species were found at Changi Beach probably due to the polluted waters in the region. Coastal development has caused Singapore waters to become turbid, leading to decrease in suitable habitats for photosymbiotic ascidians. Clean waters in Pulau Semakau probably provide a better environment for the growth of photosymbiotic ascidians and this area has a greater variety of these ascidians than the other areas in Singapore. Each of the five species has also been recorded in the Ryukyu Archipelago (Japan) and three species (*Diplosoma simile, Lissoclinum bistratum* and *Trididemnum cyclops*) have also been recorded in Taiwan.

Keywords

Algal symbiosis, Ascidian, Biogeography, Coral reefs, Didemnidae

Introduction

Photosymbioses have been known in some colonial ascidians of the family Didemnidae in tropical and subtropical waters. Photosymbionts such as *Prochloron* and *Synechocystis* are cyanobacteria (see Parry and Kott 1988; Lewin and Cheng 1989; Hirose et al. 2009b). About 30 species in four didemnid genera were described as host species (Kott 2001). Most of these ascidian hosts always harbor particular cyanobacterial species (i.e., obligate symbiosis), whereas some hosts occasionally harbor the photosymbionts (i.e., facultative symbiosis). Recent taxonomic studies described seven photosymbiotic ascidians from the Ryukyu Archipelago of Japan as new species (Oka et al. 2005; Hirose and Oka 2008; Hirose and Hirose 2009, 2011; Hirose et al. 2009a).

The biogeographic survey of photosymbiotic didemnids in Ryukyus has recorded the current distribution range for each species. To date, at least 20 photosymbiotic species are known to be distributed in Japan, mainly in the Ryukyu Archipelago (Hirose in press, and references therein). The number of species gradually decrease northward in the Ryukyu Archipelago, which ranges from around 24°N to 31°N. Nineteen species have been recorded from the Yaeyama Islands (the southernmost island group: at ca. 24°N), whereas only four species were recorded from Yakushima and Tanegashima (the northernmost islands: at ca. 30°-31°N). Taiwan (21°-25°N) is positioned close to the southernmost island group of the Ryukyu Archipelago (i.e., the Yaeyama Islands), and 10 species in total were recorded from Kenting (southern Taiwan) and Lyudao (off the southeast coast of Taiwan), but no photosymbiotic species were found in Keelung (located in northern Taiwan), probably due to the cold surface water in winter (ca. 16°C) in that region (Hirose and Nozawa 2011; Hirose and Su 2011).

Singapore is positioned at the equator and there are only a few reports on the ascidian fauna in Singapore waters (e.g., Berrill 1950; Millar 1975, 1988). Regarding photosymbiotic ascidians from Singapore, Kott (1982) listed three species, namely *Lissoclinum bistratum*, *L. punctatum*, and *Diplosoma simile*. Moreover, occurrence of some other photosymbiotic ascidians was reported as "green gum drops ascidians" awaiting identification (Wild Singapore Homepage, http://www.wildsingapore. com/wildfacts/ascidiacea/greengumdrop.htm). In view of the numbers of species recorded in Japan and Taiwan, more photosymbiotic species were expected to be found in Singapore.

During 2009-2011, we surveyed the photosymbiotic ascidians at Changi Beach, Pulau Semakau, Sentosa and St. John's Island, Singapore in collaboration with the Tropical Marine Science Institute, National University of Singapore. Herein, five photosymbiotic didemnid species were reported as additions to the marine benthic fauna of Singapore.

Material and methods

Ascidian colonies were collected by snorkeling in the shallow subtidal zone. Samples were photographed *in situ* before being collected. Collection sites were as follows:



Figure 1. Collection sites of photosymbiotic ascidians in Singapore. **A** Pulau Semakau **B** Sentosa **C** St. John's Island and **D** Changi Beach.

Changi Beach, Pulau Semakau, Sentosa, and St. John's Island (Fig. 1). The habitats consisted of sand beach, seagrass meadow, coral rubble, sheltered beach and coral reefs. The Changi Beach is a beach park located at the northeastern of Singapore. The park is approximately 3.3 km long with stretches of sandy beaches and a lot of seagrass. Pulau Semakau is located at the south of the main island of Singapore. There is a vast seagrass meadow and a wide zone of coral rubble with various marine lives and an enormous area rich in wildlife. Sentosa is a popular island resort in Singapore that includes a 2 km long sheltered beach. St. John's Island is one of the Southern Islands in Singapore. The hilly island is transformed into a tranquil getaway. Coral reefs and seagrass bed scatter in the zone. Specimens were anesthetized with menthol and 0.37 M MgCl, for approximately 2 h, and then fixed with 10% formalin-seawater. The fixed colonies were dissected under a binocular stereomicroscope and a compound microscope equipped with differential interference contrast optics. In some photomicrographs, several images were combined to increase the depth of field using the post-processing image software Helicon Focus Pro 4.2.2 (Helicon Soft, Ltd., Kharkov, Ukraine). Taxa were mainly identified following Kott (2001), Monniot and Monniot (2001), and Hirose and Su (2011). All of the specimens examined were deposited in the Raffles Museum of Biodiversity Research, Singapore (RMBR) or some of those were deposited in the National Museum of Natural Science, Taiwan (NMNS).

Results

The present report describes the occurrence of didemnid ascidians harboring prokaryotic algae from Pulau Semakau, Sentosa and St. John's Island, Singapore. In total, five species were collected, two of which were new records for Singapore. Their occurrences at each site and dates are listed in Table 1. No photosymbiotic species were found at Changi Beach.

Trididemnum cyclops Michaelsen, 1921

Trididemnum symbioticum (Peres, 1962)

Specimens examined. ZRC-TUN-0012 (St. John's Island, subtidal at depth 0.5 m).

Colonies are oval or irregularly shaped cushions of 2-6 mm on the long axis (Fig. 2A). Each zooid has a black dot, due to a pigment mass at the top of the endostyle (Fig. 2B). Berry-like spicules are distributed in the colonial margin and basal tunic, while they are rarely found in the surface tunic. Spicules are up to 40 mm in diameter (Fig. 2C). The biased distribution of the spicules allows the symbionts to receive sunlight for photosynthesis.

Diplosoma simile (Sluiter, 1909)

Diplosoma midori (Tokioka, 1954) Leptoclinum midori Tokioka, 1954 Leptoclinum simile Sluiter, 1909

Specimens examined. NMNS-7027-001, NMNS-7027-002, ZRC-TUN-0001 and ZRC-TUN-0015 (Pulau Semakau, subtidal at depth 0.5 m), ZRC-TUN-0011 (St. John's Island, subtidal at depth 0.5 m), ZRC-TUN-0009 (Sentosa, subtidal at depth 0.5 m)

Colonies are irregularly shaped sheets about 2 mm thick without spicules (Fig. 2D). They are entirely green due to the *Prochloron* cells in the common cloacal

Location	Changi Beach	Pulau Semakau			St. John's Island		Sentosa
Date	2011 Nov	2009 Dec	2010 May	2011 Nov	2010 May	2011 Nov	2010 April
Trididemnum cyclops					+		
Diplosoma simile			+	+	+		+
Lissoclinum bistratum		+	+	+			+
Lissoclinum punctatum			+	+	+		
Lissoclinum timorense		+	+	+			

Table 1. Distribution records of photosymbiotic didemnid ascidians in Singapore.

cavities. The thorax has four stigmatal rows: there are six stigmata in the first (top), second, and third row and five stigmata in the fourth row (bottom). The retractor muscle emerges from the bottom of the thorax (Fig. 2E). Testis and/or egg are found in some zooids, and vas deferens is uncoiled. Kott (1982) reported this species from Singapore. This is one of the most common species in the didemnid-*Prochloron* obligate symbioses in the tropical Pacific, and it has also been recently found in Caribbean Panama (Hirose et al., 2012).

Lissoclinum bistratum (Sluiter, 1905)

Didemnum bistratum Sluiter, 1905 Didemnum gottschaldti Tokioka, 1950 Didemnum pulvinum Tokioka, 1954 Leptoclinum bistratum (Sluiter, 1905) Lissoclinum pulvinum (Tokioka, 1954)

Specimens examined. NMNS-7027-003, NMNS-7027-004, ZRC-TUN-0002, ZRC.TUN.0004, ZRC-TUN-0007, ZRC-TUN-0008 and ZRC-TUN-0014 (Pulau Semakau, subtidal at depth 0.5 m), ZRC-TUN-0010 (Sentosa, subtidal at depth 0.5 m).

Colonies are oval cushions of 4 mm on the long axis (Fig. 2F). The photosymbiont *Prochloron* gives the colonies a green color, while the colonial margin and bottom are white due to dense aggregations of globular spicules in the tunic (Fig. 2G). The thorax has four stigmatal rows. It is difficult to count accurately the number of stigmata owing to the distortion of thoraxes caused by the shrinkage of zooids upon fixation. There are about seven stigmata in each row. Some zooids have a testis with an uncoiled vas deferens (Fig. 2H). Kott (1982) reported this species from Singapore.

Lissoclinum punctatum Kott, 1977

Specimens examined. NMNS-7027-007, ZRC-TUN-0005 and ZRC-TUN-0016 (Pulau Semakau, subtidal at depth 0.5 m), ZRC-TUN-0013 (St. John's Island, subtidal at depth 0.5 m)

Colonies are irregularly shaped sheets about 2 mm thick (Fig. 2I). Globular spicules aggregate around each zooid, which is enclosed in a capsule of white spicules (Fig. 2J). Many *Prochloron* cells are distributed in both cloacal cavities and tunic cells (tunic phycocytes) (Fig. 2K; also see Hirose et al. 1996). We could not examine the zooids in further detail because of the shrinkage of the specimens. Kott (1982) reported this species from Singapore.



Didemnum timorensis Sluiter, 1909 Didemnum voeltzkowi Michaelsen, 1920 Lissoclinum timorensis (Sluiter, 1909) Lissoclinum voeltzkowi (Michaelsen, 1920)

Specimens examined. NMNS-7027-005, NMNS-7027-006, ZRC-TUN-0003, ZRC-TUN-0006 and ZRC-TUN-0017 (Pulau Semakau, subtidal at depth 0.5 m)

Colonies are irregularly shaped sheets about 2–5 mm thick (Fig. 2L). The colonies are green due to *Prochloron* cells distributed in the common cloacal cavities, while the colonial margin and bottom are white due to the dense distribution of stellate and globular spicules. In the five zooids we examined, the thorax had four stigmatal rows: there were seven stigmata in the first row (top), eight in the second row, seven in the third row, and five or six in the fourth row (bottom) (Fig. 2M). Gonads are not found in the present specimens. There are globular spicules in the tunic (Fig. 2N). The presence of stellate spicules easily distinguishes the present species from *L. bistratum*, which lacks these spicules. However, Monniot & Monniot (2001) proposed to regard *L. timorense* as a junior synonym of *L. bistratum*, because the two species differ only in the shape of spicules and there are no distinctive features in the zooids and larvae. The phylogenetic trees established using the partial sequences of cytochrome oxidase subunit I gene did not discriminate the two species, which are distinguished only by the spicule shapes (Hirose et al., 2010).

Discussion

Five photosymbiotic ascidians were recorded in the present survey, including three species previously observed by Kott (1982) and two new records in Singapore. There were

Figure 2. Photosymbiotic ascidians collected. **A** *Trididemnum cyclops*, St. John's Island, Singapore (Depth = 0.5 m). Colonies are 2–6 mm on the long axis **B** Thorax of *Trididemnum cyclops*. Arrows indicate the endostylar pigment cap. Scale bar = 100 mm. **C** Tunic spicules in the tunic of *Trididemnum cyclops*. Scale bar = 100 mm **D** *Diplosoma simile*, Pulau Semakau, Singapore (Depth = 0.5 m). Colonies are approximately 15 mm in diameter **E** Thorax of *Diplosoma simile* (left view). Scale bar = 100 mm **F** *Lissoclinum bistratum*, Pulau Semakau, Singapore (Depth = 0.5 m). Colonies are approximately 5 mm in diameter **G** Tunic spicules in the tunic of *Lissoclinum bistratum*. Scale bar = 100 mm **H** A testis with an uncoiled vas deferens of *Lissoclinum bistratum*. Scale bar = 100 mm **I** *Lissoclinum punctatum*, Pulau Semakau, Singapore (Depth = 0.5 m). Colonies are approximately 10 mm in diameter **J** Tunic spicules in the tunic of *Lissoclinum punctatum*. Scale bar = 100 mm **K** Tunic phycocytes of *Lissoclinum punctatum*. Scale bar = 100 mm **K** Tunic phycocytes of *Lissoclinum punctatum*. Scale bar = 100 mm **K** Tunic spicules in the tunic of *Lissoclinum timorense*, Pulau Semakau, Singapore (Depth = 0.5 m). Colonies are approximately 10 mm in diameter **M** Thorax of *Lissoclinum timorense* (left view) **N** Tunic spicules in the tunic of *Lissoclinum timorense*. Scale bar = 100 mm. **r**, retractor muscle; ts, testis; vd, vas deferens.

four species in Pulau Semakau, three species on St. John's Island and two species in Sentosa, but no photosymbiotic species were found at Changi Beach. The five species listed here might be far from the entire coverage of the photosymbiotic ascidian fauna in Singapore, because the present survey was conducted over a very short period of time and at only four sites. It is expected that more species still remain to be recorded.

Once, there were over 60 offshore islands and patch reefs around Singapore, most of which were situated south of mainland Singapore. However, since the mid 1970s, Singapore has been undergoing coastal reclamation. As its population grows until more than four million, the Singapore government faces problem in providing ample land. Some of offshore islands in Singapore have been deformed or enlarged by some coastal reclamation projects. Many of the coral reef organisms were smothered by reclamation, while others were severely affected by the resulting increase in water turbidity. The high turbidity of waters restricts light penetration, and determines the maximum distribution depth for corals and photosymbiotic ascidians. Visibility has been reduced from 10 m in the 1960s to 2 m or less to date (Coral Reefs of Singapore, http://coralreef. nus.edu.sg/). As a result, up to 60% of the live coral cover has been lost in Singapore since 1986 (Chou 2006). We had recorded three species (Trididemnum cyclops, Diplosoma simile and Lissoclinum punctatum) at St. John's Island in May 2010, but since then we were unable to find any photosymbiotic ascidians at the island. There were also two species of photosymbiotic ascidians, Diplosoma simile and Lissoclinum bistratum, in Sentosa. Interestingly, no photosymbiotic species were found at Changi Beach in the present survey, although its latitude is comparable with that of Pulau Semakau. Although these results do not conclusively demonstrate the absence of photosymbiotic ascidians at Changi Beach, photosymbiotic species must be rare there.

The coastal environment of Singapore is limited and currently severely affected by coastal development and the port industry, which is one of the biggest economic businesses in the country. Harbor limits occupy most of the territorial waters, and reclamation has transformed considerably almost the entire southern and northeastern coasts of the main island (Chou and Goh 1998). Most of the coastal waters are filled with suspended particles that block photosynthetic activities of marine organisms. When these particles sink, they settle over sessile organisms, such as photosymbiotic ascidians, and adversely affect their metabolism and growth (Dionisio-Sese et al. 2001). In 1999, when the last remaining landfill on Singapore's mainland was exhausted, the Semakau Landfill was created by enclosing Pulau Semakau and a small adjacent island (Pulau Sakeng) with a rock bund. However, the original Pulau Semakau, which was not affected by the landfill construction, has an enormous intertidal area rich in amazing wildlife. There is a wide zone of coral rubble with various marine lives, leading to the coral reefs that line the edge of the island. Clean waters in Pulau Semakau provide a better environment for the growth of photosymbiotic ascidians that are able to perform both photosynthesis and suspension feeding. In Pulau Semakau, we recorded four species of photosymbiotic ascidians, namely, Diplosoma simile, L. bistratum, L. *punctatum* and *L. timorense* and it is the area in Singapore with the greatest variety of photosymbiotic ascidians.

Location	Japan	Taiwan	Singapore
Didemnum molle	+	+	
Diplosoma aggregatum	+	+	
Diplosoma gumavirens	+	+	
Diplosoma ooru	+	+	
Diplosoma simile	+	+	+
Diplosoma simileguwa	+	+	
Diplosoma variostigmatum	+		
Diplosoma virens	+	+	
Diplosoma watanabei	+		
Lissoclinum bistratum	+	+	+
Lissoclinum midui	+		
Lissoclinum patella	+		
Lissoclinum punctatum	+		+
Lissoclinum timorense	+		+
Lissoclinum triangulum	+		
Trididemnum clinides	+	+	
Trididemnum cyclops	+	+	+
Trididemnum miniatum	+		
Trididemnum nubilum	+		

Table 2. Distribution records of photosymbiotic didemnid ascidians in Japan, Taiwan and Singapore.

(Hirose and Nozawa 2011; Hirose and Su 2011; Hirose in press, and references therein)

More than 20 photosymbiotic species are known to be distributed in Japan, mainly in the Ryukyu Archipelago (Hirose in press, and references therein) and 10 species in total were recorded in Taiwan (Hirose and Nozawa 2011, Hirose and Su 2011) (Table 2). Only five species were recorded in Singapore, and each of them had also been recorded in Japan. Among them, *Diposoma simile, Lissoclinum bistratum* and *Trididemnum cyclops* were also recorded in Taiwan. The climate of Singapore is typically wet equatorial, with high temperature and high annual precipitation. The average sea surface temperature is about 29°C. The optimum temperature for *Prochloron* is 35° to 40°C, as the temperature range for proper photosynthesis is between 20°C and 45°C (Dionisio-Sese et al. 2001). Alberte et al. (1986) also showed that photosynthesis of *Prochloron* was fairly sensitive to temperature; the photosynthetic activity at 25°C is only half of that at 30°C, and it falls almost to 0 at 20°C. This sensitivity of *Prochloron* to low temperature may be a prime factor limiting the distribution of this species to tropical waters.

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SHORT COMMUNICATION



A specialist's audit of aggregated occurrence records: An 'aggregator's' perspective

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Abstract

A recent ZooKeys' paper (Mesibov 2013: http://www.pensoft.net/journal_home_page.php?journal_id=1 &page=article&SESID=df7bcb35b02603283dcb83ee0e0af0c9&type=show&article_id=5111) has high-lighted data quality issues in aggregated data sets, but did not provide a realistic way to address these issues. This paper provides an aggregator's perspective including ways that the whole community can help to address data quality issues. The establishment of GBIF and national nodes (national aggregators) such as the Atlas of Living Australia (ALA) have integrated and exposed a huge diversity of biological observations along with many associated issues. Much of the admirable work by Mesibov (2013) was enabled by having the data exposed.

Data quality, one of the highest priorities for GBIF, the national nodes and other aggregators, depends on both automatic methods and community experts to detect and correct data issues. Not all issues can however be automatically detected or corrected, so community assistance is needed to help improve the quality of exposed biological data. We do need to improve the infrastructure and associated processes to more easily identify data issues and document all changes to ensure a full record is permanently and publicly available.

Keywords

Australia, occurrence records, data quality, data cleaning, ALA, GBIF, millipede, fitness for use

Introduction

Mesibov's paper (Mesibov 2013) was a welcome audit and critique of millipede records in three sources: Millipedes of Australia (MoA; http://www.polydesmida.info/millipedesofaustralia/); the Global Biodiversity Information Facility (GBIF; http://www. gbif.org/) and the Atlas of Living Australia (ALA; http://www.ala.org.au/), the Australian node for GBIF. This paper identified a range of known issues about data that the authors and broader biodiversity informatics community would like to see addressed as efficiently as possible.

The establishment of GBIF in 2001 seeded a wide range of positive national and international developments. For example, GBIF strongly supported Biodiversity Information Standards (Taxonomic Databases Working Group) in the development of standards such as Darwin Core and ABCD (http://www.tdwg.org) that are required for the efficient communication of biological records among agencies. A wide range of publications has also been commissioned by GBIF, a number of which address data quality issues (E.g., Chapman 2005a and 2005b; Costello et al. 2012). The requirement of GBIF for participating countries to set up national nodes has also focused attention on the status of national biological records. As with any advances however, there is potential for misinterpretation of aims and outcomes coupled with an expectation that agencies such as GBIF will run before they can crawl – data issues are being addressed but not as fast as the community would wish.

The following points need to be considered in addressing data issues:

- 1. Data quality and the ability to clean and correct data are the responsibility of the community and cannot be assigned to any one agent in the process. There is the need to seamlessly integrate expert knowledge and automated processes.
- 2. Herbarium or museum records, or even a single collector's records, are all aggregations of records taken at different times and by different collectors. In the digital world, the flow of biological observations can go from observer to end user through multiple digital aggregators. Mesibov (2013) too is a data aggregator of Australian millipedes. At any node in the flow, errors can be detected, introduced or addressed.
- 3. Data should be published in secure locations where they can be preserved and improved in perpetuity. This means moving beyond storage of data by individuals, or on stand-alone computers, or even in institutions that do not have a strategy for enduring digital storage and access.
- 4. We need an effective way to support experts so all amendments form part of a persistent digital knowledge about species. Talented and committed individuals can make enormous progress in error detection and correction (as seen in Mesibov 2013) but how do we ensure that when an individual project like that on millipedes ceases, the data and all associated work are not lost? How do we achieve this in situations when different experts are able to contribute to dif-

ferent aspects of correcting the same data (some working on fine-scale georeferencing, some on taxonomy, etc.)? All of this implies standards in capturing and linking this information and maintaining the data with all amendments documented. To achieve this the biodiversity research community needs to be motivated and empowered to work in a collaborative fashion.

- 5. We need to move from a mind-set based on historical approaches that managed paper-based information to one where all relevant information is generated, managed and curated in a fully interlinked form. We need to build a comprehensive digital global knowledgebase for biodiversity to replace our paper-based knowledgebase.
- 6. Addressing data errors will involve the 'aggregators' improving their ability to detect and correct errors. These organisations have a responsibility to deliver automated mechanisms wherever possible and to facilitate new processes and tools that will support the other aspects listed above.

Discussion

'Data quality' is one of the highest priorities for agencies such as GBIF and the ALA, as well as one of the main concerns of users of data (see Otegui et al. 2013). In both agencies, considerable resources have been assigned to help identify and address errors within data records. For example, the ALA appointed a specialist for a year to assist in establishing tools and methods to help identify data issues. This work is ongoing.

While data quality is of the highest concern, published data have many different uses. Data may not need to be 100% accurate for them to have utility. Quality issues affecting some users may be of secondary or no importance to others. For example, a locational inaccuracy of 20km on a record will not invalidate its use with regional or continental scale studies. Access to information on a type specimen is likely to be of value even if georeferences are incomplete or incorrect. The term 'fitness for use' may therefore be more appropriate than 'data quality' in many circumstances. This is not an excuse to ignore errors, but recognition that effective use depends on knowledge of the data involved.

The goal of the aggregators is to address known problems in data, to understand how much confidence is appropriate in each element of each record and to enable users to filter data based on these confidence measures. The philosophy of most of the aggregators is therefore to flag potential issues, correct what is obviously correctable and expose the flag rather than hide or remove the associated record.

One of the most powerful outcomes of the publishing of digital data is that inherent problems in legacy data are revealed despite the concerted work of dedicated taxonomists over decades or longer. Data are highly variable and not always reliable. Exposing data provides the opportunity for the community to detect and correct errors. Indeed, much of the admirable work achieved by Mesibov (2013) was enabled by having data exposed by the institutions concerned. As noted by Mesibov (2013), querying and correcting records with a museum often required an email or a phone call. However, museums and herbaria do not always have the infrastructure that agencies like GBIF and the ALA have for interrogation and correction of records. GBIF and the ALA's expertise is in the area of information technology and biodiversity informatics and better placed to provide online infrastructure support.

GBIF seeks to stimulate best practice in biodiversity data publishing and this includes addressing data quality at the source. There are a range of freely available tools, documents and training programs covering issues such as data cleaning (see http:// www.gbif.org/orc and http://www.gbif.org/participation/training/). GBIF also emphasises the value of comprehensive metadata including the option of peer reviewed 'data papers' for enhancing the fitness for use of published data (see http://www.gbif. org/communications/news-and-events/showsingle/article/new-incentive-for-biodiversity-data-publishing).

Specialist domain expertise is required to detect and correct a range of error types, as is shown by Mesibov's (2013) expertise with Australian millipedes. The ALA and GBIF do not generally have this type of expertise. They do however have expertise to build infrastructure that enables integrated data to be openly discovered and where errors are more likely to be exposed. Agencies such as GBIF and the ALA are also in a good position to provide infrastructure and processes that help to address data issues. An example of the quality controls undertaken by the ALA can be seen in Table 1. Other examples from GBIF and national nodes are given below and in the Appendix.

There are two types of data quality issues, those that can be detected without domain specific taxonomic expertise and those that require domain specific taxonomic expertise for detection. Correction of detected issues may or may not require domain specific expertise (see Table 2). Obviously GBIF and the ALA have many tools that can help address Type 3 and 4 cases. For example, an observation of a terrestrial species that occurs in a marine environment would be Type 3 if the true location of the observation was known and Type 4 if not.

Many of the issues that Mesibov (2013) raised fall into Type 1, for example "Provider G supplied 67 records with the wrong species names, i.e. incorrect specimen identifications. I supplied correct identifications for these records in 2005...". 'Aggregators' such as GBIF and the ALA should strive to address all Type 4 (e.g., a transposition of longitude and latitude) and highlight Type 3 issues (e.g., a marine species on land). We would assume that Type 2 examples would be rare: The domain specific taxonomic expertise required to detect the issue would also be able to make correction possible (Type 1).

A more fundamental issue is that most biodiversity data today are managed and published through a wide range of heterogeneous databases and processes. Consistency is required for guaranteed, stable, persistent access to each data record and in establishing standardised approaches to registering and handling corrections. Any aggregator has a key role in addressing this challenge but ultimately it will depend on widespread changes in the culture of biodiversity data management.

#	FLAG	% of records
1	Missing coordinate precision	90.2%
2	Geodetic datum assumed WGS84	44.4%
3	Decimal Latitude Longitude Converted	27.6%
4	Unrecognized geodetic datum	21.1%
5	Coordinate uncertainty not specified	18.6%
6	Possible duplicate record	8.4%
7	Invalid collection date	8.0%
8	No collection date supplied	4.1%
9	Coordinate uncertainty not valid	2.6%
10	Habitat incorrect for species (user flagged issue category)	2.4%
11	Name not in national checklists	2.3%
12	Basis of record not supplied	2.1%
13	Altitude value non-numeric	2.0%
14	Name not in any national or international checklists	1.1%
15	Suspected outlier (user flagged issue category)	1.0%
16	Type status not recognized	<1%
17	Basis of record badly formed	<1%
18	Coordinates don't match supplied state	<1%
19	Supplied country not recognized	<1%
20	Image URL invalid	<1%
21	Supplied coordinates are zero	<1%
22	Collection code not recognized	<1%
23	Min and max depth reversed	<1%
24	Unparseable verbatim coordinates	<1%
25	Coordinates derived from verbatim coordinates	<1%
26	Latitude is negated	<1%
27	Depth value non-numeric	<1%
28	Outside expert range for species	<1%
29	Longitude is negated	<1%
30	Min and max altitude reversed	<1%
31	Coordinates were transposed	<1%
32	Decimal Lat/Long calculated from easting-northing (grid reference)	<1%
33	Supplied coordinates centre of state	<1%
34	Coordinate precision and uncertainty transposed	<1%
35	Coordinates are out of range for species	<1%
36	Decimal Lat/Long calculated from Easting Northing Failed	<1%
37	Coordinates centre of country	<1%
38	Geospatial issue (user flagged issue category)	<1%
39	Day and month transposed	<1%
40	Depth out of range	<1%
41	Taxon misidentified (user flagged issue category)	<1%
42	Taxonomic issue (user flagged issue category)	<1%
43	Temporal issue (user flagged issue category)	<1%
44	Altitude out of range	<1%

Table 1. Example of automated data checks within the Atlas of Living Australia.

		Domain specific expertise required to address issue?		
		Yes	No	
fic expertise tect issue?	Yes	Type 1	Type 2	
Domain speci required to de	No	Type 3	Type 4	

Table 2. A two-way decision table of issue detection versus correction.

Manual checking as demonstrated by Mesibov (2013) is time consuming yet necessary for a range of issues where automated checking cannot be guaranteed to find and correct issues. GBIF and the ALA do have an extensive suite of automated checks ('rules set', see Table 1 and https://docs.google.com/spreadsheet/ccc?key=0AjNtzhUII HeNdHJOYk1SYWE4dU1BMWZmb2hiTjlYQlE#gid=0). As pointed out by Mesibov (2013) however, they do not always work, but such checks and corrections remain a cost-effective and necessary step. A more robust rule set is in continual development and Mesibov's paper will help with this. Contributions to these rules by the community would be appreciated.

The ALA has also established a sophisticated annotations service that enables crowd sourcing to detect and correct data errors (see http://www.ala.org.au/blogs-news/an-notations-alerts-about-new-annotations-and-annotations-of-interest/). Such detected issues, with potential corrections are returned to the data provider. This is the second flow model of Mesibov (2013), viz.

specialist \rightarrow GBIF, ALA \rightarrow data providers \rightarrow OZCAM \rightarrow GBIF, ALA

This model as well as Mesibov's first model, viz.,

specialist \rightarrow data providers \rightarrow OZCAM \rightarrow GBIF, ALA

will, as noted above, depend on the resources of the data provider. Users of the GBIF data portal can also report errors which are relayed by email directly to the original data publishers. Sadly, however, museums and herbaria may not have staff resources to update their databases when issues are reported.

There is no doubt that communication between the relevant taxonomic domain experts to correct problems will be most efficient. Errors will remain if that expertise no longer resides with the data provider, or that provider doesn't have the resources.

Data providers have diverse expectations. Some data providers encourage the ALA to make corrections to the provider's records (for provider and ALA). Other data pro-
viders would withdraw their support if similar changes were attempted on their data by the ALA. Feedback from the ALA to a data provider may result in immediate corrections (and data propagation) while in other cases, the provider has no resources to resolve an issue. There is no single process here that will work effectively in all circumstances. We do however take Mesibov's paper as a prod to seek best current practice among providers and aggregators to improve data quality.

At the global level, GBIF's current Work Programme includes provision for an upgraded data portal, being rolled out progressively from 2013, to also support an annotations service. The Botanical Garden and Botanical Museum Berlin-Dahlem (BHBM), which hosts the GBIF node for Germany, has prototyped a generic annotations system for biodiversity data known as Annosys (see http://wiki.bgbm.org/annosys/index.php/Main_Page).

Conclusions

Agencies such as the ALA and GBIF enable observations to be recorded directly to their systems. These records are reviewed before being 'published', but the ALA and GBIF are not the data provider and therefore cannot assume responsibility for these records; disclaimers are therefore necessary.

There is however full agreement that aggregators such as GBIF and the ALA have a responsibility to detect and where possible address data issues with the data provider's permission and support. There is no doubt that data errors are best addressed through collaboration between all relevant agencies. GBIF itself and projects such as CReA-TIVE-B (http://creative-b.eu) are in a good position to facilitate such collaboration on the development of broadly agreed tools and processes.

Agencies such as GBIF and the ALA have the mandate to expose a large volume of data records in a systematic format. The aggregation process can itself result in an enhanced ability to identify errors. For example the ALA uses a tool that examines the environmental envelope associated with a species to help identifier environmental outliers. This process would not be possible without a critical mass of observations.

What ideally is needed is an environment created by agencies such as GBIF and the ALA that *efficiently* enables

- 1. Exposure of errors
- 2. Discussion of the errors
- 3. Addressing errors directly in *all relevant locations*

No such environment currently exists. Progress will be limited while the underlying culture of data publishing and data management does not support stable, long-term reference to each data record and community-based curation of those data in a way that ensures that each act of correcting any aspect of any data element is not lost but contributes to the development of a global digital biodiversity knowledgebase. However, it will also require a fundamental change in data management at the institutional and personal level. All data needs to be published in stable locations where it can be preserved and improved in perpetuity and the biodiversity research community needs to be motivated and empowered to do its work in an online collaborative way. A recent paper sponsored by GBIF (Costello et al. 2012), among other things, applauds data publishing but suggests that data quality could be improved by peer review.

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Appendix

Examples of data quality routines that are in place or under development by GBIF national nodes and other data aggregators are included here to indicate that data quality is both a high-priority and a rapidly developing area in our community.

The Atlas of Living Australia (ALA) is covered above.

GBIF Norway checks all scientific names against the Norwegian Species Name Database (Artsnavnebasen). Names that do not match are collected into a list and returned to the data owner, but unless anything is obviously wrong, the record is still served to the GBIF network. The coordinates of all georeferenced records are converted to WGS84 and matched against a country bounding box and a municipality bounding box. Coordinates that do not match the country and municipality bounding boxes are collected and returned to the data owner. Country names, county names and municipality names are matched against lists of approved names. Dates are validated, and for certain datasets they are matched against a known start date and end date.

8.6 million citizen science records served from the Norwegian Biodiversity Information Centre's species observation portal (http://www.artsobservasjoner.no/) are validated by other citizens and by a scientific expert panel. Only valid names from the official Norwegian list of taxa present in Norway are shared with GBIF, pending validation by a scientific name committee.

The United Kingdom's National Biodiversity Network (NBN) is engaging with experts to develop rules to help screen data – for example relating to known distributions or migration periods. If a record falls outside these rules it is flagged for further scrutiny – not implying that it is wrong but 'interesting' in that it changes our understanding of the species if proven correct. The NBN has developed a desktop tool called Record Cleaner (http://www.nbn.org.uk/record-cleaner.aspx). This tool enables a data publisher to access the source (for example a database or spreadsheet) for screening, thus identifying potential issues before publication. Record Cleaner both validates (checking syntax) and verifies (checking against expert rules). The rules are being integrated into NBN's online recording service, alerting wildlife recorders to 'interesting' records at the point of entry, helping to detect problems early and indicating that additional information or evidence may be required.

GBIF Spain places particular emphasis on data quality, for example operating a 'Biodiversity Data Quality Hub' (http://www.gbif.es/BDQ.php) bringing together tools for error detection and validation of biodiversity data (Otegui et al. 2013). These tools include the Darwin Test tool (http://www.gbif.es/darwin_test/Darwin_Test_ in.php) developed by GBIF Spain to validate data entered in Darwin Core format. As a complement to this tool, the node provides an 'apparent quality index' (http:// www.gbif.es/ICA.php) applied to all datasets published by Spanish participants, which enables a record to be kept of increases in quality as well as quantity of biodiversity data published from institutions in Spain. GBIF Spain's work on data quality has formed the basis of a number of training workshops and online learning modules involving several countries in Latin America, Africa and Europe (see for example http:// www.gbif.org/orc/?doc_id=2914&l=en, http://www.gbif.org/participation/training/ events/training-event-details/?eventid=203, http://www.gbif.es/formaciondetalles. php?IDForm=109, http://elearning.gbif.es/AContent/home/index.php).

GBIF Colombia (Sistema de información sobre biodiversidad de Colombia) has focused on data quality within the country's biological institutions as part of a recent overhaul of its data publishing and access service (see www.sibcolombia.net). The node is in the process of implementing several tools and protocols on data cleaning, including adaptation of some of the tools developed by GBIF Spain and a customized taxonomic and geographic validation tool for biodiversity records in Colombia and neighbouring countries (see http://code.google.com/p/verificacion-registros-biologicos/). The node is also working on an online data validator using Google Docs.

CRIA Brazil, (the Reference Center on Environmental Information) is a notfor-profit, non-government organization whose aim is to contribute towards a more sustainable use of Brazil's biodiversity through the dissemination of high quality information and education. CRIA has had an extensive and illustrious history in the development of tools for analysing and cleaning biological records, see http://splink. cria.org.br/tools?criaLANG=en.