RESEARCH ARTICLE



A revision of the continental species of Copa Simon, 1885 (Araneae, Corinnidae) in the Afrotropical Region

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Abstract

The cryptic ground-dwelling castianeirine genus *Copa* Simon, 1885 (Araneae: Corinnidae) is revised in the continental Afrotropical Region. The type species of the genus, *C. flavoplumosa* Simon, 1885, is redescribed and considered a senior synonym of *C. benina* Strand, 1916 syn. n. and *C. benina nigra* Lessert, 1933 syn. n. It is widespread throughout the Afrotropical Region but has not been introduced to any of the associated regional islands. A new species, *Copa kei* sp. n., is described from South Africa. *Copa agelenina* Simon, 1910, originally described from a subadult female from southern Botswana, is considered a *nomen dubium. Copa flavoplumosa* is a characteristic species of leaf litter spider assemblages and is particularly prevalent in savanna habitats on the continent, but also occurs in various forest types, grasslands, fynbos and semi-arid Nama Karoo habitats. In contrast, *C. kei* sp. n. has only been recorded from Afromontane and coastal forests in south-eastern South Africa.

Keywords

Castianeirinae, cryptic, ground-dwelling, litter, lycosiform, nomen dubium, spider, taxonomy

Introduction

The spider genus *Copa* Simon, 1885 (Araneae: Corinnidae) is only known from the Afrotropical and Palaearctic Regions, and some of the species from the latter have recently been studied by Deeleman-Reinhold (1995, 2001). Deeleman-Reinhold (2001) described the genus *Echinax* to include three species of *Copa* from South-East Asia that she had earlier described in 1995, and an additional new species. Yang et al. (2004) subsequently described a fifth species of *Echinax* from China. Thus, only two Asian species of *Copa* remain, both described from Sri Lanka (Simon 1896). Prior to this revision, seven species and one subspecies of *Copa* were known from the Afrotropical Region (Dippenaar-Schoeman and Jocqué 1997), of which one described by Simon (1909) has been transferred to *Echinax* (Haddad 2012a). Another species, described by Strand (1916), will be transferred to a new castianeirine genus (Haddad 2012b in prep.).

Although most genera in this subfamily resemble ants, *Copa* species have cryptic colouration and closely resemble wolf spiders of the family Lycosidae (Figs 1–6), a characteristic shared with *Echinax* and two undescribed lycosiform castianeirine genera (Haddad 2012a, b, in prep.). *Copa* are very common spiders in the leaf litter of various habitats and are predominantly ground-living, occurring widely in savanna woodlands but also occasionally in forests, where they are well camouflaged. They usually share litter microhabitats with species of several other castianeirine genera, including *Cambalida* Simon, 1909, *Merenius* Simon, 1909 and *Castianeira* Keyserling, 1879 (Haddad 2012b, 2012c). *Copa flavoplumosa* Simon, 1885 is also recorded here from drier habitats, including fynbos, grassland and Nama Karoo in South Africa and the arid savannas of north-western South Africa, Botswana and Angola, thereby showing considerable ecological flexibility and adaptability. In contrast, the species of the other three cryptic lycosiform genera are primarily arboreal and are rarely collected in leaf litter.

The current study presents the first revision of the continental Afrotropical species of the genus, and the Madagascan fauna, including two species described by Simon (1903) and Strand (1907) and nearly 30 new species, will be treated at a later stage in a separate paper.

Material and methods

All specimens examined during this study were observed in 70% ethanol using a Nikon SMZ800 stereomicroscope for descriptions, digital photographs and measurements. A series of digital photographs of the male emboli of each species were taken using a Nikon Coolpix 8400 mounted on a Nikon SMZ800 stereomicroscope. The photographs were then stacked using Combine ZM software (http://www.hadleyweb. pwp.blueyonder.co.uk) to increase depth of field. Photographs of live *C. flavoplumosa* and *C. kei* sp. n. were taken in the field using a Canon EOS 40D digital camera



Figures 1–6. General habitus photographs of *Copa flavoplumosa* Simon, 1885 **(1–4)** and *C. kei* sp. n. **(5, 6)**: **I** female from Lesideng Research Camp, Botswana **2** female from Livingtone, Zambia **3** male and **4** female from Wildlives Game Farm, Zambia **5** female from Hogsback, South Africa **6** male from Cwebe Nature Reserve, South Africa.

with 50mm or 100mm macro lenses. Material of both aforementioned species was prepared for scanning electron microscopy by dehydrating the specimens in a graded ethanol series and critical-point drying them in an argon chamber, after which they were fixed to aluminium stubs and sputter-coated with gold three times for three minutes. The material was then studied in a JEOL 6400 WinSEM and digital micrographs were taken.

All measurements are given in millimetres (mm). Total body length measurements are given for the smallest and largest specimens of each sex to give an indication of size variation, and body, eye and leg measurements are given for the specimens indicated in the descriptions. Descriptions of the eye arrangements are given for the anterior view of the anterior eye row and dorsal view of the posterior eye row. The epigynes and male palps of each species were dissected, cleaned in a Labcon 5019U ultrasonic bath in 70% ethanol for 30 seconds, and drawn. Scale bars were added to all microscope photographs and illustrations in Corel Draw 14.0.

Abbreviations used in the descriptions are as follows: AER – anterior eye row; AL – abdomen length; ALE – anterior lateral eye; ALS – anterior lateral spinneret(s); AME – anterior median eye; AW – abdomen width; CL – carapace length; CW – carapace width; FL – fovea length; MOQ – median ocular quadrangle; MOQAW – median ocular quadrangle anterior width; MOQL – median ocular quadrangle length; MOQPW – median ocular quadrangle posterior width; PER – posterior eye row; PERW – posterior eye row width; PLE – posterior lateral eye; PLS – posterior lateral spinneret(s); PME – posterior median eye; PMS – posterior median spinneret(s); SL – sternum length; ST – spermatheca; SW – sternum width; TL – total length. Leg spination follows the format of Bosselaers and Jocqué (2000) and includes the following abbreviations: do – dorsal; pl – prolateral; plv – prolateral ventral; rl – retrolateral; rlv – retrolateral ventral; vt – ventral terminal.

The material examined in this study is deposited in the following institutions (curators given in parenthesis):

AMNH	American Museum of Natural History, New York, USA (Norman Platnick)
BMNH	British Museum of Natural History, London, UK (Janet Beccaloni)
CAS	California Academy of Sciences, San Francisco, USA (Charles Griswold)
MNHG	Museum of Natural History, Geneva, Switzerland (Peter Schwendinger)
MNHN	Museum National d'Histoire Naturelle, Paris, France (Christine Rollard)
MRAC	Royal Museum for Central Africa, Tervuren, Belgium (Rudy Jocqué)
NCA	National Collection of Arachnida, ARC - Plant Protection Research Institute,
	Pretoria, South Africa (Ansie Dippenaar-Schoeman)
NMBA	National Museum, Bloemfontein, South Africa (Leon Lotz)
NMSA	KwaZulu-Natal Museum, Pietermaritzburg, South Africa (Audrey Ndaba)
NMZA	National Museum of Zimbabwe, Bulawayo, Zimbabwe (Moira FitzPatrick)
PCRS	Personal collection of Tony Russell-Smith, Sittingbourne, UK
SAMC	Iziko South African Museum, Cape Town, South Africa (Margie Cochrane)
TMSA	Ditsong National Museum of Natural History, Pretoria, South Africa
	(Robin Lyle)
ZMB	Zoologisches Museum, Berlin, Germany (Jason Dunlop)
ZMUC	Zoological Museum, University of Copenhagen, Denmark (Nikolaj Scharff)

Where locality co-ordinates were not provided on specimen labels or were not available in the institutional databases, they were traced using the Global Gazetteer Version 2.2 (www.fallingrain.com) and are indicated in square brackets. Distribution maps were produced using the online mapping software SimpleMappr (Shorthouse 2010).

Taxonomy

Family Corinnidae Karsch, 1880 Subfamily Castianeirinae Reiskind, 1969

Genus Copa Simon, 1885

http://species-id.net/wiki/Copa

Copa Simon 1885: 395; Simon 1897: 173; Reiskind 1969: 165; Dippenaar-Schoeman and Jocqué 1997: 128; Deeleman-Reinhold 2001: 359.

Type species: Copa flavoplumosa Simon, 1885, by monotypy.

Diagnosis. *Copa* can be recognised from other cryptic lycosiform Castianeirinae, particularly *Echinax* and two undescribed Afrotropical lycosiform genera, by the presence of fine proximal and distal dorsal setae on the anterior patellae (Figs 24, 34), and proximal and distal spines on the posterior patellae (Fig. 35), which are clearly shorter than the particular leg segment; in *Echinax* all of the patellae have well-developed spines that are longer than the patella, and in the two undescribed genera the proximal structure on the posterior patellae is a fine seta rather than a spine, as is the case in *Copa*. Further, the AME are approximately 1.25–1.50 times ALE diameter in *Copa* (Figs 14, 15, 19), while at least twice the diameter in *Echinax* and 1.25 times or less in the two undescribed genera. Lastly, the carapace of *Copa* is 3.30–3.75 times broader than the PER, while less than 3 times broader in the other three genera. These characteristics are also applicable to immature specimens.

Description. Medium-sized spiders, 5.20-9.80mm in length; carapace usually pale yellow to dark orange-brown with black markings, rarely black with white markings (Figs 1–8, 10, 11); carapace surface smooth, with black feathery setae covering markings (Fig. 13); several long curved setae on clypeus, eye region and posterior to PER up to midpoint (Figs 14, 15, 19); carapace oval, broadest at posterior of coxae II, eye region narrow, fovea distinct; posterior margin very slightly concave or straight (Figs 7, 8, 10, 11). AER procurved, AME approximately 11/4 to 11/2 times ALE diameter; AME separated by 1/2 or less their diameter, nearly touching ALE (Figs 14, 15, 19); PER strongly procurved, PME very slightly larger than PLE; PME closer to PLE than to each other; MOQ width equal anteriorly and posteriorly, or very slightly broader posteriorly, longer than wide. Chilum distinct, triangular, bilateral with clear median separation; cheliceral promargin with two or three teeth, retromargin with two teeth; shaggy seta absent; curved setae on cheliceral promargin pectinate in females (Figs 16, 20) and finely plumose in males (Fig. 17); endites straight laterally, with distinct serrula comprising sharp, ventrally curved denticles, with dense maxillar hair tuft on mesal margins (Figs 18, 22, 23); labium hemispherical, wider than long. Pleural bars sclerotised, isolated; sternum slightly longer than broad, shield-shaped, slightly narrowed anteriorly, with or without markings; surface smooth, densely covered in feathery setae, with many long erect straight setae; precoxal triangles present,



Figures 7–12. Digital microscope photographs of *Copa flavoplumosa* Simon, 1885 from D.R. Congo **(7–9)** and *C. kei* sp. n. from South Africa **(10–12)**: **7, 10** female, dorsal habitus **8, 11** male, dorsal habitus **9, 12** sternum of female in ventral view. Scale bars = 1.0 mm.

intercoxal sclerites only present between coxae I and II (Figs 9, 12). Leg formula 4132 in females, 4312 or 4123 in males, legs I and III nearly equal in length; legs strongly spined, femora, patellae, tibiae and metatarsi covered in short straight black setae and black and white feathery setae (Figs 24–27, 31–39), feathery setae sparse on tarsi; retrocoxal window absent; femora with several scattered erect ventral setae (Figs 24, 31); anterior patellae with proximal and distal long fine dorsal setae (Figs 24, 34); posterior patellae with fine long proximal dorsal seta and distal spine, clearly shorter than patella (Fig. 35); patellar indentation narrow, broad at proximal end (Figs 25, 26, 32, 33); metatarsi III longer than metatarsi I and II; metatarsi distally scopulate (Fig. 39); tibiae, metatarsi and tarsi with several dorsal and lateral trichobothria with sunken distal plate (Fig. 29), also with several short erect setae (Fig. 38); tarsal organ oval, slightly elevated from integument, surface finely wrinkled, opening oval (Figs 30, 42); paired tarsal claws short, with very dense claw tufts in between (Figs 28, 41); metatarsi III and IV without terminal preening brush or comb. Abdomen oval,

either yellow-orange with black markings or black with white markings; three pairs of fine straight setae on anterior margin above pedicel; dorsal scutum small, strongly sclerotized, extending less than 1/8 abdomen length in females and slightly more than 1/2 abdomen length in males; two pairs of distinct sclerotised dorsal sigilla present in both sexes (Figs 7, 8, 11, 12); epigastric region moderately sclerotised, venter without post-epigastric sclerites and ventral sclerite, inframamillary sclerite present, distinct, densely covered in short setae; two paired rows of tiny sclerites from epigastric furrow to spinnerets, outer row weakly sclerotised and indistinct. Spinnerets: ALS of female (Figs 43, 49) with two major ampullate gland spigots and many piriform gland spigots; ALS of male (Figs 44, 50) with single major ampullate gland spigot, single large adjacent nubbin and many piriform gland spigots; PMS of female (Figs 45, 51) with three large cylindrical gland spigots, one small minor ampullate gland spigot and one or two aciniform gland spigots; PMS of male (Figs 46, 52) with one large minor ampullate gland spigot, one tartipore and one nubbin, with zero aciniform gland spigots in C. flavoplumosa and two in C. kei sp. n.; PLS of female (Figs 47, 53) with two large cylindrical gland spigots and zero (in C. flavoplumosa) or several (in C. kei sp. n.) aciniform gland spigots; PLS of C. flavoplumosa male with two reduced aciniform gland spigots and several tiny nubbins present (Fig. 48); PLS of C. kei sp. n. with three aciniform gland spigots only (Fig. 54). Female epigyne with 6-shaped or curved sclerotized epigynal ridges leading to lateral copulatory openings (Figs 55, 57); copulatory ducts directed anteriorly or transversely before entering ST II posteriorly; ST II usually oval, sometimes expanded posterolaterally, connected broadly to somewhat elongated posterior ST I. Male palpal segments without apophyses; cymbium with spines prolaterally and ventrally, dorsal surface covered in curved finely plumose setae with round tip and thicker straight setae with sharp tips (Fig. 59); distal end of cymbium in C. kei sp. n. with shallow depression, densely covered in setae (Fig. 60); embolus with variable width and angle of base, and length and curvature of distal coil (Figs 56, 58, 61–66).

Key to the continental Afrotropical species of Copa

1	Males
_	Females
2	Embolus with broad base and long curved distal section (Fig. 56)
_	Embolus with narrow base and narrow coiled distal section (Fig. 58)
3	Epigyne with large 6-shaped epigynal ridges with lateral copulatory openings
	(Fig. 55); entrance ducts directed anteriorly, with distinct loop before enter-
	ing ST II (Fig. 68) C. flavoplumosa Simon, 1885
-	Epigyne with small cup-shaped epigynal ridges covering copulatory openings
	(Fig. 57); entrance ducts directed transversely and slightly anteriorly before
	entering ST II (Fig. 74)

Copa flavoplumosa Simon, 1885

http://species-id.net/wiki/Copa_flavoplumosa Figures 1–4, 7–9, 12–18, 31–48, 55, 56, 61–65, 67–70, 71

Copa flavoplumosa Simon 1885: 396; Simon 1897: 168, 173, fig. 159. *C. flavopilosa* Simon 1897: 160, fig. 159 (misspelling). *Copa benina* Strand 1916: 93; Lessert 1921: 429, figs 66–69 syn. n. *Copa benina nigra* Lessert 1933: 129, fig. 48 syn. n.

Type material. Female lectotype and one female paralectotype, here designated, together with one non-type male: ANGOLA: Landana [05°13'S, 12°08'E], MNHN 5338 (examined).

Type material of synonyms. *Copa benina* Strand, 1916. Female holotype. D.R. CONGO: Fort Beni [00°29'N, 29°27'E], Ruwenzori, leg. Expedition Adolf Friedrich Herzog von Mecklenburg, I.1908, ZMB 28199 (examined); *Copa benina nigra* Lessert, 1933. Syntypes? ANGOLA: one male from Chimporo and one female from Rio Mbale, MNHG (examined).

Other material examined. BOTSWANA: Okavango Delta: Airstrip near Delta Camp, 19°32'S, 23°05'E, leg. K. Wilkins, 13.I.2001 (bush beating), 1∂ (NMZA 14085); Lesideng Research Camp, Near Shakawe, 18°25.822'S, 21°53.771'E, leg. C. Haddad, 25.XI.2006 (leaf litter), 1 Q (NCA 2007/936); Same locality, leg. C. Haddad, 26–29.XI.2006 (under bark), 1♀ (NCA 2007/987); Maun [19°59'S, 23°25'E], leg. A. Russell-Smith, 27.X.1978 (in deep litter, riverine forest), 2 d (BMNH); Same locality, Government Camp house 36 [19°59'S, 23°25'E], leg. A. Russell-Smith, I-II.1977, 1^Q (BMNH); Botswana, Maun, Maphaneng Pan [19°55'S, 23°26'E], leg. A. Russell-Smith, 8.II.1976 (riverine woodland, leaf litter), 2Å (BMNH); Moremi Game Reserve [19°15'S, 23°05'E], leg. W. & I. Barnard, 13–24.I.1991 (mopane woodland), 1♀ (NCA 91/985); Moremi Game Reserve, Maxwee [19°28'S, 23°39'E], leg. A. Russell-Smith, 2.I.1976 (mopane woodland), $1\bigcirc 1\bigcirc$ (PCRS); Samochima lagoon, Shakawe Fishing Camp, 18°25.749'S, 21°54.035'E, leg. C. Haddad, 10.XII.2006 (leaf litter), 1 d (NCA 2007/1051); "Woody" Island, NW of Xugana Island, 19°04'S, 23°03'E, leg. B.H. Lamoral, 21–22.XI.1980, 2d (NMSA); Xugana Island, 130km NNW of Maun, 19°04'S, 23°03'E, leg. B.H. Lamoral, 18–21.XI.1980, 1♂ (NMSA); Same data (forest floor and logs), $4^{\uparrow}_{\circ} 2^{\bigcirc}_{\circ}$ (NMSA); Same locality, leg. B.H. Lamoral, 22–24.XI.1980, 1 \bigcirc (NMSA); Same data, 1 \bigcirc (NMSA). North-East Region: Near Francistown, Selkirk Mine, 21°19.332'S, 27°44.148'E, leg. D.H. Jacobs, 28.III-5. IV.2008, 1^Q (NCA 2008/2905). CAMEROON: Bali, Bafuchu Mbu, Shum Laka, 05°51'N, 10°05'E, 1600m a.s.l., leg. H. Doutrelepont, XII.1991–II.1992 (pitfall), 1 (MRAC 174794); Chabal Mbabo, South-western slope, 07°25'N, 12°49'E, 1250m a.s.l., leg. Bosmans & Van Stalle, 7–13.IV.1983 (grassland with shrubs, pitfalls), 1 🖒 (MRAC 162220); Same locality, 1500m a.s.l., leg. Bosmans & Van Stalle, 11.IV.1983 (gallery forest, litter), 1° (MRAC 162222); Ebolowa, Nkoumvom [02°55'N, 11°09'E], leg. M.C. Day, 1980 (pitfall traps), 13 (BMNH); Faro Game Reserve,



Figures 13–24. Scanning electron microscope photographs of *Copa flavoplumosa* Simon, 1885 female (13, 14, 16) and male (15, 17, 18) and *C. kei* sp. n. female (19–24): 13 dorsal carapace setae 14, 15, 19 eye region and clypeus, anterolateral (14, 15) and anterior (19) views 16, 17, 20 cheliceral promarginal bent setae, anterior view 18, 22 mouthparts, ventral view 21 chelicerae, ventral view 23 serrula 24 femur, patella and tibia of leg II, indicating erect ventral setae on femora (EVS) and proximal and distal dorsal patellar setae (PS).

08°24'N, 12°49'W, leg. R. Jocqué, K. Loosveldt, L. Baert & M. Alderweireldt, 3.V.2007 (river bed, pitfall), 1 \bigcirc (MRAC 221128); Same locality, leg. R. Jocqué, K. Loosveldt, L. Baert & M. Alderweireldt, 2.V.2007 (gallery forest, pitfall), 2 \bigcirc (MRAC 221134); Same data, 4.V.2007, 1 \bigcirc 2 \bigcirc (MRAC 221169); Same data, 5.V.2007, 3 \bigcirc 1 \bigcirc (MRAC 221229); Same locality, leg. R. Jocqué, K. Loosveldt, L. Baert & M. Alderweireldt, 27.IV.2007 (gallery forest, sieving), 1 \bigcirc (MRAC 221434); Same locality, leg. R. Jocqué, Same locality, Sa



Figures 25–30. Scanning electron microscope photographs of *Copa kei* sp. n. female: **25** patella II, indicating patellar indentation **(PI) 26** same, detail of lyriform organ at proximal end of PI **27** metatarsus IV, spine and setae **28** tarsus III, tarsal claw and claw tuft **29** tarsus IV, trichobothrium base **30** same, tarsal organ.

leg. R. Jocqué, K. Loosveldt, L. Baert & M. Alderweireldt, 1.V.2007 (mature gallery forest, by hand), 1 \bigcirc (MRAC 221359); Same locality, leg. R. Jocqué, K. Loosveldt, L. Baert & M. Alderweireldt, 5.V.2007 (mature gallery forest, pitfall), 6 \bigcirc 2 \bigcirc (MRAC 221211); Same locality, leg. R. Jocqué, K. Loosveldt, L. Baert & M. Alderweireldt, 26.



Figures 31–36. Scanning electron microscope photographs of *Copa flavoplumosa* Simon, 1885 male **(31)** and female **(32–36)**: **31** femur I, erect ventral setae **32** patella II, indicating patellar indentation **(PI) 33** same, detail of lyriform organ at proximal end of PI **34** patella II, arrows indicating proximal and distal dorsal patellar setae **35** patella III, arrows indicating proximal and feathery setae.

IV.2007 (litter, by hand), 3 (MRAC 221280); Same locality, leg. R. Jocqué, K. Loosveldt, L. Baert & M. Alderweireldt, 19.IV.2007 (wooded savanna, beating), 13 (MRAC 221407); Same locality, leg. R. Jocqué, K. Loosveldt, L. Baert & M. Alderweireldt, 3.V.2007 (litter under tree, by hand), 13 19 (MRAC 221432); Mbam



Figures 37–42. Scanning electron microscope photographs of *Copa flavoplumosa* Simon, 1885 female (37, 39–42) and male (38): 37 tibia I, long dorsal seta 38 tibia I, arrows indicating short erect setae 39 meta-tarsus II, spines and scopula 40 tarsus III 41 same, claw tuft and tarsal organ (arrow) 42 same, tarsal organ.

mountain area, near Katoupi, Western slope, 05°54'N, 10°44'E, 1550m a.s.l., leg. Bosmans & Van Stalle, 31.III.1983 (gallery forest), $2\bigcirc$ (MRAC 162244). CENTRAL AFRICAN REPUBLIC: Bambari, 04°15'N, 21°54'E, leg. G. Pierrard, II.1969, 1 \bigcirc (MRAC 136635). D.R. CONGO: Mikembo, 11°28'S, 27°39'E, leg. M. Hasson, 26.XI.2010 (miombo woodland, Uapaca forest, pitfall traps), 1 \bigcirc (MRAC 234447),



Figures 43–48. Scanning electron microscope photographs of *Copa flavoplumosa* Simon, 1885 female **(43–45)** and male **(46–40)** spinneret morphology: **43, 46** anterior lateral spinneret **44, 47** posterior median spinneret **45, 48** posterior lateral spinneret. Abbreviations: **Ac** aciniform gland spigot(s) **Cy** cylindrical gland spigot(s) **MAmp** major ampullate gland spigot(s) **mAmp** minor ampullate gland spigot(s) **n** nubbin **Pi** piriform gland spigot(s) **PLS** posterior lateral spinneret **PMS** posterior median spinneret **ta** tartipore.

 1° 1° (MRAC 234384); Same locality, leg. M. Hasson, 26.XI.2010 (gallery forest, alongside river, pitfall traps), 7° 4° (MRAC 234461); Parc National Albert, Northern Sector, Talya River, area to the right of Lume, near Mutsora [00°19'N, 29°45'E],



Figures 49–54. Scanning electron microscope photographs of *Copa kei* sp. n. female **(49–51)** and male **(52–54)** spinneret morphology: **49, 52** anterior lateral spinneret **50, 53** posterior median spinneret **51, 54** posterior lateral spinneret. Abbreviations: **Ac** aciniform gland spigot(s) **Cy** cylindrical gland spigot(s) **MAmp** major ampullate gland spigot(s) **mAmp** minor ampullate gland spigot(s) **n** nubbin **Pi** piriform gland spigot(s) **ta** tartipore.

1140m a.s.l., leg. P. van Schuytbroeck, 14.II.1955, 1° (MRAC 234182); Tshopo, Masako Forest, 15 km N of Kisangani, 00°35'N, 25°11'E, leg. L. de Vos, 19–27.I.1998, 1°_{\circ} (MRAC 169357); Same locality, leg. J.-L. Juakaly, 17.XII.2002 (pitfalls, young



Figures 55–60. Scanning electron microscope photographs of *Copa flavoplumosa* Simon, 1885 (55, 56) and *C. kei* sp. n. (57–60): 55, 57 female epigyne, ventral view 56, 58 male embolus, ventral view 59 male palpal cymbial setae 60 distal end of cymbium, retrolateral distal view.

fallow), 1° (MRAC 214341); Same data, 2°_{\circ} (MRAC 214334); Same locality, leg. J.-L. Juakaly, 2.VII.2002 (young fallow, pitfall), 1 (MRAC 214363). ETHIOPIA: Yayu Coffee Forest, 08°23'N, 35°48'E, leg. N. Aklilu, 15.II.2004 (secondary forest, look down), 13 19 (MRAC 229596); Same locality, leg. N. Aklilu, 14.XI-12. XII.2003 (pitfall trap), 1imm. 2 49 (MRAC 220773); Same locality, leg. N. Aklilu, 2004 (sieving, plantation), 18 (MRAC 230893). GABON: Estuaire, Ntoum, 00°23'N, 09°47'E, leg. A. Pauly, 5–15.X.1985 (pelouse jardin, pièges moericke), 1 (MRAC 172826); Same locality, leg. A. Pauly, X-XI.1985 (piège bac d'Eau, forêt), 1 (MRAC 172837); Same locality, leg. A. Pauly, 7.XI.1985 (carrier de sable, piège bac d'Eau), 1 (MRAC 172934). GUINEÉ: F.C. de Ziama, 08°24'N, 09°17'W, leg. D. Flomo, 26.XII.1998 (pitfalls, rain forest), 1 (MRAC 216225); Same data, 8.I.1999, 1♂ (MRAC 216208); Same data, 21.I.1999, 2♀ (MRAC 216209); Same data, 15.II.1999, 1♀ (MRAC 216226). IVORY COAST: Appouesso, F.C. Bossematié, 06°35'N, 03°28'W, leg. R. Jocqué & Tanoh, 23.IV.1995 (pitfalls in forest), 1 (MRAC 204369); Same data, 7.V.1995, 1♀ (MRAC 204366), 1♀ (MRAC 204368); Same data, 20.V.1995, 1 (MRAC 204365), 1 (MRAC 204370); Same data, 8.X.1995, 1 (MRAC 204372); Same data, 22.X.1995, 1 (MRAC 204364); Same data, 5.XI.1995, 1^Q (MRAC 204367), 1imm. 1^A (MRAC 204371); Same locality, leg. R. Jocqué, 1.XII.1995 (modified Malaise trap), 1d (MRAC 200963); Bouaflé, 06°59'N, 05°45'W, 12.I.1981, leg. J. Everts (pitfalls), 3∂ 3♀ (MRAC 174002); Same data, 14.I.1981, 2⁽⁷⁾ 1⁽²⁾ (MRAC 173992); Bouaké, F.-Foro, 07°41'N, 05°02'W, leg. G. Couturier, 3–5.VI.1974 (piège coloré), 1 (MRAC 216367); Same data, 15–17. VII.1974, 4 (MRAC 216400); Same data, 12–14.VIII.1974, 2 (MRAC 216484); Same data, 19–21.VIII.1974, 1♀ (MRAC 216414); Same data, 26–28.VIII.1974, 2♂ (MRAC 216456); Same data, 2–4.IX.1974, 1♂ (MRAC 216433), 1♂ 1♀ (MRAC 216448), 2d (MRAC 216420); Bouitha, near Degbézéré, 15km E of Bouaflé, 07°22'N, 06°28'W, leg. R. Schouten & J. Buysen, 21.II.1984, 3imm. 1 (MRAC 165970); Gagnoa [06°08'N, 05°56'W], leg. A. Russell-Smith, 30.III.1993 (pitfalls, upland rice), $2\sqrt[3]{19}$ (PCRS); Mankono, Ranch de la Marahoué, $08^{\circ}27$ 'N, $06^{\circ}52$ 'W, leg. J. Everts, I.1980 (riverine forest), 102imm. 40♂ 16♀ (MRAC 172282); Same data, II.1980, 19imm. 58 23 (MRAC 172281); Same data, III.1980, 61imm. 106 32 (MRAC 172284); Same data, IV.1980, 24imm. 39 34 (MRAC 172283); Same data, V.1980, 8♂ 20♀ (MRAC 172280); Same data, VI.1980, 4imm. 2Å (MRAC 172278); Pakodji, near Degbézéré, 15km E of Bouaflé, 06°59'N, 05°38'W, leg. R. Schouten & J. Buysen, 20.II.1984 (pitfall), 22imm. 19 (MRAC 165977); Titekro, 20km E of Bouaflé, 06°52'N, 06°20'W, leg. R. Schouten & J. Buysen, 15. II.1984 (pitfalls), 8imm. 10 42 (MRAC 165965); Touba [08°16'N, 07°41'W], leg. A. Russell-Smith, 19.VI.1995 (pitfalls, upland rice), 13 (PCRS); Warda, Bouaké $[07^{\circ}41'N, 05^{\circ}01'W]$, leg. A. Russell-Smith, 7.X.1994 (pitfalls, upland rice), $3\stackrel{\circ}{\circ}2^{\circ}$ (PCRS). KENYA: Kakamega Forest, pitfall near quarry, 00°13'N, 34°54'E, 1626m a.s.l., leg. D. Shilabira Smith, 13.XII.2001, 18 (MRAC 212708); Same locality, leg. D. Shilabira Smith, 3.I.2001, 1^Q (MRAC 212715); Same locality, 1654m a.s.l., leg. D. Shilabira Smith, 23.II.2002, 1d (MRAC 212656); Mathews Range Forest, Near Kitich camp, 01°13'N, 37°18'E, 1339m a.s.l., leg. D. van den Spiegel, 9.XII.2002, 1 3 (MRAC 212743); Mount Kasigau, Jora Village, 03°50'S, 38°39'E, leg. E. Selempo, 1-3.XII.2001, 1^Q (MRAC 213056); Ngaia Forest, 00°19'N, 38°02'E, leg. Jocqué, Warui & Van den Spiegel, 24.IV.2004 (sieved litter), 1 (MRAC 215332); Rift Valley Province, Marich Pass Field Studies Centre, 01°32.2'S, 35°27.4'E, leg. W.J. Pulawski & J.S. Schweikert, 26–29.VII.1999, 17 (CAS, CASENT 9033277). MA-LAWI: Chisasira Forest, 25km South of Chintheche, 11°50'S, 33°13'E, leg. R. Jocqué, 1.XII.1977, 1 (MRAC 153232); Same data, 20.XII.1977, 3 (MRAC 153196); Same data, 3–20.I.1978, 1imm. 1 (MRAC 153649); Same locality, leg. R. Jocqué, 3-20.III.1978 (Brachystegia woodland), 1 12 (MRAC 152985); Nyika plateau, Chelinda [10°35'S, 33°47'E], 2300m a.s.l., leg. R. Jocqué, 7-19.XII.1981 (grassland burned in 1979, pitfalls), 1 (MRAC 155686); Same locality, leg. R. Jocqué, 7–19. XII.1981 (grassland burned in 1980, pitfalls), 13 (MRAC 155744); Nyika plateau, Chowo rocks [not traced], leg. R. Jocqué, 6-18.XII.1981 (pitfalls in herbaceous vegetation with *Philippia*), 1 (MRAC 156302); Same data, 1 (MRAC 156384); Nyika plateau, Lake Kaulime [10°34'S, 33°45'E], 2200m a.s.l., leg. R. Jocqué, 6-19. XII.1981 (pitfalls on grassy bank), 2∂ 2♀ (MRAC 155886); Same locality, leg. R. Jocqué, 6–19.XII.1981 (pitfalls on wet bank with *Lobelia*), $1 \stackrel{>}{\bigcirc} 1 \stackrel{\bigcirc}{\bigcirc} (MRAC \ 156021);$ Nyika plateau, Manyanjere Forest [not traced], 2100m a.s.l., leg. R. Jocqué, 15. XII.1981 (grassland with stones), 1° (MRAC 156722); Nyika plateau, near entrance gate on road Chelinda-Rumphi [not traced], 1700m a.s.l., leg. R. Jocqué, 3-22. XII.1981 (*Brachystegia* woodland, pitfalls), $5\sqrt[3]{2}$ (MRAC 155822); Same locality, leg. R. Jocqué, 3-22.XII.1981 (secondary Brachystegia woodland with Uapaca, pit-

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falls), $1 \stackrel{?}{_{\sim}} 1 \stackrel{?}{_{\sim}}$ (MRAC 155703), $1 \stackrel{?}{_{\sim}} 1 \stackrel{?}{_{\sim}}$ (MRAC 156006), $1 \stackrel{?}{_{\sim}} 1 \stackrel{?}{_{\sim}}$ (MRAC 156062); Same locality, leg. R. Jocqué, 3–22.XII.1981 (pitfalls under large Brachystegia), 148 5º (MRAC 156289). MOZAMBIQUE: Bartholomew Diaz Point, BD Lodge, 21°15.585'S, 35°06.851'E, 5m a.s.l., leg. C. Haddad, R. Lyle & R. Fourie, 10. XII.2007 (leaf litter, mangroves), 1 32 (NCA 2008/194); Bilene, Praia do Bilene, 25°15.649'S, 33°17.659'E, 27m a.s.l., leg. C. Haddad, R. Lyle & R. Fourie, 20. XII.2007 (leaf litter, coastal forest), 13 (NCA 2008/210); Chidenguele, Paraiso de Chidenguele, 24°57.276'S, 34°11.860'E, 38m a.s.l., leg. C. Haddad, R. Lyle & R. Fourie, 16.XII.2007 (leaf litter, dune forest), 2imm. 1 (NCA 2008/205); Inhaca Island, 26°01'S, 32°54'E, leg. T. Steyn, 6-20.VIII.1994 (beach and dunes, by hand), 1 (MRAC 215918); Same locality, leg. T. Steyn, 21.VIII-4.IX.1993 (pitfalls, coastal woodland), 1imm. 4 (MRAC 209025); Same data, 18.IX–2.X.1993, 2 (MRAC 209418); Same data, 2–16.X.1993, 1^Q (MRAC 209037); Same data, 2–16.X.1993, 2∂ 9♀ (MRAC 209044); Same data, 16–30.X.1993, 7∂ 2♀ (MRAC 208995); Same data, 13–23.XI.1993, 5 52 (MRAC 209304); Same data, 27.XI–11.XII.1993, 4imm. 9 12 (MRAC 209392); Same data, 25.XII.1993-8.I.1994, 13 (MRAC 209400); Same data, 8-22.I.1994, 6∂ 1♀ (MRAC 209468); Same data, 19.II-5. III.1994, 3♂ 3♀ (MRAC 209898); Same data, 5–19.III.1994, 1imm. 4♂ (MRAC 209441); Same data, 19.III-2.IV.1994, 1 (MRAC 209732); Same data, 13-30. IV.1994, 1♂ (MRAC 209888); Same data, 30.IV-14.V.1994, 3♂ 1♀ (MRAC 209750); Same data, 14-28.V.1994, 2d (MRAC 209774); Same data, 19-25. VI.1994, 2♂ (MRAC 209801); Same data, 9–23.VII.1994, 2♀ (MRAC 209699); Same data, 23.VII-6.VIII.1994, 2d (MRAC 209880); Same locality, leg. T. Steyn, 18.IX-2.X.1993, (pitfalls, open parkland), 2imm. 1 (MRAC 215982); Same data, 2-16.X.1993, 1♀ (MRAC 209475); Same data, 16-30.X.1993, 5imm. 6♂ 3♀ (MRAC 215999); Same data, 30.X-13.XI.1993, 1 (MRAC 209709); Same data, 13-27.XI.1993, 1^Q (MRAC 209414); Same data, 27.XI-11.XI.1993, 2^A (MRAC 209418); Same data, 11-25.XII.1993, 13 (MRAC 209681); Same data, 11-25. XII.1993, 2♂ 2♀ (MRAC 209684); Same data, 25.XII.1993–8.I.1994, 3♂ (MRAC 209693); Same locality, leg. T. Steyn, 15–29.XI.1993 (pitfalls, wetland), 1^Q (MRAC 209325); Same data, 27.XII.1993–10.I.1994, 1 (MRAC 209360); Same data, 10– 24.I.1994, 1∂ 1♀ (MRAC 209344); Same data, 24.I-7.II.1994, 4∂ (MRAC 208950); Same data, 21.II-5.III.1994, 28 (MRAC 209774); Same data, 5-15. III.1994, 2♂ 1♀ (MRAC 209372); Same data, 19.III–2.IV.1994, 4♂ 1♀ (MRAC 209350); Same data, 8–23.IV.1994, 6∂ 2♀ (MRAC 209743); Same data, 23–30. IV.1994, 2∂ 1♀ (MRAC 209786); Same data, 30.IV–14.V.1994, 3∂ 1♀ (MRAC 209903); Same data, 28.V–19.VI.1994, 1^Q (MRAC 209717); Same data, 19–25. VI.1994, 1♂ (MRAC 209796); Same data, 25.VI–9.VII.1994, 1♂ (MRAC 209985); Same data, 20.VIII–3.IX.1994, 1 (MRAC 215949); Same data, 3–24.IX.1994, 3 3♀ (MRAC 215922); Same data, 3–24.IX.1994, 3♂ (MRAC 215926); Maxixe [23°52'S, 35°20'E], I.1914, no collector, 1imm. 2^Q (SAMC B6589); Morrungulo, Morrungulo Resort, 23°13.983'S, 35°29.587'E, 12m a.s.l., leg. C. Haddad, R. Lyle & R. Fourie, 6.XII.2007 (leaf litter, dune forest), 1 12 (NCA 2008/185); Near Mar-

racuene, Blue Anchor Inn, 25°35.124'S, 32°39.568'E, 50m a.s.l., leg. C. Haddad & R. Fourie, 28.XI.2007 (sifting leaf litter, savanna), 1imm. 2Å (NCA 2008/165); Near Marracuene, Marracuene Lodge, 25°46.379'S, 32°41.046'E, 12m a.s.l., leg. C. Haddad, 1.XII.2007 (leaf litter, riverine forest), 1imm. 1^Q (NCA 2008/171); Vilankulos, Casa Chibububo, 22°01.231'S, 35°19.237'E, 3m a.s.l., leg. C. Haddad, R. Lyle & R. Fourie, 12.XII.2007 (leaf litter, coastal bush), 1imm. 2° (NCA 2008/199); Xai-Xai, Montego's Camp, 25°03.659'S, 33°40.633'E, 28m a.s.l., leg. C. Haddad, 2. XII.2007 (leaf litter, dune forest), 2^Q (NCA 2008/179). NAMIBIA: Caprivi Strip, Popo Falls, 18°07.366'S, 21°34.971'E, leg. R. Lyle, 17.XII.2006 (leaf litter, riverine forest), 1♂ (NCA 2008/4279); Hoarusib River, leg. Museum Expedition, I.1926, 1♀ (SAMC B7110). NIGERIA: Borgu Game Reserve [10°19'N, 03°56'E], leg. A. Russell-Smith, 5-6.V.1973 (flood debris by river bank), 1° (BMNH); Ibadan, International Institute of Tropical Agriculture [07°29'N, 03°53'E], leg. A. Russell-Smith, 24.V.1973 (bush fallow), 2♂ 5♀ (BMNH); Same data, VII.1973, 4♂ (BMNH); Same data, 25–29.V.1975, 1 (PCRS); Same locality, leg. A. Russell-Smith, 22–26. VI.1973 (cultivated plots), 1∂ 2♀ (BMNH); Iseri [06°30'N, 03°16'E], leg. B. Malkin, 26–30.III.1949, 1^Q (CAS, CASENT 9033106). RWANDA: P.N. Akagera, 50 km north of la pêcherie Ihema, près du lac Mihindi, 01°32'S, 30°43'E, leg. Jocqué, Nsengimana & Michiels, 23.XI–6.XII.1985 (pièges en forêt sèche), 3∂ 2♀ (MRAC 165007); Same locality, leg. Jocqué, Nsengimana & Michiels, 23.XI-6.XII.1985 (bordure de forêt), 13 (MRAC 165020); Same locality, leg. Jocqué, Nsengimana & Michiels, 14.XI-3.XII.1985 (Forêt sêche à Sansevieria, pièges), 5∂ 1♀ (MRAC 165416). SOUTH AFRICA: Eastern Cape Province: Grahamstown [33°18'S, 26°31'E], leg. W.F. Purcell, X.1905, 13 (SAMC B7539); Great Fish River at Selbourne, 33°28'S, 27°08'E, leg. M. Burger, 5.XII.1993 (pitfall trap), 1∂ (NCA 96/59); Kentani district [32°30'S, 28°18'E], leg. Abernethy, 1903, 1Å (SAMC 1289); Mkambathi Nature Reserve, 31°17.364'S, 30°00.284'E, 52m a.s.l., leg. University of KwaZulu-Natal students, 29.I.2008 (pan traps, grassland), 1 (NCA 2008/2906); Same locality, 31°15.816'S, 30°02.098'E, 28m a.s.l., leg. Inland Invertebrate Initiative - University of KwaZulu-Natal, 29.I.2008 (pan traps, grassland), 1♀ (NCA 2010/233), 1♀ (NCA 2010/234); Sterkstroom district, Hazelmere Country Lodge, 31°30.126'S, 26°40.815'E, 1542m a.s.l., leg. R. Lyle & R. Fourie, 3–7.XI.2008 (pitfall traps, poplar trees), 1 (NCA 2008/4284); Sundays River Valley, 33°23'S, 25°26'E, leg. H. Potgieter, 23.I.1999 (pitfalls in citrus), 3♂ 5♀ (NCA 2000/237); Same data, 23.XI.1999, 3∂ 1♀ (NCA 2000/238). Free State Province: Erfenis Dam Nature Reserve, Site 3, Acacia karroo trees, 28°30.272'S, 26°47.527'E, leg. R. Fourie & A. Grobler, 30.IX-28.X.2009 (pitfall traps, woodland), 1 (NCA 2009/3590); Kroonstad district, Doornkloof farm, 27°43.376'S, 27°42.042'E, leg. R. Fourie & A. Grobler, 29.X-5. XII.2009 (pitfall traps, grassland), 13 (NMSA 22690); Mpetsane Conservation Estate, near Clocolan, 28°48'S, 27°39'E, leg. C. Haddad, 9.III.2007 (Rhus lancea leaf litter), 1imm. 1^Q (NCA 2008/558); Sandveld Nature Reserve, 27°40'S, 25°41'E, leg. C. Haddad, 25.X.2003 (leaf litter under *Acacia erioloba*), 1° (NCA 2002/511); Same data, 25.XI.2003, 1d (NCA 2005/77); Tussen-die-Riviere Nature Reserve, 30°29'S,

26°11'E, leg. L. Lotz & C. Haddad, 13.X.2008 (active searching, dense Acacia woodland), 18 (NMBA 12623). Gauteng Province: Balmoral, 25°49.013'S, 28°51.970'E, leg. R. Koko, 11.VII.2006 (pitfall traps), 1° (NCA 2008/2782); Buffelsdrift, 25°24.251'S, 28°03.581'E, 1700m a.s.l., leg. R. Koko, I.2006 (incidentals), 1 Q (NCA 2008/2780); Pretoria, Weavind Park, 25°43'S, 28°16'E, leg. C. Anderson, 15.III.1997 (in house), 1∂ (NCA 96/455); Pretoria National Botanical Gardens, 25°44'S, 28°16'E, leg. E. Kassimatis, 6.X–24.XI.2007 (pitfall traps), 1^Q (NCA 2008/1966); Suikerbosrand Nature Reserve, Heidelberg, 26°30.102'S, 28°14.165'E, 1830m a.s.l., leg. H. Roux, 13.XI.2001 (pan trap, grassland plateau), 1 (NCA 2008/4278). KwaZulu-Natal Province: 15km N of Richard's Bay, 28°40'S, 32°13'E, leg. T. Wassenaar, 5. XII.1995 (rehabilitated coastal forest, sweep net), 1° (NCA 96/492); Same locality, leg. T. Wassenaar, 10.XII.1996 (pitfalls, rehabilitated coastal forest), 12 (NCA 97/840); Same data, 27.II.1997, 1 (NCA 97/842); Botha's Hill [29°43'S, 30°44'E], leg. R.F. Lawrence, XI.1953, 1♀ (NMSA 5951); Cathedral Peak, 28°58.688'S, 29°15.586'E, 1916m a.s.l., leg. Maluti-Drakensburg Transfrontier Park survey, 18. IX.2005 (white pan trap 5, grassland), 1 (NCA 2008/1911); Cathedral Peak Forest Station, 75 km WSW of Estcourt [28°56'S, 29°13'E], 1400 m a.s.l., leg. S. & J. Peck, 7-31.XII.1979 (dung traps, veld pasture), 18 (AMNH); Drummond [29°45'S, 30°41'E], leg. R.F. Lawrence, XII.1939, 1 (NMSA 2633); Empangeni, 28°45'S, 31°54'E, leg. P. Reavell, 1.X.1983 (in pool), 1^Q (NMSA); Enseleni Game Reserve, 13km N Richard's Bay [28°41'S, 31°59'E], leg. P. Reavell, 10.III.1981, 1Q (NCA 81/198); Garden Castle, 29°44.700'S, 29°12.663'E, 1842m a.s.l., leg. Maluti-Drakensburg Transfrontier Park staff, 2.XI.2005 (white pan trap 5, grassland), 13 (NCA 2008/1913); iSimangaliso Wetlands Park, False Bay Park, 27°55'S, 32°16'E, leg. J. Esterhuizen, 13.X.2003 (tsetse fly traps), 1♀ (NCA 2004/769); Same data, 22.X.2003, 1 (NCA 2004/765); Same locality, 27°54.014'S, 32°23.543'E, leg. Earthwatch team 9, 15.I.2005 (yellow pan traps, open savanna), 1imm. 1° (NCA 2007/1309); Ithala Game Reserve, Near ruins, Ngubhu loop, 27°30.817'S, 31°14.304'E, leg. C. Haddad, 1.VII.2007 (leaf litter), 11imm. 1°_{\circ} 1 $^{\circ}_{\circ}$ (NCA 2007/2809); Kosi Bay [26°52'S, 32°52'E], leg. R.F. Lawrence, VII.1936, 1 (NMSA 158); Same locality, Banga Nek, near third lake, 27°05.134'S, 32°50.533'E, leg. P. & G. Van Niekerk, X. Combrink & J. Warner, 27.II.2007 (sweeps in grass), 1^Q (NCA 2009/4608); Illovo Beach, Mount Edgecombe [30°07'S, 30°51'E], leg. C. Cilliers, 7.I.1977, 1imm. 1Q (NCA 2007/1137); Mkuzi Game Reserve, 27°40.356'S, 32°15.065'E, leg. Earthwatch Team 1, 18.III.2005 (yellow pan traps, *Terminalia sericea* woodland), 1 (NCA 2007/1297); Same locality, 27°35.768'S, 32°14.365'E, leg. Earthwatch Team 10, 22.I.2005 (blue pan traps, *T. sericea* woodland), 1 (NCA 2007/1298); Mtunzini, "Twin Streams" Farm (I.F. Garland), 28°57'S, 31°46'E, leg. T. & C. Griswold, P. Croeser & P. Reavell, 19–20.I.1984 (coastal dune forest), 1 \bigcirc (NMSA); Natal, no date, leg. Martin?, 1 \bigcirc 1 \bigcirc (MNHN 6383); Ndumo Game Reserve, Crocodile farm, 26°53'S, 32°19'E, leg. C. Haddad, 8-23.I.2002 (pitfalls), 18 (NCA 2002/391); Same locality, Ezikhebeni, Pongola River, 26°53.380'S, 32°19.098'E, leg. C. Haddad, R. Lyle & V. Butler, 28.VI.2009 (leaf litter, riverine forest), 1^Q (TMSA 23612); Same locality, Pongola

River floodplain, near pump, Riverine forest, 26°54.323'S, 32°19.435'E, leg. C. Haddad & F. Jordaan, 27.VI.2006 (sieving leaf litter), 1imm. 3 42 (NCA 2006/1201); Same locality, Pongola River floodplain, 26°53.384'S, 32°19.097'E, 16.I.2006, leg. C. Haddad (riverine forest leaf litter), 5 d 1 (NCA 2006/710); Same locality, Viewing tower, 26°54.762'S, 32°16.290'E, leg. C. Haddad, R. Lyle & V. Butler, 30.VI.2009 (leaf litter, broadleaf woodland), 2Å 2Q (TMSA 23564); Same locality, Western shore of Shokwe Pan, 26°50'S, 32°12'E, leg. C. Haddad, 3.VII.2002 (leaf litter, Ficus sycomorus forest), 1 (NCA 2002/392); Same locality, Western shore of Shokwe Pan, 26°52.418'S, 32°12.590'E, leg. C. Haddad, R. Lyle & V. Butler, 8.VII.2009 (leaf litter, Ficus forest), 1^Q (TMSA 23548); Near Port Shepstone [30°45'S, 30°26'E], leg. W.F. Purcell, IX.1905, 1♀ (SAMC 150751); Ngome State Forest, 27°49'S, 31°26'E, leg. M. van der Merwe, XI.1992 (pitfalls, open forest), 1 (NCA 94/396); Same locality, leg. M. van der Merwe, XII.1992 (pitfalls, grass), 1♂ (NCA 94/475); Same data, I.1993, 1 (NCA 94/441); Ophathe Game Reserve, Ophathe River bed, 28°22.693'S, 31°24.442'E, leg. C. Haddad & R. Fourie, 5. VII.2007 (leaf litter, river bank), 4imm. 2Å (NCA 2007/2969); Same locality, Montane grassland, 28°25.344'S, 31°23.957'E, 897m a.s.l., leg. C. Haddad, 4.X.2008 (sifting leaf litter), 1 imm. 1° (NCA 2008/3910); Same locality, Ophathe River Bed, 28°23.727'S, 31°23.643'E, 455m a.s.l., leg. C. Haddad, 30.IX-4.X.2008 (pitfall traps), 2⁽⁷⁾ (NCA 2008/4245); Same locality, leg. C. Haddad, 2.X.2008 (active searching), 132 (NCA 2008/4222); Same locality, Rocky mountainside, 28°23.202'S, 31°24.077'E, 505m a.s.l., leg. C. Haddad, 1.X.2008 (active searching), 1♀ (NCA 2008/4068); Same locality, leg. C. Haddad, 1.X.2008 (sifting leaf litter), 3imm. 1 🖒 (NCA 2008/4039); Pietermaritzburg [29°37'S, 30°23'E], leg. P. Croeser, 7.XII.1983 (dense fern in garden), 1^Q (NMSA 18487); Same locality, Town Bush Valley, Southern slopes of Hogsback Mountain, 29°33'S, 30°21'E, 3200-3400ft a.s.l., leg. C. Griswold & T. Meikle-Griswold, 11.XI.1984 (weedy vegetation), 1imm. 1312 (NMSA); Sani Pass, 29°39.022'S, 29°27.047'E, 1500m a.s.l., leg. D. Prentice, IX.2009 (pitfall traps, 6d), 1 (NCA 2010/271); Same locality, 29°37.217'S, 29°23.330'E, 1800m a.s.l., leg. D. Prentice, IX.2009 (pitfall traps, 5d), 1 (NCA 2010/272); Same locality, 29°36.205'S, 29°18.753'E, 2400m a.s.l., leg. D. Prentice, IX.2009 (pitfall traps, 3c), 1♂ (NCA 2010/221); Scottburgh [30°17'S, 30°45'E], leg. W.G. Rump, II.1943, 1♀ (NMSA 3882); Sodwana Bay, 27°24′S, 32°45′E, leg. R. Harris, XI.1982, 1♀ (NCA 83/247); Tembe Elephant Park, 27°01'S, 32°24'E, leg. C. Haddad, 5.I.2002 (leaf litter, deep sand forest), 1imm. 1 (NCA 2002/396); Same locality, 27°01'S, 32°24'E, leg. C. Haddad, 3–23.I.2002 (pitfalls, deep sand forest), 1imm. 7Å 12 (NCA 2002/393); Same locality, 26°57'S, 32°26'E, 3-23.I.2002, leg. C. Haddad (pitfalls, closed woodland/clay), 1 (NCA 2002/394); Same locality, near offices, 27°03'S, 32°25'E, leg. C. Haddad, 3–23.I.2002 (pitfalls, open woodland/sand), 4d (NCA 2002/395); Same locality, 27°03'S, 32°25'E, leg. C. Haddad, 8.II.2005 (sifting leaf litter, open woodland/sand), 3^Q (NCA 2007/3606); Vernon Crookes Nature Reserve, camp, 30°16'S, 30°37'E, leg. L. Lotz, 27.IX.1995, 1 (NMBA 7719). Limpopo Province: Kruger National Park, Maduringwe, 22°35'S, 31°09'E, leg. R.F. Lawrence,

20.XII.1962, 1♂ (NMSA); Lajuma Mountain Retreat, 23°02'S, 29°27'E, leg. N. Schönhofer, 9.X.2002 (hand collecting), 1 d (NCA 2007/1153); Same locality, Island 3, 23°01.890'S, 29°26.167'E, leg. M. Mafadza, 23.XI.2004 (sifting leaf litter), 1♀ (NCA 2005/1882); Same locality, Short Forest 3, 23°02.165'S, 29°26.985'E, leg. M. Mafadza, 28.XI.2004 (pitfall trap), 1^Q (NCA 2005/2021); Same locality, Tall forest 3a, 23°02.229'S, 29°26.717'E, leg. M. Mafadza, 28.XI.2004 (pitfall trap), 18 (NCA 2005/2022); Same locality, Woodland 3, 23°02.532'S, 29°26.897'E, leg. M. Mafadza, 6.XII.2004 (active search), 1^o (NCA 2005/1881); Same locality, Woodland 5c, 23°02.528'S, 29°26.866'E, leg. M. Mafadza, 28.XI.2004 (pitfall trap), 1∂ 1♀ (NCA 2005/2023); Little Leigh, 22°56.910'S, 29°52.177'E, 1084m a.s.l., leg. F. Mbedzi, 22.XI.2005 (leaf litter, gallery forest), 1♀ (NCA 2008/2764), 1♂ (NCA 2008/2765); Marble Hall, Schoeman Boerdery, 24°57'S, 29°17'E, leg. P. Stephen, 16.XI.1999 (pitfalls in citrus), 1 (NCA 2000/204); Nylsvley Nature Reserve, 24°39'S, 28°40'E, leg. C. Schultz, 1.XII.1975, 1d (NCA 2007/1154); Springbokvlakte, Settlers (wildskamp), 24°54'S, 28°43'E, leg. M. van Jaarsveld, 9.I.2002 (pitfalls, grassland), 1 (NCA 2003/1328). Mpumulanga Province: 20km NE of Brondal, 25°21'S, 30°50'E, leg. M. van den Berg, 16.IX.1997 (on Hass avocados), 1imm. 1 (NCA 98/196); Same data, 2.XII.1997, 1 (NCA 98/197); Same locality, leg. M. van den Berg, 16. IX.1997 (on Fuerte avocados), 1⁽²⁾ (NCA 98/198); Groblers Farm, 25°29'S, 30°05'E, leg. L. Makaka, 29.XI–2.XII.2008 (pitfall traps, grassland AF2), 1 (NCA 2010/265); Same locality, leg. L. Makaka, 26–29.XI.2008 (pitfall traps, grassland AF3), 1 d (NCA 2010/229); Same data, 29.XI-2.XII.2008, 18 (NCA 2010/227), 18 (NCA 2010/266); Same locality, 26–29.XI.2008, leg. L. Makaka (pitfall traps, grassland AF4), 2⁽³⁾ (NCA 2010/228), 1⁽³⁾ (NCA 2010/267), 1⁽³⁾ (NCA 2010/268); Guernsey Farm, 15km NW of Klaserie [24°03'S, 31°12'E], leg. S. & J. Peck, 19-31.XII.1985 (Malaise traps, woodland), 23 (AMNH); Hall and Sons, 10km NE of Nelspruit, 25°21'S, 31°46'E, leg. M. van den Berg, 21.VII.1997 (on Hass avocados), 6imm. 20 3♀ (NCA 98/216); Same data, 10.III.1998, 3imm. 1♂ (NCA 98/1065); Same locality, leg. M. van den Berg, 23.X.1997 (on Fuerte avocados), 1imm. 3° (NCA 98/217); Same data, 12.XII.1997, 1d (NCA 98/776); Hectorspruit, Vergelegen, 25°25'S, 31°40'E, leg. P. Stephen, 12.X.1998 (pitfalls in citrus), 1imm. 19 (NCA 99/193); Nelspruit, 25°21'S, 31°46'E, leg. M. van den Berg, 9.XII.1997 (on macadamia nuts), 1^Q (NCA 98/829); Nelspruit, Institute for Tropical and Subtropical Crops, Waaierproef, 25°21'S, 31°46'E, leg. M. van den Berg, 18.XI.1997 (on macadamia tree), 1imm. 1♀ (NCA 98/174); Same data, 9.XII.1997, 1♀ (NCA 98/829); Same data, 12.II.1998, 1ð (NCA 98/830); Nelspruit Agricultural College, 25°21'S, 31°46'E, leg. P. Stephen, 12.XI.1999 (pitfalls in citrus), 1^Q (NCA 2000/185); Nelspruit Nature Reserve [25°30'S, 30°58'E], leg. Endrody-Younga, 23.XI.1986, 1♂ (TMSA 19679); Roger Croall, 25°33'S, 30°05'E, leg. L. Makaka, 26–29.XI.2008 (pitfall traps, grassland R1), 1 (NCA 2010/269); Same locality, leg. L. Makaka, 26–29.XI.2008 (pitfall traps, grassland R4), 1 (NCA 2010/263), 1 (NCA 2010/264); Sakhelwe location, 25°24'S, 30°05'E, leg. L. Makaka, 26–29.XI.2008 (pitfall traps, grassland COM3), 16 (NCA 2010/224); Veloren Vallei Nature Reserve, Block 3, 25°18.832'S,

 $30^{\circ}07.791$ 'E, leg. L. Makaka, 4–7.III.2009 (pitfall traps, grassland V3.4), 1° (NCA 2010/225); Witbank Dam Nature Reserve, 25°51'S, 29°18'E, leg. A. Leroy, 9.XI.1991 (grassland), 1^Q (NCA 92/172). North West Province: Matshaneng district, Hermitage Farm, 27°04.136'S, 23°40.991'E, leg. C. Haddad, 1.XII.2003-22.I.2004 (pitfalls under trees), 1^Q (NCA 2005/2012); Potchefstroom district, Thabela Thabeng Mountain Retreat, 26°51.825'S, 28°17.819'E, leg. R. Fourie & A. Grobler, 1–29.X.2009 (pitfall traps, woodland grassland), 10° (NCA 2009/3553); Same locality, 26°51.828'S, 28°17.805'E, leg. R. Fourie & A. Grobler, 1–29.X.2009 (pitfalls, Vaal River bank), 4 12 (NCA 2009/3561). Northern Cape Province: Prieska district, Green Valley Nuts, 29°35'S, 22°56'E, leg. C. Haddad, 19.XII.2001 (fogging, pistachio tree canopy), 1 (NCA 2002/481); Same locality, 22°56.683'S, 29°35.184'E, leg. C. Haddad, 23.XI-18.XII.2001 (pitfalls, *Eucalyptus* trees), 20 19 (NCA 2006/1289); Kuruman district, Sunnyside Farm, 27°43.514'S, 23°36.812'E, leg. C. Haddad, 1.XII.2003–22.I.2004 (pitfalls, gravel bed), 1♀ (NCA 2005/2013). Western Cape Province: Brenton-on-Sea, 34°04'S, 23°02'E, leg. H.G. Robertson, 1–7.XII.1996 (pitfall traps, broken fynbos), 1 (SAMC ENW-C005376); De Hoop Nature Reserve, Bitou number 2, 34°27.194'S, 20°24.250'E, leg. C. Haddad & R. Lyle, 25. IX.2007 (sifting leaf litter), 2 12 (NCA 2007/3896); Same locality, Potberg, 34°22.549'S, 20°32.004'E, leg. C. Haddad, 4.IV.2004 (sieving leaf litter), 16∂ 19 (NCA 2008/576); Knysna, Uitzicht Annex, 34°00'S, 23°20'E, leg. L. Lotz, 13-19.X.1998 (pitfall trap), 3 (NMBA 7420). TANZANIA: Coast Region: Kisarawe District, Kazimzumbwe Forest Reserve, 06°57'S, 39°03'E, leg. Frontier Tanzania, I-II.1991, 1 (ZMUC), 1 (ZMUC), 1 (ZMUC), 7 (ZMUC), 2 (ZMUC), 2 (ZMUC), 5∂ 2♀ (ZMUC); Same locality, leg. Frontier Tanzania, I–II.1992, 1∂ (ZMUC); Rufigi District, Namakutwa Forest Reserve, 08°19'S, 39°00'E, leg. Frontier Tanzania, VIII-IX.1992, 19 52 (ZMUC). Iringa Region: Uzungwa Mountains, Uzungwa Scarp Forest Reserve, above Chita Village [08°20'S, 35°56'E, 1500m a.s.l., leg. N. Scharff, 2–13.XI.1984 (pitfall traps, montane rain forest), 2 (ZMUC); Same locality, leg. N. Scharff, 25–29.X.1984 (pitfall traps, lowland rain forest), 1^Q (ZMUC). Kilimanjaro Region: Mkomazi Game Reserve, Ibaya camp, 03°58'S, 37°48'E, leg. A. Russell-Smith, 19–20.XI.1994 (pitfalls, unburnt grassland), $4\bigcirc 6\bigcirc$ (MRAC 211327). Lindi Region: Lindi District, Litipo Forest Reserve, 10°02'S, 39°29'E, leg. Frontier Tanzania, VII–IX.1993, 17 39 (ZMUC), 21 310 (ZMUC), 20 38 (ZMUC). Mbeya Region: 8km NE of Kyela, 09°35'S, 33°48'E, leg. R. Jocqué, 10–19.XI.1991 (pitfalls in miombo relict), $4\bigcirc 4\bigcirc$ (MRAC 173 920); Itungi, 09°36'S, 33°55'E, leg. R. Jocqué, 10.XI–1.XIII.1991 (pitfalls in swamp with floating vegetation, edge high reeds), 1 (MRAC 173940), 1 (MRAC 173960); Matema, 1km N of Livingstone mountains, 09°30'S, 34°03'E, leg. R. Jocqué, 14-24.XI.1991 (pitfalls, evergreen forest), 2Å (MRAC 173204). *Morogoro Region*: 62 road km SW of Morogoro, 07°02.5'S, 37°15.3'E, leg. W.J. Pulawski, 2.I.2003, 1♀ (CAS); Morogoro District, Kimboza Forest Reserve, 07°01'S, 37°48'E, leg. Frontier Tanzania, I-III.1994, 90 80 (ZMUC); Mwanihana Forest Reserve, 700m a.s.l., leg. N. Scharff, 8-16.IX.1984 (pitfall traps, lowland rain forest), 1 (ZMUC), 1 (ZMUC), 1 (ZMUC), 1 (ZMUC). Pwani

Region: Bagamoyo District, Sadani Zaraninge Forest Reserve, 06°10'S, 38°39'E, leg. Frontier Tanzania, VII–VIII.1991 (pitfalls, dry coastal forest), 1 (ZMUC). Tanga Region: Mbomole Hill, 05°05.7'S, 38°37'E, 1000m a.s.l., leg. C.E. Griswold, N. Scharff & D. Ubick, 5–8.XI.1995, 1d (CAS, CASENT 9033142); Muheza District, Magrotto Hill, 05°07'S, 38°45'E, leg. Frontier Tanzania, VII–IX.1994, 3∂ 1♀ (ZMUC), $2\sqrt[3]{2}$ (ZMUC); Muheza District, Manga Forest Reserve, 05°02'S, 34°47'E, leg. Frontier Tanzania, VIII.1997, 1 (ZMUC); Muheza District, Pangani Falls Forests, 05°20'S, 38°40'E, leg. Frontier Tanzania, I-III.1993 (riverine and dry forest), 8⁽⁷⁾ (ZMUC). TOGO: Bassari, 09°15'N, 00°47'E, leg. P. Douben, V-VII.1994 (pitfalls), 1 (MRAC 173991); Bassari, Entre Bassari et Sokode, 09°15'N, 00°47'E, leg. P. Douben, V–VII.1984 (savanna boisée), 4∂ 2♀ (MRAC 166237), 1º (MRAC 166176); Dzobégan, 07°14'N, 00°41'E, leg. S. Tchibozo, I.2003 (in house), 1 (MRAC 212776). UGANDA: Entebbe [00°04'N, 32°27'E], leg. P.L.G. Benoit, 1959, 1 (MRAC 131303); Kampala, Namulonge Research Station [00°32'N, 32°35'E], leg. A. Russell-Smith, 22.IV.1994 (in maize field), 1 (PCRS); Kanyawara, 00°34'S, 30°21'E, 1600m a.s.l., leg. V. & B. Roth, 30.X.1992, 1 (CAS, CASENT 9033135). ZAMBIA: Between Namwala and Lake Itezhi-Tezhi, Pontoon road, 15°41.887'S, 26°21.588'E, leg. C. Haddad, 5.XII.2006 (leaf litter), 1imm. 1^Q (NCA 2007/900); Kafue National Park, Near Namwala, Chibila Camp, 15°46.636'S, 26°00.405'E, leg. C. Haddad & J. Parau, 7.XII.2006 (leaf litter), 1 (NCA 2007/576); Kasanka National Park, Fibwe Camp, 12°33'S, 30°13'E, leg. C. Stuart, 15.II.2001, 1♀ (NCA 2002/540); Same data, 11.XI.2001, 1♀ (NCA 2002/550); Livingstone, Quarry nr Livingstone Airport, 17°47.998'S, 25°46.588'E, leg. C. Haddad & J. Parau, 1.XII.2006 (leaf litter), 32 (NCA 2007/624); Near Mpulungu, 08°48'S, 31°05'E, leg. W.J. Pulawski, 20.III.1998, 1♀ (CAS, CASENT 9033105); Wildlives Game Farm, near Choma, Hunter's Camp, 16°58.957'S, 26°36.973'E, leg. C. Haddad, J. Parau & F. Jordaan, 3.XII.2006 (leaf litter), 1∂ 7♀ (NCA 2007/470); Same locality, Open savanna, 16°58.974'S, 26°38.974'E, leg. C. Haddad, 4.XII.2006 (leaf litter), 1 (NCA 2007/553); Same locality, Siatichema River, 16°59.615'S, 26°38.093'E, leg. C. Haddad, 3.XII.2006 (leaf litter), 4Q (NCA 2007/1128). ZIMBABWE: Bulawayo, Hillside, 20°10'S, 28°35'E, leg. M. FitzPatrick, II.1999 (pitfalls), 1^Q (NMZA 13854); Harare, 6km NW of Westwood HQ, Girls College [17°49'S, 30°59'E], leg. Natural History Museum of Zimbabwe staff, 7.XII.1993 (under logs), 2⁽⁷⁾ (NMZA 11157); Victoria Falls, 17°56'S, 25°50'E, leg. W.J. Pulawski, 1–8.II.1995, 1♂ (CAS, CASENT 9033083).

Diagnosis. *Copa flavoplumosa* is a distinctive species, easily recognisable from congeners by the large 6-shaped epigynal ridges and long copulatory ducts with an anterior loop in the females, and males by the embolus with a broad base and long, slightly curved distal section.

Remarks. The type locality of *C. flavoplumosa* is given by Simon (1885) as Congo: Landana. This locality is within the modern Angolan enclave of Cabinda that is surrounded by the D.R. Congo. Although the syntype series includes a male, this sex was not originally described by Simon (1885), and this specimen is therefore not desig-

nated as a paralectotype. A lectotype female and paralectotype female are designated here, of which the larger of the two in the type series is the lectotype.

The specimens of *Copa benina nigra* Lessert, 1933 available in the MNHG are not specifically labelled as types and their status is thus uncertain, although the labels indicate localities consistent with that in Lessert's (1933) description, i.e. Chimporo and Rio Mbale. Neither of these localities could be traced on modern maps or electronic resources. Some maps from the early 20th century indicate that the Rio Mbale runs northwards between 16°20'E and 16°40'E with its source at approximately 12°00'S in central Angola. Chimporo has been cited by Mansell (1996) as being located at 17°20'S, 17°17'E in southern Angola. From Lessert's (1933) figure of the male embolus it is clear that *C. b. nigra* is a junior synonym of *C. flavoplumosa*.

Female (Parc National Albert, MRAC 234182). Measurements: CL 3.60, CW 2.69, AL 4.85, AW 3.10, TL 8.20 (6.35–9.30), FL 0.40, SL 1.70, SW 1.58, AME–AME 0.10, AME–ALE 0.02, ALE–ALE 0.44, PME–PME 0.12, PME–PLE 0.13, PLE–PLE 0.56, PERW 0.78, MOQAW 0.40, MOQPW 0.43, MOQL 0.57.

Length of leg segments: I 2.60 + 1.23 + 2.04 + 2.05 + 1.20 = 9.12; II 2.58 + 1.20 + 1.93 + 2.03 + 1.18 = 8.85; III 2.55 + 1.16 + 1.89 + 2.25 + 1.25 = 9.10; IV 3.08 + 1.30 + 1.98 + 3.56 + 1.38 = 11.30.

General appearance as in Fig. 7. Carapace bright yellow-orange, eye region black; broad median black line comprising black feathery setae from PER to posterior slope of carapace, broken up by narrow asetose line from between PME to midpoint and Y-shaped asetose area from fovea towards anterior coxae and posterior of carapace; striae absent; lateral margins with narrow fringe of black feathery setae; areas between markings covered in orange feathery setae. All eyes with black rings; AER procurved, medians much larger than laterals; AME separated by distance equal to 1/2 their diameter; AME separated from ALE by distance approximately $\frac{1}{10}$ AME diameter; clypeus height slightly less than 11/2 AME diameter; PER strongly procurved, eyes subequal in size; PME separated by distance equal to 34 their diameter; PME separated from PLE by distance equal to ⁴/₅ PME diameter; CW:PERW = 3.45:1. Chelicerae yelloworange, with pectinate curved setae on promargin; promargin with two teeth separated by basal width of proximal tooth, distal tooth much larger; retromargin with two teeth separated by ¹/₂ their basal width, distal tooth slightly larger than proximal tooth, close to fang base. Endites yellow, cream prolaterally and distally, with small black prolateral proximal markings; labium yellow-orange, cream distally, without markings; sternum pale orange, without markings (Fig. 9). Legs yellow-brown, posteriors slightly darker, femora slightly darker dorsally than ventrally; femora with broad dorsal line between proximal and distal spines and incomplete dorsal rings at ²/₃ their length and distally, each composed of black feathery setae; patellae with dense black feathery setae laterally; tibiae I & II without markings, with scattered black feathery setae, III & IV with rings proximally and medially corresponding to ventral spines, distal ends with black ring, all covered in black feathery setae with white feathery setae between them; metatarsi I & II without markings, with scattered black and white feathery setae, III & IV with proximal, medial and distal rings corresponding to paired leg spines, covered in black



Figures 61–66. Digital microscope photographs of emboli of *Copa* species in ventral view: **61–65** *Copa flavoplumosa* Simon, 1885 from D.R. Congo **(61)**, Cameroon **(62)**, Tanzania **(63)**, Botswana **(64)** and South Africa **(65) 66** *C. kei* sp. n. from South Africa. Scale bars = 0.1 mm.

feathery setae with white feathery setae between them; tarsi uniform yellow; palp yellow, spines without spots. Leg spination: femora: I pl 2 do 3 rl 2, II pl 2 do 3 rl 2, III pl 2 do 3 rl 1-2, IV pl 2 do 3 rl 1; all femora with scattered erect ventral setae; patellae: I & II with fine proximal and distal do setae, III & IV with proximal and distal do spines, proximal spine finer and shorter than distal; tibiae: I do 1 pl 2 long fine setae, plv 2 rlv 2 spines, II do 1 long fine seta, pl 2 plv 2 rlv 1 spines, III pl 2 do 1 rl 2 plv 2 rlv 2 vt 2, IV pl 2 do 1 rl 2 plv 2 rlv 1 vt 2; metatarsi: I plv 2 rlv 2, II plv 2 rlv 2, III pl 3 rl 3 plv 2 rlv 2 vt 3, IV pl 3 rl 3 plv 2 rlv 2 vt 3. Palpal spination: femora: pl 1 do 2 rl 1, with scattered erect ventral setae, mainly retrolaterally; patellae: pl 1 do 2; tibiae: pl 1 do 2 plv 1-2; tarsi: pl 1 rl 1 plv 2 rlv 1. Abdomen with very small orange-brown anterior dorsal scutum; dorsum cream, densely covered in black straight and feathery setae, interspersed with white feathery setae forming small spots in anterior two-thirds and fine transverse chevrons posteriorly; sides of abdomen cream, densely covered in white feathery setae; venter cream, covered in short straight black setae, with broad



Figures 67–70. Genitalic morphology of *Copa flavoplumosa* Simon, 1885: **67** female epigyne, ventral view **68** same, dorsal view **69** male palp, ventral view **70** same, retrolateral view. Scale bars = 0.25 mm.

densely setose subrectangular marking medially from epigastric furrow to spinnerets, comprising black and white feathery setae and short straight black setae. Epigyne longer than broad, with large 6-shaped ridges laterally at midpoint of epigyne, separated by approximately 1½ times their width, with copulatory openings distinct (Figs 55, 67); copulatory ducts directed anteriorly, slightly obliquely, with anterior bend and characteristic loop before entering anterior ST II; broad ducts connecting ST II to elongate posterior ST I; ST I clearly narrower than ST II (Fig. 68).

Male (Mikembo, MRAC 234447). Measurements: CL 3.30, CW 2.55, AL 3.55, AW 2.00, TL 6.60 (5.20–8.90), FL 0.37, SL 1.43, SW 1.41, AME–AME 0.06, AME–ALE 0.02, ALE–ALE 0.38, PME–PME 0.10, PME–PLE 0.11, PLE–PLE 0.49, PERW 0.68, MOQAW 0.37, MOQPW 0.37, MOQL 0.50.

Length of leg segments: I 2.28 + 1.08 + 1.90 + 1.95 + 1.23 = 8.44; II 2.23 + 1.06 + 1.78 + 1.93 + 1.18 = 8.18; III 2.20 + 1.05 + 1.80 + 2.20 + 1.20 = 8.45; IV 2.95 + 1.20 + 2.25 + 3.32 + 1.33 = 11.05.

General appearance as in Fig. 8, male more slender than female. Carapace bright orange, markings and setae as for female. All eyes with black rings; AER procurved, medians much larger than laterals; AME separated by distance equal to $\frac{2}{5}$ their diameter; AME separated from ALE by distance approximately $\frac{1}{10}$ AME diameter; clypeus height slightly larger than double AME diameter; PER strongly procurved, medians

very slightly larger than laterals; PME separated by distance slightly less than ²/₃ their diameter; PME separated from PLE by distance slightly larger than ⁴/₅ PME diameter; CW:PERW = 3.75:1. Chelicerae orange, with curved setae on promargin not pectinate; dentition as for female. Endites, labium and sternum as for female. Legs yellowbrown, posteriors slightly brighter yellow and darker, markings as for female. Leg spination: femora: I pl 2-3 do 3 rl 1-2, II pl 2 do 3 rl 2, III pl 2 do 3 rl 2, IV pl 2 do 3 rl 2; all femora with scattered erect ventral setae; patellae: I & II with fine proximal and distal do setae, III & IV with proximal and distal do spines, proximal spine finer and shorter than distal; tibiae: I pl 1 do 1 rl 1 long fine setae, plv 2 rlv 2 spines, II do 1 rl 1 long fine setae, pl 2 plv 2 rlv 2, III pl 2 do 1 rl 2 plv 2 rlv 2 vt 2, IV pl 2 do 1 rl 2 plv 2 rlv 2 vt 2; metatarsi: I plv 2 rlv 2, II plv 2 rlv 2, III pl 3 rl 3 plv 2 rlv 2 vt 3, IV pl 3 rl 3 plv 2 rlv 2 vt 3. Palpal spination: femora: pl 1 do 2 rl 1, with scattered erect ventral setae; patellae: pl 1 do 2; tibiae: pl 1 do 1 plv 1; tarsi: pl 1 plv 2. Abdomen with orangebrown dorsal scutum extending just past midpoint; dorsum cream, densely covered in black straight and feathery setae with scattered white feathery setae, with patches of white feathery setae forming small spots in anterior two-thirds and fine transverse chevrons posteriorly; sides of abdomen cream, densely covered in white feathery setae with scattered yellow-orange feathery setae; venter cream, covered in short straight black setae, with broad densely setose marking medially from epigastric furrow, converging at spinnerets, comprising black and white feathery setae and short straight black setae. Male palpal cymbium orange-brown, with several thicker bent setae distally (Fig. 70); tegulum pear-shaped, dark red-brown, with nearly black ducts; embolus with broad oblique base directed prolaterally and distally, proximal coil broad and nearly transverse, distal section slightly curved and variable in length (Figs 56, 61-65, 69).

Colour variation. Throughout the geographical range of *C. flavoplumosa* there is considerable variation in the colouration of specimens, particularly with regard to the intensity of yellow/orange and white/cream markings on the body. Three main generalised colour forms can be found. The most widespread variation has a yellow-brown to bright orange carapace and abdomen, with black markings (Fig. 1), and is found throughout the region except in the rainforests of central Africa. This colour form is mainly associated with populations in savanna and grassland habitats.

The second colour form (corresponding to the redescriptions above) has a yellow to orange carapace with black markings and a black abdomen with white markings, similar in pattern and arrangement to the previous form (Figs 2, 3, 7, 8). This form is found in moist savannas and forests across tropical Africa. While most South African populations of this species have colouration corresponding to the first form described here, the populations in the fynbos and grasslands along the southern coast of the country also have a black abdomen with white markings, but the carapace is even darker, nearly dark red-brown in colour.

The third form, corresponding to the description of *C. benina nigra*, is a nigrito form restricted to central and western Africa but only occurring in isolated populations. This form has an entirely black body with white markings corresponding to those described for the other two types above (Fig. 4).



Figure 71. Distribution of Copa flavoplumosa Simon, 1885 in the Afrotropical Region.

The distribution of the three forms can partly be explained by the habitats they occupy, although some populations (e.g. Faro Game Reserve in Cameroon and Mankono in Ivory Coast) have representatives of all three colour forms but in varying proportions. The colouration of the first form is clearly an adaptation for camouflage in the litter layer of savanna and other habitats that are exposed to sunlight for a considerable portion of the day. The second form apparently occurs in closed canopy forests and dense woodlands that are shaded for most of the day or the entire day. The black abdominal colouration with strongly contrasting markings enables these spiders to blend into dark patches with low light levels in these habitats. The nigrito form can exploit such microhabitats in a similar way, but this does not explain the occurrence of this colour form at some Miombo woodland localities (e.g. Wildlives Game Farm

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in Zambia). A possible explanation for this case could be the occurrence of natural fires in these habitats. The burned trees, logs and grasses in such disturbed environments may provide sites where these spiders may optimally exploit their colouration for camouflage. Whether individuals have the capability for colour change in response to changing environmental conditions (e.g. following fire) through the use of chromatophores or ommochromes, or whether individual phenotypes are stable, has yet to be determined and should be the subject of future research.

Distribution. Widespread throughout the continental Afrotropical Region (Fig. 71).

Biology. Specimens were mainly collected from the leaf litter layer of all of the main biome types in Africa except for true deserts and karoo habitats, although records from semi-arid temperate grasslands and dry savannas are scarce. The greatest density of records is in moist savannas and closed canopy forests, although the species seems largely absent from rainforests; considering the extensive sampling in the D.R. Congo, especially by the MRAC, only three records from rainforests in this country are reported here. Specimens were most regularly collected by pitfall traps, litter sifting and by hand from the ground surface.

Copa kei sp. n.

urn:lsid:zoobank.org:act:A4CC7016-5E90-4687-8936-2F07FE3BDE0F http://species-id.net/wiki/Copa_kei Figures 5, 6, 10–12, 19–30, 49–54, 57–60, 66, 72–75, 76

Type material. Holotype female. SOUTH AFRICA: *Eastern Cape Province*: Kei Mouth, 32°41.206'S, 28°22.497'E, leg. C. Haddad, 25.IX.2004 (grass at tree base) (NCA 2007/3843).

Paratypes. SOUTH AFRICA: Eastern Cape Province: Cwebe Nature Reserve, The Haven, 32°14.497'S, 28°54.653'E, leg. C. Haddad, 30.X.2006 (grassy litter behind dunes), 13 (NCA 2008/270); Dwesa Nature Reserve, 32°16.2'S, 26°52.2'E, leg. M. Mgobozi, X.2004 (pitfall traps), 2³/₀ 2^Q (NCA 2008/1967); East London, Pineapple Research Station, 33°00.6'S, 26°54.0'E, leg. D. Keetch, 15.III.1985 (on soil, coastal dune forest), $1 \bigcirc 5 \bigcirc$ (NCA 95/325); Hogsback, Never Daunted Lodge, 32°35.729'S, 26°55.894'E, 1250m a.s.l., leg. C. Haddad, 7.I.2011 (night collecting), 1° (NCA 2010/2750); Same locality, Tyume Forest, near Big Tree, 32°36.123'S, 26°56.687'E, 1070m a.s.l., leg. C. Haddad, 28.III.2011 (sifting litter, Afromontane forest), 1Å (TMSA 24012); Katberg, Katberg Pass, 32°28.710'S, 26°40.337'E, leg. J.A. Neethling & C. Luwes, 4.X.2011 (leaf litter, Afromontane forest), 2Å (NCA 2012/5502); Kei Mouth, 32°41.280'S, 28°22.484'E, leg. C. Haddad, 6.XII.2005 (leaf litter, coastal dune forest), 1^Q (NCA 2008/1907); Same locality, 32°41.206'S, 28°22.497'E, leg. C. Haddad, 10.VIII.2002 (leaf litter, coastal dune), 1 (NCA 2002/414); Lusikisiki district, Mzimhlava River mouth, 31°20'S, 29°40'E, leg. Baddeley, II.1980 (coastal evergreen forest), 12 (MRAC 164163). KwaZulu-Natal Province: Howick, Shooter's Hill [29°26'S, 30°19'E, 790m a.s.l.], leg. R.F. Lawrence, X.1937, 1 \bigcirc (NMSA 2124); Karkloof Nature Reserve, 29°19.1'S, 30°15.5'E, 1325m a.s.l., leg. M. Mostovski, 28.IX–3.X.2005 (yellow pan trap), 2 \bigcirc 2 \bigcirc (NMSA 21486); Pietermaritzburg, Town Bush [29°36'S, 30°23'E], leg. R.F. Lawrence, IX–XI.1950, 2 \bigcirc (NMSA 5513); Same locality, southern slopes of Hogsback, 29°33'S, 30°21'E, 1000m a.s.l., leg. C.E. Griswold & T. Meikle-Griswold, 20.IX.1984 (Berlese extracted leaf litter, native forest), 1 \bigcirc (NMSA 24463).

Other material examined. None.

Diagnosis. The species is easily recognisable by the distinct dorsal black spot on the anterior margin of the abdomen. Males are characterised by the narrow coiled embolus and females by the small copulatory openings and the nearly transverse copulatory ducts.

Etymology. The specific name is a noun in apposition taken from the type locality, the town Kei Mouth, located at the estuary of the Great Kei River in the Eastern Cape Province.

Female (holotype, Kei Mouth, NCA 2007/3843). Measurements: CL 3.84, CW 2.75, AL 6.00, AW 4.55, TL 9.65 (6.40–9.80), FL 0.40, SL 1.75, SW 1.60, AME–AME 0.10, AME–ALE 0.01, ALE–ALE 0.46, PME–PME 0.20, PME–PLE 0.13, PLE–PLE 0.63, PERW 0.83, MOQAW 0.44, MOQPW 0.51, MOQL 0.54.

Length of leg segments: I 2.60 + 1.25 + 2.03 + 2.05 + 1.18 = 9.11; II 2.50 + 1.24 + 1.90 + 2.00 + 1.16 = 8.80; III 2.45 + 1.23 + 1.88 + 2.30 + 1.16 = 9.02; IV 3.15 + 1.38 + 2.63 + 3.40 + 1.39 = 11.95.

General appearance as in Fig. 10. Carapace bright yellow-orange, eye region black except between PME; broad median black line covered in black feathery setae from PER to posterior slope of carapace, broken up by asetose line from PME to midpoint and paired oblique asetose line from fovea towards anterior coxae; black striae present, falling within broad median band; lateral margins black from chelicerae to posterior marking, markings expanded from coxae I and from coxae I-IV, densely covered in black feathery setae; areas between markings covered in white feathery setae. All eyes with black rings; AER procurved, medians much larger than laterals; AME separated by distance equal to ¹/₂ their diameter; AME separated from ALE by distance approximately 1/10 AME diameter; clypeus height approximately 1¹/₂ AME diameter; PER strongly procurved, medians very slightly larger than laterals; PME separated by distance equal to 11/4 their diameter; PME separated from PLE by distance equal to $\frac{4}{5}$ PME diameter; CW:PERW = 3.31:1. Chelicerae yellow-orange, with pectinate curved setae on promargin; three closely spaced teeth on promargin, distal tooth smallest, median tooth largest; median tooth closer to distal tooth than to proximal tooth; retromargin with two teeth separated by their basal width, distal tooth slightly smaller than proximal tooth, close to fang base. Endites yellow, cream prolaterally; labium yellow-brown, cream distally, with broad transverse black marking along proximal margin; sternum bright yellow, with broad black marking along margins, expanded at coxae (Fig. 12). Legs yellow-brown, with faint black mottling; spine bases with distinct black spot; trochanters with distal margins black laterally; femora all with black lateral and distal mottling, ventrally

with faint distal ring; patellae with fine dorsal proximal line and lateral and distal mottling; tibiae with faint rings proximally and medially corresponding to ventral spines, distal ends with black ring; metatarsi with proximal, medial and distal rings, corresponding to paired leg spines; tarsi yellow; palp yellow, spines with black spots. Leg spination: femora: I pl 2 do 3 rl 1, II pl 2 do 3 rl 1, III pl 2 do 3 rl 2, IV pl 2 do 3 rl 2; all femora with scattered erect ventral setae; patellae: I & II with fine proximal and distal do setae, III & IV with proximal and distal do spines, proximal spine finer and shorter than distal; tibiae: I do 1 long fine seta, plv 2 rlv 2, II do 1 long fine seta, plv 1 rlv 2 spines, III pl 2 do 1 rl 2 plv 2 rlv 1-2 vt 2, IV pl 2 do 1 rl 2 plv 2 rlv 2 vt 2; metatarsi: I plv 2 rlv 2, II plv 2 rlv 2, III pl 3 rl 3 plv 2 rlv 2 vt 3, IV pl 3 rl 3 plv 2 rlv 2 vt 3. Palpal spination: femora: pl 1 do 2, with scattered erect ventral setae, mainly retrolaterally; patellae: pl 1 do 2; tibiae: pl 1 do 2 plv 1; tarsi: pl 1 rl 1 plv 3 rlv 1. Abdomen with very small red-brown anterior dorsal scutum beneath marking; dorsum mottled grey, with large black spot anteriorly, dark grey median stripe from anterior spot to midpoint, and small cream chevrons posteriorly; short straight black setae and white feathery setae on markings dorsally and laterally; sides of abdomen cream; venter cream, covered in short straight black setae, with dark marking medially on epigastric plate covering epigyne, broadened from epigastric furrow, extending to and surrounding spinnerets. Epigyne small, with strongly curved ridges laterally at midpoint of epigyne, separated by approximately three times their width, with copulatory openings distinct (Figs 57, 72); copulatory ducts almost straight, nearly transverse, slightly oblique, entering rounded anterior ST II; broad ducts connecting ST II to subrectangular posterior ST I; ST I slightly narrower than ST II (Fig. 73).

Male (paratype, Kei Mouth, NCA 2002/414). Measurements: CL 3.44, CW 2.54, AL 3.50, AW 2.30, TL 6.98 (5.20–6.98), FL 0.34, SL 1.55, SW 1.48, AME–AME 0.07, AME–ALE 0.01, ALE–ALE 0.40, PME–PME 0.20, PME–PLE 0.11, PLE–PLE 0.55, PERW 0.75, MOQAW 0.42, MOQPW 0.48, MOQL 0.52.

Length of leg segments: I 2.35 + 1.13 + 1.87 + 1.97 + 1.20 = 8.52; II 2.32 + 1.10 + 1.75 + 1.93 + 1.15 = 8.25; III 2.28 + 0.98 + 1.75 + 2.13 + 1.10 = 8.24; IV 2.90 + 1.13 + 2.40 + 3.30 + 1.30 = 11.03.

General appearance as in Fig. 11, male more slender than female. Carapace deep orange, markings and setae as for female. All eyes with black rings; AER procurved, medians much larger than laterals; AME separated by distance equal to $\frac{2}{5}$ their diameter; AME separated from ALE by distance approximately $\frac{1}{10}$ AME diameter; clypeus height equal to $\frac{1}{2}$ AME diameter; PER strongly procurved, medians very slightly larger than laterals; PME separated by distance equal to $\frac{1}{2}$ their diameter; PME separated from PLE by distance slightly larger than $\frac{4}{5}$ PME diameter; CW:PERW = 3.39:1. Chelicerae yellow-orange, with curved setae on promargin not pectinate; dentition as for female. Endites, labium, sternum and leg colouration and markings as for female. Leg spination: femora: I pl 2 do 3 rl 1, II pl 2 do 3 rl 1, III pl 2 do 3 rl 2; all femora with scattered erect ventral setae; patellae: I & II with fine proximal and distal do setae, III & IV with proximal and distal do spines,



Figures 72–75. Genitalic morphology of *Copa kei* sp. n.: 72 female epigyne, ventral view 73 same, dorsal view 74 male palp, ventral view 75 same, retrolateral view. Scale bars = 0.25 mm.

proximal spine finer and shorter than distal; tibiae: I do 1 long fine seta, plv 3 rlv 3 spines, II do 1 long fine seta plv 2 rlv 3, III pl 2 do 1 rl 2 plv 2 rlv 2 vt 2, IV pl 2 do 1 rl 2 plv 2 rlv 2 vt 2; metatarsi: I plv 2 rlv 2, II plv 2 rlv 2, III pl 3 rl 3 plv 1-2 rlv 1-2 vt 3, IV pl 3 rl 3 plv 2 rlv 2 vt 3. Palpal spination: femora: pl 1 do 2, with scattered erect ventral setae, mainly retrolaterally; patellae: pl 1 do 2; tibiae: pl 1 do 1 plv 1; tarsi: pl 2 rl 1 plv 2 rlv 1. Abdomen with narrow red-brown dorsal scutum extending just past midpoint; dorsum mottled grey, with large black spot anteriorly, broad dark grey median stripe from anterior spot narrowing towards posterior of scutum, and small cream chevrons in posterior half; short straight black setae and white feathery setae on markings dorsally and laterally; lateral margin of abdomen creamy--grey; venter creamy-grey, covered in short straight black setae, with narrow dark grey marking medially on epigastric plate, broadened from epigastric furrow, extending to and surrounding spinnerets. Male palpal cymbium yellow, with several thicker bent setae distally (Fig. 75); tegulum pear-shaped, orange-brown, with nearly black ducts; embolus with narrow base and 11/2 narrow coils around a central prong; distal section slightly curved (Figs 58, 66, 74).

Distribution. Known from the south-eastern parts of South Africa (Fig. 76); endemic to the Maputaland-Pondoland-Albany Centre of Endemism (Driver et al. 2005).

Biology. Specimens were mainly collected from the leaf litter layer of closed canopy Afromontane and coastal forest habitats.



Figure 76. Map of South Africa indicating the distribution of *Copa flavoplumosa* Simon, 1885 (black circles) and *C. kei* sp. n. (yellow triangles).

Species nomen dubium

Copa agelenina Simon, 1910 Figures 77–80

Copa agelenina Simon 1910: 202.

Type material. Subadult female holotype. BOTSWANA: Kalahari, Sekcoma [24°24'S, 23°53'E] – Khakea [24°42'S, 23°30'E], leg. L. Prueltje?, XI.1904, ZMB 28198 (examined).

Remarks. The holotype is a subadult female specimen (Figs 77–79), clearly with a pre-epigynum and lack of epigynal sclerotisation typical of adults, and is not an adult female as described by Simon (1910) and listed on Platnick (2012). The species is definitely different to *C. flavoplumosa* specimens collected in north-western South Africa (Sunnyside and Hermitage) and has a clearly broader PER (CW:PERW = 2.84:1 as opposed to 3.45:1 in *C. flavoplumosa* females) that is less strongly procurved than in *C. flavoplumosa*. Since no adult *Copa* material is available from the arid savanna of southern Botswana, it is impossible to match this specimen to either of the two conti-



Figures 77–80. Digital microscope photographs of the holotype subadult female of *Copa agelenina* Simon, 1910: **77** dorsal habitus **78** abdomen, ventral view **79** pre-epigynum **80** eye region, dorsal view. Scale bars: 77, 78 = 1.0 mm; 79, 80 = 0.25 mm.

nental species or to recognise it as a distinct species. I would therefore propose that *C. agelenina* be considered a species *nomen dubium*.

The eye arrangement and measurements (Fig. 80) suggest that this species may belong to one of the new cryptic lycosiform castianeirine genera (Haddad 2012b, in prep.), but adults will have to be collected before the generic placement can be confirmed and the species be revalidated and redescribed.

Discussion

The current study treated the continental species of *Copa* in the Afrotropical Region, reducing the number of species from four to two, of which one species is newly described. The type species of the genus, *C. flavoplumosa*, is widespread throughout the region and includes two synonyms newly proposed here. It is distributed from Guineé in the west to Tanzania in the east, and from Nigeria in the north to South Africa in the south. The new species, *C. kei*, is endemic to south-eastern South Africa. While *C. flavoplumosa* provides a useful example of extreme habitat flexibility, occupying habitats from forests to semi-deserts, *C. kei* is very closely associated with Afromontane and coastal forests in South Africa. The latter species has a distribution falling entirely within the Maputaland-Pondoland-Albany Centre of Endemism in South Africa (Driver et al. 2005). Surprisingly, very few *C. flavoplumosa* records exist from the tropical rainforests of the D.R. Congo and Congo Republic, despite the former being one of the best sampled countries on the continent (Fig. 71). The two species therefore represent extremes regarding both vagility and ecological flexibility.

Both species are clearly ground-dwelling leaf litter specialists and were mainly collected by pitfall trapping, litter sifting and hand collecting. *Copa flavoplumosa* may be very abundant in some habitats (e.g. forests in Ivory Coast), but they tend to be considerably less common in savannas and other habitat types (Modiba et al. 2005; Dippenaar-Schoeman and Wassenaar 2006; Foord et al. 2008; Haddad et al. 2010; Muelelwa et al. 2010). They have occasionally been collected in agroecosystems, specifically from the canopies of orchard crops in South Africa (avocadoes, macadamias and pistachios), but never exceed 2% of the total spider fauna (Dippenaar-Schoeman et al. 2001, 2005; Haddad et al. 2005). Their arboreal habits in agroecosystems are in stark contrast to their almost exclusive ground-dwelling habits in natural habitats, and the reasons for this ecological divergence are unknown.

Acknowledgments

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RESEARCH ARTICLE



A new species of *Newportia* Gervais, 1847 from Puerto Rico, with a revised key to the species of the genus (Chilopoda, Scolopendromorpha, Scolopocryptopidae)

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Abstract

A new species of the centipede genus *Newportia*, *N. stoevi* **sp. n.**, is described from Rio Encantado Cave, Puerto Rico. It differs from all congeners by having sternites distinctly margined laterally and ultimate legs bearing 4 spinous processes on both prefemur and femur, and 2 on tibia. The value of some terms used in the taxonomy of the genus have been analyzed and an amended identification key to the species of *Newportia* is provided.

Keywords

Newportia, Newportiinae, new species, identification key, external characters

Introduction

The genus *Newportia* Gervais, 1847 is still poorly known. It is especially so with regards to the Puerto Rican fauna where only two species have hitherto been registered. Silvestri (1908) reported *N. ernsti* Pocock, 1891 from Coamo Springs, while Chagas and Shelley (2003) recorded *N. heteropoda* Chamberlin, 1918 from two localities – 8.4 mi (13.4 km) SW Luquillo, trail to Minas Falls off hwy. 191, Luquillo Division, Carib-

bean National Forest and from 4 mi (6.4 km) N Villalba, Dona Juaña Recreation Area. To these should be added Chamberlin's (1950) uncertain record of *Newportia* sp. from Maricao Insular Forest, based on a specimen with missing ultimate legs.

Herewith, I describe a new species of *Newportia* recently collected in Puerto Rico by Dr Petar Beron from the National Museum of Natural History, Sofia (NMNHS). The specimen was assigned to *Newportia* and tentatively identified as a new species by Dr Pavel Stoev, curator of Myriapoda at the NMNHS who committed it for further study to me. This specimen differs from all congeners, in the first place, by important traits of the ultimate legs (which are normally developed and have no traces of regeneration) and unusually developed lateral margination of sternites.

The identification key to the species of *Newportia* (Schileyko and Minelli 1998) has been updated to accommodate this and other new species described recently (e.g., *Newportia troglobia* Chagas & Shelley, 2003), as well as to reflect other nomenclature novelties proposed in the genus. Some general notes on the external anatomy of *Newportia* have been made, too. The terminology follows Bonato et al. (2010).

Systematic part

SCOLOPENDROMORPHA Pocock, 1895 Scolopocryptopidae Pocock, 1896 Newportiinae Pocock, 1896 *Newportia* Gervais, 1847

Newportia stoevi sp. n.

urn:lsid:zoobank.org:act:AE5E2F31-F3F2-45EB-9AD6-24EDA31D1D66 http://species-id.net/wiki/Newportia_stoevi Figs 1–10

Holotype: Puerto Rico, Florida Co., Rio Encantado Cave, 1 (sub?)adult, 29.07.2009, leg. P. Beron (NMNHS).

Locus typicus. Puerto Rico, Florida Co., Rio Encantado Cave.

Derivatio nominis: named after my friend and colleague Dr Pavel Stoev who drew my attention to this new species.

Diagnosis. Tergite 1 with rounded anterior transverse suture and incomplete paramedian sutures. Sternites distinctly margined laterally. Ultimate legs: prefemur with 4, femur with 3 small spinous processes medially and 1 ventrally; tibia with 2 small spinous processes medially. Tarsus 1 large and clavate (bulbous), clearly differing from the much thinner tarsus 2; the latter consisting of 19–20 articles.

Description. Length of body *ca* 17 mm, length of ultimate legs about 9 mm. Color (in ethanol): entire animal uniformly light-yellow with cephalic plate and forcipular segment slightly darker (Fig. 1). Body sparsely pilose; sternites and legs less setose than tergites.



Figures 1–4. *Newportia stoevi*, sp. n. **I** Habitus **2** Head and anterior segments, ventral view **3** Forcipular segment, ventral view **4** Tergites 22 and 23 and prefemora of ultimate legs, dorsal view; (**pt**) – pretarsus of second maxilla, (**ar3**) – article 3 of telopodite of second maxilla, (**cxs**) – forcipular coxosternite, (**am**) – anterior margin of coxosternite, (**t**) – tarsungulum, (**ps**) – paramedian sutures, (**lls**) – lateral longitudinal sutures, (**ut**) – tergite of ultimate leg-bearing segment, (**sup**) – spurs of ultimate prefemur.

Antennae composed of 17 articles (Fig. 2), reaching rear edge of tergite 5 when folded backwards; 2.5 basal antennal articles covered by a few long setae, subsequent articles densely pilose. Basal antennal articles somewhat flattened dorso-ventrally.

Head: cephalic plate visibly longer than wide, with rounded corners and very short paramedian sutures at posterior margin.

Second maxillae: as in all other *Newportia* species but dorsal spur on article 2 of the telopodite not recognisable. Pretarsus without spurs, with well-developed dorsal brush. The angle between the longitudinal axes of pretarsus and article 3 of telopodite slightly more than 100° (Fig. 3), which is quite unusual condition in Scolopendromorpha.

Forcipular segment: coxosternite without any visible sutures (including the chitinlines). Anterior margin of coxosternite evidently convex (Fig. 3), divided by a median diastema into two low additionally sclerotised lobes; each lobe bearing a long seta. Trochanteroprefemoral process absent. Tarsungula normal.

Tergites: anterior margin of tergite 1 covered by the cephalic plate; tergite 1 with a rounded anterior transverse suture and paramedian sutures stretching from the transverse suture to the posterior tergal margin. Tergite 3 with a very characteristic thin oblique sutures bordering the anterior corners of tergite. Tergites 2-22 with complete paramedian sutures, tergites 3-21(22) with lateral longitudinal sutures (Fig. 4). Tergite 23 lacking sutures, its posterior margin convex. Tergite margination virtually absent, only tergite 23 distinctly margined laterally. Tergite 23 much wider rather than long and nearly rectangular in shape; its lateral sides slightly rounded (Fig. 4). All tergites without medial keel; pretergites also missing.

Sternites: trapeziform, 2-22 with incomplete (equally shortened from both sides) but with a well expressed median longitudinal sulcus. Sternites 2-21 with definite and complete lateral margination (Fig. 5) through lateral longitudinal sutures (see Remark 2); endosternites absent. Sternite 23 trapeziform, with a few very short (spur-like) setae on lateral sides (Fig. 6), with a straight posterior margin.

Legs: prefemur, femur and tibia with a few large setae (Fig. 5); tarsi with more numerous setae of various length and size. Tibia of legs 1–20 with a lateral spur; both, ventral tibial spur and tarsal spur absent. Tarsi of legs 1–21 (Fig. 5) without distinct division between tarsus 1 and 2; pretarsi long, thin and sharply pointed. Pretarsi of legs 1-22 with two thin and long (as long as 1/2 of pretarsus) accessory spines.

Coxopleuron (Figs 6, 7): nearly completely pierced with coxal pores of various size – only coxopleural process and a narrow area bordering posterior margin of coxopleuron remaining poreless. Coxopleural process (Figs 6, 7) as long as ultimate sternite, conical, without additional spines. Coxopleural surface without setae. Posterior margin of pleuron of ultimate leg-bearing segment forming a very obtuse angle.

Ultimate legs (Fig. 8): slender, *ca* 9 mm long, width of prefemur *ca* 0.5 mm. Prefemur triangular in cross-section, with a standard row of 4 ventral spinous processes (Fig. 7), some spurs (strong, spine-like setae of various length) dorso-laterally and more numerous similar spurs dorso-medially (Fig. 4). All four prefemoral ventral spinous processes are of the same size, apically curved and ending in a pointed harpoon-like tip, which is accompanied by a long seta. Femur cylindrical, with 3 small spinous processes medially (Fig. 9) and 1 ventrally in the middle of femur (Fig. 10). Tibia cylindrical, with 2 small spinous processes medially: one close to its base and another at mid length (Figs 9, 10). Both femoral and tibial spinous processes are ac-



Figures 5–8. *Newportia stoevi*, sp. n. **5** Segments and midbody legs, ventral view **6** Posterior body end, ventral view **7** Left side of ultimate leg-bearing segment and prefemora of ultimate legs, ventro-lateral view; (**mls**) – median longitudinal sulcus, (**ls**) – lateral sutures, (**lm**) – lateral margination, (**s**) – setae, (**t**) – monoarticulated tarsus of locomotory leg, (**us**) – sternite of ultimate leg-bearing segment, (**cx**) – coxopleuron, (**cxp**) – coxopleural process, (**pm**) – posterior margin of pleuron of ultimate leg-bearing segment, (**vsp**) – ventral spinous processes of ultimate prefemur, (**p**) – prefemur, (**f**) – femur, (**t**) – tibia, (**t**1) – tarsus 1, (**t**2) – tarsus 2.



Figures 9–12. *Newportia stoevi*, sp. n. **9** Femora, tibiae and tarsi 1 of ultimate legs, dorsal view **10** Femora, tibiae and tarsi 1 of ultimate legs, ventral view; *Newportia divergens* Chamberlin, 1922 **11** Forcipular segment, ventral view (after Schileyko and Minelli 1998); *Newportia unguifer* Chamberlin, 1921 **12** Ultimate legs, dorso-lateral view (after Schileyko and Minelli 1998); (**mspf**) – medial spinous processes of ultimate femur, (**mspt**) – medial spinous processes of ultimate femur, (**t1**) – tarsus 1, (**up**) – ultimate pretarsus, (**chl**) – chitin-lines, (**ptp**) – process of tro-chanteroprefemur.

companied by a single long ventral seta. Tibia practically as long as prefemur or femur. Tarsus well divided into tarsus 1 and tarsus 2 (Fig. 8), former as long as 1/2 of tibia. Tarsus 1 (Figs 8–10) is enlarged and clavate (bulbous); tarsus 2 thin, consisting of 19 (or 20) articles (Fig. 8). In a few places annulation of tarsus 2 is somewhat vague; for example, the very long ultimate article seems to consist of two articles, which are not well divided. Ultimate legs without pretarsus.

Range. The species is hitherto known only from its type locality.

Habitat and associated fauna. Being -250 m deep and 16 910 m long Rio Encantado is the deepest and the longest cave system in Puerto Rico. This system lies in the Tertiary limestone area which stretches along the northern coast of the island (Peck 1974). *N. stoevi* has been collected deep inside the cave, in the aphotoc zone and although apparent troglomorphic traits are lacking it may well represent a troglobite, as its congener from Sistema de Purificacion, Mexico, *N. troglobia* (Chagas and Shelley 2003). In the cave it co-occurs with amblypigs, spiders, beetles (Dr. P. Beron, pers. comm.).

Discussion

- 1 This species is morphologically close to *Newportia heteropoda* Chamberlin, 1918 from which it can be readily distinguished by the following traits of the ultimate pair of legs: number of articles of tarsus 2 (19 vs. 9 in *N. heteropoda*); presence of 4 (vs. 3 in *N. heteropoda*) spinous processes on femur; presence of 2 (vs. 0 in *N. heteropoda*) such processes on tibia.
- 2 Schileyko (2009) wrote that in the family Scolopocryptopidae the lateral sternal sutures are known in *Newportia, Tidops* Chamberlin, 1915, *Kartops* Archey, 1923, *Kethops* Chamberlin, 1912 and *Ectonocryptoides* Shelley & Mercurio, 2005. It should be noted, that Chagas (2011) considered *Kartops* as a junior synonym of *Tidops*. The lateral sternal sutures may be developed in various degrees (from complete to quite short), but only *Kethops* (see fig. 144 in Shelley 2002) and *Ectonocryptoides* sandrops Schileyko, 2009 have sterna with elevated lateral margins. However, in *Newportia stoevi* the lateral longitudinal sutures border the complete lateral margination, which seems to be considerably elevated over the surface of sternite.
- 3 Some groups of scolopendromorphs (the majority of Scolopendrinae, Otostigminae, Scolopocryptopinae and Plutoniumidae) have a well-developed, strongly sclerotized disto-medial projection of the forcipular trochanteroprefemur. Formerly, I used the term "forcipular median tooth" for it, but Bonato et al. (2010) proposed the term "process of trochanteroprefemur". The Newportiinae either entirely lack this process, or have it only as a small denticle (Fig. 11), similar to some geophilomorphs, for which Bonato et al. (2010) proposed the term 'distal denticles of trochanteroprefemur'.
- 4 As for the vague annulation of some articles of ultimate tarsus 2 in *N. stoevi*, I should mention that there are a few other species of *Newportia* in which this trait is observed, for example *N. albana* Chamberlin, 1957 and *N. diagramma* Cham-

berlin, 1921 (see REMARKS to *N. albana* and Figure 5c of *N. diagramma* in Schileyko and Minelli 1998).

5 In some species of *Newportia* legs have one tarsal spur and two (lateral and ventral) tibial spurs, other species have one (lateral) tibial spur only (as *N. stoevi*) and in *N. phoretha* Chamberlin, 1950 spurs are entirely lacking (see p. 290 in Schileyko and Minelli 1998). In some species of *Newportia* (for example in *N. longitarsis stechowi* Verhoeff, 1938) lateral tibial spur is situated on an outgrowth of disto-lateral side of the tibia (see Fig. 2a in Schileyko and Minelli 1998). It is also worth mentioning that tibial spurs do not break off easily in *Newportia* as these spurs would do, for example, in *Otostigmus*. Absence of tibial spurs is another character that separates Ectonocryptopinae from Newportinae.

Identification key to the species of Newportia

One of the main problems for identification of scolopendromorph centipedes is the high number of new species, described in the last decades that are still remaining outside the contemporary identification keys. I suggest that every description of new species in large genera (like *Newportia*) to be accompanied by the respective update of the available identification key. In cases where the genus includes just a few species, the identification key should be completely re-written.

The most recent key to the species of Newportia was provided by Schileyko and Minelli (1998). Since then several new species have been described by González-Sponga (1997, 2000) and Chagas and Shelley (2003) from Venezuela and Mexico, respectively. The latter authors have also revived N. azteca Humbert & Saussure, 1869, although in the same paper they also stated (pp. 13-14): "We ... do not think that any conclusion [about the validity of *azteca*] can be reached". In 1998 Schileyko and Minelli wrote (p. 291): "Another nominal taxon very similar if not identical to N. oriena and N. spinipes seems to be N. azteca Humbert & Saussure, 1869: 158 [cf. Attems, 1930: 275] whose true identity, however, remains to us as doubtful as it was to Attems [1930]". However, Chagas and Shelley (2003) were absolutely correct when writing (p. 13) that N. azteca is the third oldest name in Newportia (after N. longitarsis and N. mexicana) and in case of synonymy would have priority by 27 years over N. spinipes. Since there is no available characters at the moment to separate these two species I put them together in the following identification key. Both, N. stoevi sp. n. and N. troglobia, are included in the key provided below. With regards to the seventeen new species of Newportia described from Venezuela by González-Sponga (1997, 2000), they will be analyzed in a paper dedicated to the scolopendromorph fauna of Venezuela that is currently in progress.

1	Tarsus 2 of ultimate legs clearly divided into distinct articles
_	Tarsus 2 of ultimate legs undivided
2	Ultimate leg with a well-developed (claw-shaped) pretarsus which is as long as,
	or longer than half of the ultimate article of tarsus 2 (Fig. 12) N. unguifer

_	Ultimate leg without a well-developed pretarsus
3	Tergite 1 without an anterior transverse suture
_	Tergite 1 with an anterior transverse suture
4	Tergite 1 with a rounded anterior transverse suture and, generally, with para- median sutures which do not form a "W" just behind the anterior transverse
_	suture; in a few species these sutures are absent or extremely short (Fig. 13) 5 Tergite 1 with an anterior transverse suture in the form of a very obtuse angle and with paramedian sutures forked anteriorly, thus forming a "W" just be-
~	hind the anterior transverse suture (Fig. 14)
2	Some pairs of legs, usually $2(4)$ -(19)20, with tibial spurs
_	I ibial spurs missing on all legs
6	Femur of ultimate legs without spinous processes
_ 7	Tergite 1 with rudimentary paramedian sutures (Fig. 13) or sutures com
/	pletely locking N parametrial sutures (Fig. 15) of sutures com-
	Paramedian sutures of terraite 1 half complete or complete, sometimes shortly
_	interrupted in the middle
8	Covonleural process extremely short: tergite 1 with poorly developed paramedian
0	sutures (Fig. 15) which cross the anterior transverse suture N diagramma
_	Coxopleural process normal (Fig. 7): tergite 1 with well-developed paramed-
	ian sutures stretching between anterior transverse suture and posterior tergal
	maroin 9
9	Tarsus 2 of ultimate legs composed of 19–25 articles
_	Tarsus 2 of ultimate legs composed of 6–7 articles <i>N. longitarsis tropicalis</i>
10	Tibiae 2-20 with lateral and ventral spurs
_	Tibiae 2-20 with a lateral spur only
11	Femur of ultimate legs with 1(-2) ventral spinous process(es) N. cubana
_	Femur of ultimate legs with 2-3 medial spinous processes
12	Tarsus 2 of ultimate legs composed of 4 articles; tarsus 1 almost as long as the tibia
-	Tarsus 2 of ultimate legs composed of 7-26 articles; tarsus 1 quite shorter than the tibia
13	Tarsus 2 of ultimate legs composed of 26 articles; cephalic plate without
	paramedian sutures N. leptotarsis
_	Tarsus 2 of ultimate legs composed of 7–20 articles; cephalic plate often with
	incomplete paramedian sutures14
14	Anterior ends of the half-complete paramedian sutures of tergite 1 very short-
	ly bifurcate behind the anterior transverse suture (Fig. 16)
_	Paramedian sutures of tergite 1 from absent to complete, never bifurcated
	anteriorly15
15	Tarsus of ultimate legs uniformly divided, without distinction into tarsus 1
	0



Figures 13–16. *Newportia* sp. **13** Cephalic plate and tergites 1-3, dorsal view (after Schileyko and Minelli 1998, re-drawn); *Newportia ignorata* Kraus, 1955 **14** Cephalic plate and tergite 1, dorsal view (after Schileyko and Minelli 1998); *Newportia diagramma* Chamberlin, 1921 **15** Cephalic plate and tergites 1-3, dorsal view (after Schileyko and Minelli 1998); *Newportia diagramma* Chamberlin, 1921 **15** Cephalic plate and tergites 1-3, dorsal view (after Schileyko and Minelli 1998); *Newportia oligopla* Chamberlin, 1945 **16** Cephalic plate and tergite 1, dorsal view (after Chamberlin 1945, re-drawn); (**ats**) – anterior transverse suture, (**ps**) – paramedian suture.

_	Tarsus of ultimate legs distinctly divided into tarsus 1 and tarsus 216
16	Femur of ultimate legs with 3-4 spinous processes
_	Femur of ultimate legs with 1-2 spinous processes
17	Femur of ultimate legs with 3 spinous processes, tibia without spinous pro-
	cesses and tarsus 2 composed of 9 articles
_	Femur of ultimate legs with 4 spinous processes, tibia with 2 spinous pro-
	cesses (Figs 9, 10) tarsus 2 of 19 articles (Fig. 8) Newportia stoevi sp. n.
18	Tergite 1 with complete paramedian sutures which cross the anterior trans-
	verse suture
-	Tergite 1 with incomplete paramedian sutures of various length, from half-
	complete (Fig. 17) to rudimentary (Fig. 13), running between the posterior
	tergal margin and the anterior transverse suture; rarely without any trace of
	paramedian sutures
19	Cephalic plate with a thin transverse suture which crosses the short paramedian
	sutures close to the posterior margin of the cephalic plate <i>N. longitarsis sylvae</i>
-	Cephalic plate without any transverse suture
20	Prefemur of ultimate legs with 3 large ventral spinous processes
	N. longitarsis guadeloupensis
-	Prefemur of ultimate legs with 4 large ventral spinous processes
01	N. longitarsis stechowi
21	1 arsus 2 of ultimate legs composed of 39–40 articles N. sabina
-	1 arsus 2 of ultimate legs composed of less than 30 articles
LL	Lace with a tarsal spur; tibia of ultimate legs longer than femur
-	Eagle without tarsal spurs; tibla of untillate legs shorter of as long as tellur20
23	Femur of ultimate legs with 2 ventral spinous processes
- 24	Outer branches of forked paramedian sutures of territe 1 extending in front
27	of the anterior transverse suture up to the anterior border of this territe
	N spinipes + N artera
_	Forked paramedian sutures of territe 1 ending up in the anterior transverse
	suture 25
25	Tarsus 2 of ultimate legs consists of $11-12$ articles, prefemur laterally with
	strong setae
_	Tarsus 2 of ultimate legs consists of 5–8 articles, prefemur laterally with small
	spinesN. oriena
26	Tarsus of ultimate legs composed of uniform articles (Fig. 18)27
_	Tarsus 1 and tarsus 2 of ultimate legs with different shapes (Fig. 19)29
27	Tergite 1 with paramedian sutures in front of the anterior transverse suture
	(Fig. 14); tibia of ultimate legs cylindrical, tarsus composed of 7-9 articles
	(Fig. 18)
_	Tergite 1 without paramedian sutures in front of the anterior transverse su-
	ture; tibia of ultimate legs distinctly claviform distally (Fig. 20), tarsus com-
	posed of ca. 15 articles (<i>N. weyrauchi</i>)



Figures 17–20. *Newportia adisi* Schileyko & Minelli, 1998 **17** Cephalic plate and tergites 1-3, dorsal view (after Schileyko and Minelli 1998); *Newportia ignorata* Kraus, 1955 **18** Right ultimate leg, medially (after Schileyko and Minelli 1998); *Newportia monticola* Pocock, 1890 **19** Right ultimate leg, ventral view (after Schileyko and Minelli 1998); *Newportia weyrauchi* Chamberlin, 1955 **20** Ultimate leg: distal portion of tibia and tarsus, ventral view (after Chamberlin 1955); (**ats**) – anterior transverse suture, (**ps**) – paramedian suture, (**t**) – tibia, (**t1**) – tarsus 1, (**t2**) – tarsus 2.

28	Prefemur of ultimate legs with 4 ventral spinous processes <i>N. w. weyrauchi</i>
- 29	Outer branches of the forked paramedian sutures of tergite 1 crossing the ante-
_	rior transverse suture (Fig. 14) and ending onto the tergal anterior margin 30 Forked paramedian sutures of tergite 1 ending in the anterior transverse su-
	ture
30	Femur of ultimate legs medially with one basal and one distal spinous pro- cesses ventrally without them. Sternites $2-12(15)$ each with a median longi-
	tudinal sulcus
_	Femur of ultimate legs medially with one basal spinous process, ventrally
	with 1-2 such processes. Sternites 2-19 each with a median longitudinal sul-
31	Ultimate legs with a well-developed claw-shaped pretarsus (which is as long
51	as the poorly distinct ultimate article of tarsus 2)
_	Ultimate legs normally without claw-shaped pretarsus (if a small ultimate
	claw is present, then it is less than half as long as the poorly distinct ultimate article of tarsus 2)
32	Tibia of ultimate legs with 3 ventral spinous processes; medial spinous pro- cesses of prefermur almost as large as the ventral ones.
_	Tibia of ultimate legs without spinous processes medial spinous processes of
	prefemur (when present) considerably smaller than the large ventral ones 33
33	Tergite 1 with rounded anterior transverse suture and with or without para-
	median sutures
-	Tergite 1 with anterior transverse suture angulated caudad to midline and
	giving rise to short longitudinal suture, which bifurcate caudally (fig. 1 in
24	Chagas & Shelley, 2003)
34	anterior transverse suture, rarely with very short tracks just behind the ante-
	rior transverse suture (Fig. 13)
_	Tergite 1 with complete (more rarely half-complete) paramedian sutures
35	Paramedian sutures of cephalic plate very short. Forcipular coxosternite with-
	out median suture. Ultimate sternite without median longitudinal sulcus.
	Femur of ultimate legs with a row of 2-3 spinous processes
_	Paramedian sutures of cephalic plate almost reaching its middle. Forcipular
	coxosternite with a well-developed median suture. Ultimate sternite with a
	clear median longitudinal sulcus or depression. Femur of ultimate legs with-
	out or with a single very small spinous process
36	Tarsus of ultimate legs uniform, without distinct division into tarsus 1 and 2.
	Forcipular trochanteropretemur without process
_	I arsus or ultimate legs distinctly divided into a shorter tarsus 1 and a longer tar- au 2 (Fig. 21). Eacoing lar transformation with a propose
37	Sus 2 (Fig. 21). Forcipular trochanteropretemur with a process N. patavina
	Paramedian sutures of tergite 1 hifurcate N to large
_	i arametian sutures of tergite i onureate



Figures 21, 22. *Newportia patavina* Schileyko & Minelli, 1998 **21** Right ultimate leg, medially (after Schileyko and Minelli 1998); *Newportia divergens* Chamberlin, 1922 **22** Cephalic plate and tergites 1-3, dorsal view (after Chamberlin 1922, re-drawn); (**ats**) – anterior transverse suture, (**ps**) – paramedian suture, (**t**) – tibia, (**t1**) – tarsus 1, (**t2**) – tarsus 2.

38	Anterior transverse suture of tergite 1 interrupted between the paramedian
	sutures (Fig. 22)N. divergens
_	Tergite 1 with a complete anterior transverse suture (Figs 15, 17)39
39	Tarsus of ultimate legs uniform
_	Tarsus 1 of ultimate legs abruptly differing from the tarsus 240
40	Cephalic plate with a transverse suture crossing the paramedian sutures near
	the posterior margin (N. ernsti)41
_	Cephalic plate without transverse suture (Fig. 13)
41	Prefemur of ultimate legs with 6 (rarely 7) ventral spinous processes. Trans-
	verse suture of cephalic plate very distinct

-	Prefemur of ultimate legs with 5 ventral spinous processes. Cephalic plate:
	median part of transverse suture between the paramedian sutures often poor-
	ly visible
42	Paramedian sutures of tergite 1 ending up in the anterior transverse suture;
	tergite 2 with complete paramedian sutures
_	Paramedian sutures of tergite 1 complete, crossing the anterior transverse su-
	ture; tergite 2 with short paramedian sutures or sutures totally missing43
43	Tergite 2 without paramedian sutures (these begin from tergite 5-6 onwards);
	four basal articles of tarsus 2 of ultimate legs definitely separated from each
	other (fig. 9 in Chamberlin 1957)
_	Tergite 2 with shortened paramedian sutures (Fig. 22); all articles of tarsus 2
	of ultimate legs not well separated
44	All legs with a tarsal spur and both lateral and ventral tibial spurs N. stolli
_	All legs with a lateral tibial spur only

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RESEARCH ARTICLE



Distinguishing Bolboceras inaequale Westwood, 1848 and two new relatives from India (Coleoptera, Geotrupidae, Bolboceratinae)

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Abstract

The taxonomy of the *Bolboceras inaequale* group of species is discussed. The group as here conceived comprises three species in the Indian subcontinent: *B. inaequale* Westwood, 1848 (reputedly also ranging into sub-Saharan Africa), and two new species: *B. duplicatum*, and *B. orissicum*, both from India. All three are keyed, diagnosed, and illustrated; variability and potential taxonomic obstacles are briefly discussed.

Keywords

Coleoptera, Geotrupidae, Bolboceras inaequale group, key, new species, India

Introduction

Within the mainly South Asian genus *Bolboceras* Kirby, 1819 (nomenclature, cf. ICZN 2006) various operational groups of species can be recognized (Krikken in press). One is the *Bolboceras inaequale* group, comprising a few species with – at least in major individuals – a characteristic set of three pronotal concavities behind and between a transversely arranged double pair of antediscal tubercles (two discoparamedian and two

discolateral tubercles, terminology by Krikken (in press)); the discomedian impression is enclosed all around (basin-like), and characteristically shaped in major individuals. The single named species in the group, *Bolboceras inaequale* Westwood, 1848, has been recorded from both the Indian subcontinent and northern sub-Saharan Africa. This paper is intended to show that there is more to the *inaequale* group than this single described species, by discussing the diversity among South Asian group members, while focusing on the identification of two new relatives from India. It is very likely that in the future, based on informative series from more localities, additional taxa will be recognized, while any minor individuals can then be interpreted better than is currently the case; the identity of sub-Saharan material referred to *B. inaequale* (by Paulian 1941) may also be clarified in the process.

Comparisons of the aedeagi are, as usual in Bolboceratinae, important, but the principle is: externally different aedeagal shapes indicate potentially different species, similar shapes do not necessarily indicate a single particular species. The basic structure and terminology of the aedeagus in *Bolboceras* is illustrated in Krikken (in press).

The *inaequale* operational group is defined below, the second paragraph including the broader generic *Bolboceras* features as applicable to the Asian species.

Material and methods

For more information on *Bolboceras*, its nomenclature, subdivision into groups, related genera, and technical conventions, cf. Krikken (2013). The list of material examined under *B. inaequale* follows the original label texts. Specimens and body parts are pictured as is – no remounting, to prevent damage.

Collections

The material on which this study is based comes from the collections listed hereafter. I most gratefully acknowledge the patient collaboration of the staff concerned.

BMNH	The Natural History Museum, London, UK
BPBM	Bernice P. Bishop Museum, Honolulu, USA
IRSNB	Institut Royal des Sciences Naturelles de Belgique, Brussels, Belgium
MHNG	Musée d'Histoire Naturelle, Geneva, Switzerland
MNHN	Muséum National d'Histoire Naturelle, Paris, France
OUMNH	University Museum of Natural History, Oxford, UK
RMNH	Naturalis Biodiversity Center, Leiden, Netherlands
SMF	Senckenberg Museum, Frankfurt, Germany
SMTD	Staatliches Museum für Tierkunde, Dresden, Germany
USNM	National Museum of Natural History, Washington DC, USA
ZMHB	Zoologisches Museum, Humboldt Universität, Berlin, Germany

The Bolboceras inaequale group

Group characters. Upright conical-triangular discoparamedian tubercles on pronotum distinct, more or less approximated, connected by variably wide transverse saddle (watch out for minor morphs); major specimens with broad, well defined discomedian concavity situated (largely) behind these tubercles (shape of its posterior edge varying, arcuate to W-shaped) – minor specimens with similar, more superficial ornamentation; discomedian concavity on either side separated from discolateral concavity by variably elevated saddle (connecting discoparamedian tubercles to posterior disc). Outline of clypeus subtrapeziform (i.e. oblique lateral perimarginal ridges running to anterolateral angles of main surface on either side of transverse anterior ridge, not converging to a single anteromedian tubercle); clypeal surface inside perimarginal ridges without protrusion(s).

Frons with long, distinct, transverse interocular ridge (may reach paraocular ridges on either side). Canthus protuberant, distal tip beyond protuberance arching backward, not reaching temporal area behind eye. Pronotum with set of four distinct tubercles transversely arranged; pronotal base distinctly, completely marginate (ridged). Elytra with 7 shallow punctate striae between suture and humeral umbone, stria 1 ending at sinuate lateral edge of scutellum, stria 2 somewhat effaced near basal scutellar angle, striae 3-7 usually reaching elytral base. Elytral interstrial surface (on cross-section) flat or very slightly convex. Mesocoxae separated by metasternal lobe, intervening space without recurved anterior hook or other isolated protrusions. Antennal lamellae unmodified (lacking grooves, with moderately delimited glabrous area on internal side of lamella 1). Abdominal tip unmodified. Aedeagus with complex median apparatus between (more or less membraneous) parameres; median apparatus usually with pair of sclerotized movable lateral stalks, each just inside parameral sheath (in resting position; note aberrant situation in B. duplicatum). Sexual dimorphism absent or slight. Colour lighter or darker brown, no colour pattern. Body length usually 9–14 mm (5.5–15 mm in other Bolboceras groups).

List of species in the Bolboceras inaequale group

Bolboceras inaequale Westwood, 1848 – India, Bangladesh; northern sub-Saharan Africa [to be verified, Paulian 1941, Krikken 2011].
Bolboceras orissicum sp.n. – India: Orissa and Jharkhand.
Bolboceras duplicatum sp.n. – India: Tamil Nadu.

Key to species in the *Bolboceras inaequale* group (major individuals)

1 Transverse interocular ridge not reaching longitudinal paraocular ridge along eyes (Figs 16, 18, 22). Angles on either side of anterior transverse ridge of clypeus strongly elevated, forming U-shaped saddle. Parameres tapering, lateral stalks on median aedeagal apparatus distinct, with tip recurved-hooked (Figs 13–14)......**2** Transverse interocular ridge reaching paraocular ridge along eyes (Fig. 20). Angles on either side of anterior transverse ridge of clypeus not elevated. Parameres blunt, membraneous, lateral stalks on median aedeagal apparatus indistinct (Fig. 15). Saddle from each discomedian tubercle posteriorly to pronotal disc broad Fig. 21). Tips of pronotal protrusions rounded off B. duplicatum Discomedian concavity of pronotum with anterior saddle widely separating discoparamedian tubercles, posterior part delimited by simply rounded edge (Fig. 23); lateral saddle short, not lowered (not expanding into adjacent concavity); this lateral concavity posteriorly delimited by sinuate edge. Tips of Discomedian concavity of pronotum situated entirely behind closely approximated discoparamedian tubercles, posteriorly delimited by variably pronounced W-shaped edge (Fig. 17, less obvious in minors, Fig. 19); lateral ridge narrow, lowered, hence more or less "overflowing" to discolateral concavity, which may extend onto anterolateral pronotal corner. Tips of pronotal protrusions (sub)acute (Fig. 2) B. inaequale

Bolboceras inaequale Westwood, 1848

http://species-id.net/wiki/Bolboceras_inaequale Figures 1–4, 9–10, 13, 16–19

Bolboceras inaequalis Westwood, 1848: 386 (description); 1952: 24 (description), pl. IV: figs 14, 14a.
Bolboceras inaequale: Paulian 1941: 11, 33 (records from Sudan, Senegal).
Indobolbus inaequalis: Krikken 1984: 34 (recombination in checklist).
Bolboceras inaequale: Krikken 2011: 239, 240 (transfer to original combination).

Material examined. Syntype, unsexed, from "Centr Ind \ [J.B.] Hearsey" (handwritten), and two more specimens from Westwood's collection(OUMNH, see comments below).

Non-type material (specimens without data excluded). Bangladesh: Dhaka: Dacca [Dhaka], ex Pascoe coll., 1 spm., in BMNH. Dinajpur: Dhanjuri, v/1963, Mapelli, 2 spm., in MHNG. vi/1963, Mapelli, 2 spm., in MHNG. Rajshahi: Andharkota, vii/1963, Mapelli, 1 spm., in MHNG.

India: Bihar: Buxar, ex Felsche coll., 1 spm., in SMTD. Chapra, Mackenzie, 6 spm., in BMNH. Pusa, 03/viii/1926, Pillai, at light, 1 spm., in BMNH. Pusa, 1913, Fletcher TB, 1 spm., in BPBM. 19/vi/1911, TMH, 1 spm., in BMNH. 30/vii/1915, Bahadur U, at light, 1 spm., in BMNH. 28/vii/1928, Sarkar SC, 1 spm., in BMNH. 20/vii/1908, TNS, at light, 1 spm., in BMNH. 24/vii/1919, Austin GD, verandah 1-10 PM, 1 spm., in BMNH. 08/vii/1915, at light, 1 spm., in BMNH. 12/vii/1915, at light, 1 spm., in BMNH. 05/vii/1924, Mukerjee, 1 spm., in BMNH. 31/vii/1918,

2



Figures 1–8. Oblique and lateral habitus views of *Bolboceras*: **1–4** *B. inaequale* (**1–2** major specimen from Kolkata, length 11 mm **3–4** minor specimen from Dhanjuri, length 9 mm) **5–6** *duplicatum*, holotype **7–8** *orissicum*, holotype. Scale lines 1 mm.

Ghosh, underground, 1 spm., in BMNH. 15/viii/1908, RDD, at light, 1 spm., in BMNH. 20/viii/1919, Austin GD, 1 spm., in BMNH. 08/ix/1912, NML, 1 spm., in BMNH. 27/ix/1915, Bahadur U, at light, 1 spm., in BMNH. 04/ix/1915, Bahadur U, at light, 1 spm., in BMNH. 04/x/1915, Bahadur U, at light, 1 spm., in BMNH. 18/xi/1920, Sarkar SC, 1 spm., in BMNH. Tamil Nadu: Madras [Chennai; to be confirmed], ex Felsche coll., 2 spm., in SMTD. Uttar Pradesh: Allahabad, ex Bowring coll., 1 spm., in BMNH. Sitapur, HGC [Champion HG], 4 spm., in BMNH. West Bengal: Calcutta [Kolkata], 1 spm., in BMNH. Kalkutta [Kolkata], ex Felsche coll., 5 spm., in SMTD.

Bengal: unspecified, Parish HM, 1 spm., in BMNH. unspecified, ex Gillet coll., 1 spm., in IRSNB.

India: "Inde", unspecified, ex Boucomont coll., 1 spm., in MNHN. unspecified, 1 spm., in USNM.

Total 47 males and females, 33 collection records, and Westwood's material.

Diagnosis. Ridge (or saddle) separating discomedian and discolateral concavities on pronotum narrow, lowered in relation to surrounding discal surface; discoparamedian tubercles approximated (connected by saddle), their tip subacute; discolateral concavity in major males extending down, onto anterolateral surface. Posterior edge of discomedian concavity usually distinctly W-shaped in major individuals, in minors the pronotal ornamentation may be only just distinct (in oblique view); bottom of concavities more or less sericeous. Interocular ridge low, not reaching paraocular ridge on either side, situated between posterior part of eyes. Anterolateral corners of clypeus usually protuberant (in majors intervening ridge concave in axial view). Scutellum usually closely punctate. Intermesocoxal lobe of metasternum anteriorly with arcuate ridge. Aedeagus (Fig. 13) with acuminate parameres, median apparatus with pair of strongly sclerotized lateral stalks, their tip broad, shortly recurved-hooked. Colour uniformly brown. Body length usually 11-13, some series down to ca 9 mm or less (see next section).

Variation. There are small individuals (minors) from Northeast India and Bangladesh (a male from Dhanjuri in Bangladesh pictured here, ca 9 mm long, Figs 3–4, 10, 18–19), characterized by a minimal set of pronotal protrusions and impressions, but still with distinct traces of the basic pattern – and also with a smaller, but externally quite similar aedeagus. Some intermediates between these minors and the real majors (including the type) were seen. At this moment I find no morphological support for ranking the minors as a separate taxon – informative material from different locations required. Paulian (1941) mentions a length range for *B. inaequale* of 7–12 mm.

Sexual dimorphism. Apparently no notable sexual dimorphism.

Comments. Note the recent retransfer of this species from *Indobolbus* Nikolajev, 1979, to *Bolboceras* Kirby, 1819, and the ensuing suffix change of the species-group name, following the ICZN (2006) ruling. The specimen of *Bolboceras inaequale* labelled as the type (OUMNH) cannot be considered the holotype, as there are two more historical specimens having the usual large (pale blue) rhomboid label with



Figures 9–15. Forebody and aedeagus of *Bolboceras*: 9–12 head and pronotum, frontodorsal view 9– 10 *B. inaequale* (9 major specimen from Kolkata 10 minor specimen from Dhanjuri) 11 *duplicatum*, holotype 12 *orissicum*, holotype 13–15 aedeagus, upper side view, of 13 *B. inaequale*, major specimen from Kolkata 14 *orissicum*, holotype 15 *duplicatum*, holotype. Scale lines 1 mm.

"W" (meaning Westwood's original collection), one of them with this label only. The specimen here qualified as syntype has a curatorial label of the 1960s, indicating its registration as Coleoptera type 516, plus additional post-Westwood labels. The three

specimens are considered conspecific, and consequently, at this moment, an explicit lectotype designation appears unnecessary.

Distribution. India (southern occurrences to be confirmed), Bangladesh; northern sub-Saharan Africa (needs confirmation).

Bolboceras duplicatum sp. n.

urn:lsid:zoobank.org:act:DDE7EE13-C2C5-4187-9CF5-1B290729ACDE http://species-id.net/wiki/Bolboceras_duplicatum Figures 5–6, 11, 15, 20–21

Material examined. Holotype male (RMNH) from South India: Madras [Chennai], x.1975, T.R.S. Nathan.

Diagnosis. Saddle separating discomedian from discolateral concavities on pronotum short, thick, slightly lowered in relation to surrounding surface; discoparamedian tubercles approximated, but less than in the preceding species; discolateral concavity in no way extending onto anterolateral pronotal declivity. Interocular transverse ridge low, reaching paraocular ridge on either side, about halfway eye. Posterior edge of discomedian concavity only vaguely W-shaped. Pronotal tubercles with rounded tip. Anterolateral corners of clypeus appearing not strongly protuberant. Scutellum sparsely, finely punctate. Aedeagus unusual for *Bolboceras*: with blunt, membraneous parameres, the median apparatus lacking projecting sclerotized lateral stalks. Colour uniformly medium-brown. Body relatively large (length assumed roughly 10–11 mm).

Description (holotype, male). Body length ca 11.5 mm. Colour uniformly medium-brown, shiny (surface locally worn, dull).

Labrum with vaguely emarginate anteromedian border, transverse ridge on coarsely punctate upper surface distinct. Clypeal surface with supra-anterolateral angles distinct, not raised (worn), intervening transverse anterior ridge very slightly convex in full-face view, almost straight; lateral perimarginal ridges distinct, moderately evenly curved, genal angle distinct. Clypeus densely, unevenly, distinctly punctate, frons abundantly, more finely punctate; secondary punctation on frons sparse. Anterior edge of eye canthus thickened-raised to slight arcuate-raised edge of short distal lobe; surface coarsely rugulate-punctate; paraocular ridge distinct, starting at genal angle, virtually straight, extending posteriorly along eye. Transverse interocular elevation situated halfway to eyes (in dorsal view), long, low, distinctly reaching paraocular ridges, its lateral slope slight, crest narrow, unmodified, lateral angle obsolete on either end (axial view).

Pronotum anteromedially steeply declivous, shortly depressed at base (lateral view), outline of marginate (raised) anterior border convex (dorsal view); discoparamedian and discolateral protrusions on pronotum distinctly protuberant, their tip rounded, particularly in discoparamedians (axial view); discomedian concavity very distinct, broad, largely situated behind closely set discoparamedian tubercles (not simply continuing over ante-



Figures 16–23. Head, full-face view, and pronotum, dorsal view, of *Bolboceras*: **16–19** *B. inaequale* (**16–17** major specimen from Kolkata **18–19** minor specimen from Dhanjuri) **20–21** *duplicatum*, holotype **22–23** *orissicum*, holotype. Scale lines 1 mm.

rior declivity), posterior edge slightly bisinuate (dorsal view); discolateral concavity deep, posterior edge rounded, anteriorly delimited by crowdedly, coarsely punctate patch behind eyes; saddle from discoparamedian tubercle to posterior disc broad, slightly lowered; bottom of discal concavities more or less matt; basomedian surface with sparsely punctate midline impression; anterolateral angle of marginal pronotal ridge ca 100° (full-face view). Pronotal surface with double punctation, primary punctation (size variable) laterally generally abundant; secondary punctation sparse, minute. Pronotal base broadly marginate, lined with row(s) of fine punctures. Scutellum with scattered, sparse double punctation.

Elytra with discal striae shallowly impressed, finely punctate; punctures separated by 3-5 puncture diameters, slightly crenulating interstriae (striae 2 and 5 slightly effaced in front). Elytral interstriae (on cross-section) very slightly convex, vaguely, sparsely, micropunctate.

Intercoxal anterior lobe of metasternum simply truncate in front.

Protibia with 6 external denticles (tips worn off); apex unmodified, with robust, complanate, slightly tapering spur. Outher side of meso- and metatibiae with bilobate apical and one complete anteapical fossorial elevation (their crest fringed with fine spines).

Aedeagus, Fig. 15; lateral stalks apparently absent, parameral sheaths membraneous, with blunt, folded tip.

Measurements of body parts. Median length of head (full-face, excluding labrum and mandibles) 2.5 mm, width 3.6 mm. Median length of pronotum (dorsal) 4.2 mm, maximum width 7.1 mm. Median length of scutellum 1.2 mm, maximum width 1.4 mm. Sutural length of elytra (dorsal) 4.1 mm, maximum width combined 7.2 mm. Width of genital capsule 1.20 mm.

Variation. Only one male seen – beware of possibly deceptive polymorphism.

Distribution. Southeast India.

Etymology. Name refers to its similarity to the preceding species.

Bolboceras orissicum sp. n.

urn:lsid:zoobank.org:act:64EA91B5-7AB9-4EE0-BAF7-33C24FCB6BE3 http://species-id.net/wiki/Bolboceras_orissicum Figures 7–8, 12, 14, 22–23

Material examined. Holotype male (MNHN, ex Boucomont coll.) from India: [Orissa:] Ganjam: Surada [also spelled Sorada], H. Donckier. Male and female paratypes (SMF) from [India: Jharkhand:] "Burju \ Bengal".

Diagnosis. Saddle separating discomedian and discolateral concavities on pronotum very short, broad, not lowered in relation to surrounding discal surface, discoparamedian tubercles distinctly separated by anterior part of discomedian concavity between them; discolateral concavity quasi-extending onto shallowly concave anterolateral corner; posterior edge of discolateral concavity well defined, "swollen" near saddle with discomedian concavity (outline in dorsal view sinuate). Posterior edge of discomedian concavity virtually rounded. Interocular transverse ridge situated between posterior part of eyes, low, not reaching paraocular ridge on either side. Anterolateral corners of clypeus strongly protuberant (intervening ridge concave in axial view). Scutellum usually abundantly punctate. Aedeagus with narrow, acuminate parameres, median apparatus with pair of strongly sclerotized lateral stalks, their tip very broadly recurved-hooked. Colour uniformly light-brown. Body length roughly 12.5–13.5 mm.

Description (holotype, male). Body length ca 13 mm. Colour uniformly lightbrown, shiny, certain parts sericeous.

Labrum with emarginate anteromedian border, transverse ridge on rugulate upper surface fine, distinct. Clypeal surface with supra-anterolateral angles distinctly raised, dentate, intervening ridge concave in axial view, straight in full-face view; lateral perimarginal ridges distinct, strongly evenly curved, genal angle distinct. Clypeus densely punctate, remainder of head surface abundantly, evenly, distinctly punctate, primary punctures interspersed with fine secondary punctation being denser behind interocular ridge. Anterior edge of eye canthus raised to slight anterolateral angle, thence arcuate along edge of distal lobe; surface coarsely rugulate; paraocular ridge distinct, fine issuing from genal angle, virtually straight, extending posteriorly along eye. Transverse interocular elevation between posterior part of eyes, long, low, not reaching paraocular ridges, lateral slope slight, crest fine, unmodified, lateral angle obtuse on either end (axial view). Much of head surface subsericeous.

Pronotum anteromedially steeply declivous, outline of marginate (raised) anterior border slightly convex (dorsal view); discoparamedian and discolateral protrusions on pronotum distinctly protuberant, subrectangular (lateral view), their tip rounded; discomedian concavity very distinct, evenly concave, broad, anterior part situated between discoparamedian tubercles (not continuing over anterior declivity), posterior edge broadly rounded (dorsal view); discolateral concavity deep, posterior edge sinuate; anteriorly, at bottom, delimited by crowdedly, coarsely punctate patch behind eyes; saddle from discoparamedian tubercle to posterior disc very short, not lowered; bottom of discal concavities and anterior declivity subsericeous; basomedian surface glossy, with abundantly, finely punctate midline impression; anterolateral angle of marginal pronotal ridge ca 100° (full-face view). Pronotal surface with double punctation, primary punctation (size variable) laterally generally abundant, denser on anterior declivity; secondary punctation sparse, minute. Pronotal base broadly marginate, lined with numerous punctures. Scutellum with abundant, double punctation.

Intercoxal anterior lobe of metasternum simply truncate in front.

Elytra with discal striae shallowly impressed, finely punctate; punctures separated by 2-3 puncture diameters, slightly crenulating interstriae. Elytral interstriae (on crosssection) very slightly convex, vaguely, sparsely, micropunctate.

Protibia with 6 external denticles; apex unmodified, with robust, complanate, slightly tapering spur. Outer side of meso- and metatibiae with bilobate apical and one complete anteapical fossorial elevation (their crest fringed with fine spines).

Aedeagus, Fig.14; sclerotized lateral stalks broad with recurved, hooked tip, parameral sheaths narrow, acuminate.

Measurements of body parts. Median length of head (full-face, excluding labrum and mandibles) 2.6 mm, width (including eyes) 4.2 mm. Median length of pronotum

(dorsal) 4.6 mm, maximum width 8.2 mm. Median length of scutellum 1.1 mm, maximum width 1.4 mm. Sutural length of elytra (dorsal) 3.9 mm, maximum width combined 8.3 mm. Width genital capsule 1.35 mm.

Variation. Variation slight, but beware of possibly deceptive polymorphism (may be obvious in larger series).

Sexual dimorphism. No obvious sexual dimorphism.

Distribution. Northeast India, apparently South of the Ganges.

Comment. The place called Burju, origin of the paratypes, is mentioned in the list of "post-office pincodes" in the Ranchi District of Jharkhand (India), and at the time of the collection of the SMF specimens there was a German mission school in the area, with staff sending specimens to German entomologists (around 1890–1910).

Etymology. Named after the type region.

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RESEARCH ARTICLE



A curious abnormally developed embryo of the pill millipede Glomeris marginata (Villers, 1789)

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Abstract

This paper reports on an abnormally developed embryo (ADE) of the common pill millipede *Glomeris* marginata. This ADE represents a modified case of *Duplicitas posterior*, in which two posterior ends are present, but only one anterior end. While the major posterior germ band of the embryo appears almost normally developed, the minor posterior germ band is heavily malformed, has no clear correlation to the single head, little or no ventral tissue, and a minute amount of yolk. The anterior end of the minor germ band is fused to the ventral side of the major germ band between the first and second trunk segment. At least one appendage of the second trunk segment appears to be shared by the two germ bands. Morphology and position of the minor germ band suggest that the ADE may be the result of an incorrectly established single *cumulus* [the later posterior segment addition zone (SAZ)]. This differs from earlier reports on *D. posterior* type ADEs in *G. marginata* that are likely the result of the early formation of two separate *cumuli.*

Keywords

Teratology, Diplopoda, Development, Segmentation, vasa

Introduction

Abnormally developed myriapods have been reported repeatedly in the past (Balazuc and Schubart 1962). However, most of these specimens represent adult or earlier postembryonic stages, and only very few studies investigate abnormal development during embryogenesis. The disadvantage of studying post-embryonic stages, including adults,

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is obvious: many of the malformations that occur during embryogenesis are lethal, and thus these specimens and their developmental abnormalities are never seen in such late developmental stages. Apart from that, the in-detail investigation of abnormal development in adults and earlier post-embryonic stages is often hampered by their complexity, while in embryonic stages the morphology of the abnormal germ band is much easier to interpret.

The majority of data on abnormally developed myriapods comes from centipedes (Selbie 1913, Minelli and Pasqual 1986, Kettle et al. 1999, Lesniewska et al. 2009) and symphylans (Juberthie-Jupeau 1962). Data from progoneate species including diplopods are rather scarce (Balazuc and Schubart 1962, Juberthie-Jupeau 1968, 1970, 1974, Hubert 1968, Ceuca 1989, Janssen 2011a, 2013). Most data on diplopods are known from the pill millipede *Glomeris marginata* (Villers, 1789) (Juberthie-Jupeau 1968, 1970, 1974, Hubert 1968, Janssen 2011a, 2013). The early development of this species is sensitive to variation in temperature, and development at high temperatures regularly leads to germ band duplications. Interestingly, all confirmed reports on germ band duplications in *G. marginata* appear to be of the type *Duplicitas posterior*. That means that the germ band is composed of two posterior ends that share one anterior end (the head) (Janssen 2013). This kind of abnormality is likely a result of the formation/splitting of two *cumuli*, the posterior organization center(s), early during development (Janssen 2013).

This paper reports on the rare find of an abnormally developing embryo of *D. posterior* in which one of the posterior ends of the embryo is minute, lacking portions of its ventral ectodermal tissue, is detached from the yolk, and is atypically connected to the major germ band. The way in which the minor germ band is connected to the major germ band, and its point of connection, suggests that both posterior germ bands may have formed from one single (disturbed) posterior *cumulus*.

Material and methods

Animal husbandry, embryo collection, and fixation

Mature specimens of *G. marginata* were collected in Germany (Nordrhein-Westfalen, Kreis Kleve) and cultivated in plastic boxes (22 cm \times 13 cm \times 5 cm) filled with decomposing leaves and moist clay. During egg deposition and embryogenesis the temperature was constantly held between 21–22°C. Eggs were manually separated from the clay egg-chambers and the chorion was removed by incubation in 2% so-dium hypochloride for 1–2 minutes. Developing eggs were fixed for four hours in a mixture of 1 ml 4% formaldehyde in phosphate buffered saline pH 7.4 with 0.1% Tween-20 (PBST) and 1ml heptane. After fixation, embryos were washed in methanol at -20°C for at least three weeks prior to in situ hybridization. The vitelline membrane was removed manually with fine forceps (Dumont No. 5, Fine Science Tools).

Gene cloning

RNA isolation and cDNA synthesis were performed as per Janssen et al. (2004). A fragment of the *G. marginata* ortholog of *vasa* was amplified via RT-PCR with the degenerate primers *vasa_*fw (GGN WSN GGN AAR CAN GCN GCN T) and *vasa_*bw (CK NCC DAT NCK RTG NAC RTA YTC). The fragment was cloned into a plasmid vector (pCRII-TOPO, Invitrogen). The sequence of the gene fragment was determined by sequencing (Big Dye Terminator Cycle Sequencing Kit; Perkin-Elmer Applied Biosystems, Foster City, CA, USA) chemistry on an automatic analyzer (ABI3730XL; Perkin-Elmer Applied Biosystems) by a commercial sequencing service (Macrogen, Seoul, Korea). The sequence is available in GenBank under the accession number HF543674.

Whole mount in situ hybridization and nuclear staining

Cell nuclei were visualized with the fluorescent dye 4-6-Diamidin-2-phenylindol (DAPI). Embryos were incubated in 1 μ g/ml DAPI in phosphate buffered saline with 0.1% Tween-20 (PBST) for 30 minutes. Excess DAPI was removed by washes in PBST for at least one hour. Whole mount in situ hybridization (WISH) was performed as described in Janssen et al. (2011).

Data documentation

Pictures were taken with a digital camera (Axiocam; Zeiss, Jena, Germany) attached to a dissection microscope (Leica, Heerbrugg, Switzerland). Brightness, contrast and color values were corrected using image processing software (Adobe Photoshop CS2, V.0.1 for Apple Macintosh; Adobe Systems Inc. San Jose, CA, USA).

Results and discussion

A single abnormally developed embryo (ADE) with the here-described teratological morphology was found (Fig. 1). The specimen was stained for the DEAD-box helicase *vasa*. It represents a developing embryo at approximately stage 5 (staging after Janssen et al. 2004). The anomaly is principally of the type *Duplicitas posterior* with two separate posterior ends and a single anterior end. A variety of *D. posterior*-type embryos have been described for *G. marginata* (Hubert 1968, Juberthie-Jupeau 1968, 1970, Janssen 2013). Although other germ band duplications, such as duplicated anterior regions (*D. anterior*) and completely or cross-wise duplicated embryos (*D. cruciata* and *D. completa*), have been described for *G. marginata* (Juberthie-Jupeau 1968, 1970), these latter ADEs may indeed represent cases of *D. posterior* as well (discussed in Janssen 2013).

In the *D. posterior*-type embryo described here the development of the major germ band is almost normal, and its posterior part is clearly aligned with the single anterior pole (the complete head) (Fig. 1A–C). The development of the major germ band is abnormal in two respects. First, the posterior part of the major germ band is bent towards the embryo's right side (Fig. 1A/A'). Second, all segments of the major germ band that are situated posterior to the contact point with the minor germ band are dorsoventrally compressed, especially with respect to ventral tissue (Fig. 1A/E). This effect is more pronounced in tissue that is close to the contact point with the minor germ band. The limbs on the third trunk segment (T3), for example, are even fused and form a single broadened appendage (Fig. 1A/E). The limb buds of T4 and T5 stand unnaturally close together. The rear end of the major germ band, however, appears normal with a properly formed segment addition zone (SAZ), a pair of anal valves and an anus (Fig. 1A-E). Remarkably, while the amount of ventral tissue is reduced, the dorsal segmental units appear to have formed normally in the complete posterior part of the major germ band. This supports earlier findings that ventral and dorsal segmental patterning is decoupled (Janssen et al. 2004), and that ventral tissue can develop (or be maintained) in the absence of dorsal tissue (Janssen 2011a). Obviously, this embryo represents the opposite case in which dorsal tissue can develop independently from properly developing ventral tissue.

The minor germ band is less well developed and lacks crucial parts of normally developing embryos (Fig. 1). It is fused to the left side of the major germ band between the first and the second trunk segments (Fig. 1B/E). The lateral view on the left side of the embryo reveals that at least one T2 appendage is shared by the two (major and minor) germ bands (Fig. 1B); otherwise a major germ band with four pairs (instead of three pairs) of primary outgrowing trunk limbs has to be assumed. Note that in G. marginata the walking limbs of the first three trunk segments develop faster than the posterior walking limbs. Two pairs of developing limb buds are recognizable in the anterior region of the minor germ band. These represent the appendages of T3 and T4. The terminal region of the minor germ band ends in an unpaired region, which may represent the fused anal valves. This region lies posterior to the strong expression of vasa in the SAZ (Fig. 1F-G'). Unlike the situation in the major germ band, this domain of *vasa* expression is in a continuous transversal stripe, rather than with a ventral gap as in the major germ band and in normally developing embryos (Fig. S1). This implies that ventral tissue is lacking from the posterior end of the minor germ band. This assumption is further supported by the lack of the anus, and the fused anal valves. Tissue anterior to the SAZ may also comprise mainly dorsal tissue since in this area the expression of vasa is in continuous transverse stripes (Fig. 1F'/ G'). In normally developing embryos vasa is strongly expressed in the mesoderm of dorsal segmental units, but only very weakly in the ventral mesoderm (Fig. S1). This indicates that ventral tissue may be lacking from most of the minor germ band. In the anterior part of the minor germ band, however, at least ectodermal ventral tissue must be present as indicated by the presence of the limb buds. The stripes of *vasa*-positive tissue in the minor germ band do not surround the complete 'embryo', but are discon-



Figure 1. An unusual abnormally developed embryo of the type *Duplicitas posterior*. **A'–E** Wholemount embryo. Anterior is towards the top. **F–G'** Separated minor germ band. Posterior is to the left. **A'** shows the bright-field photography of the embryo stained for *vasa*. Ventral view. Arrow points to stripe of expression in the minor germ band. **A** DAPI corresponding to A'. The asterisk marks the minor germ band. Arrowheads point to strong expression of *vasa* near the rear end. **B** Lateral view on left side. Asterisk and arrowhead as in **A**. Arrows point to T2 appendages. **C** Lateral view on right side. Asterisk and arrowhead as in **A**. Arrow points to strong expression of *vasa* in the minor germ band. **D** Ventral view. Embryo tilted towards beholder. Asterisk and arrow as in **C**. Red arrowhead points to contact point of minor germ band with major germ band. **E** Ventral view. Minor germ band was surgically removed. Red arrowhead as in **D**. **F/G** Separated minor germ band. Lateral views at different angles. **F'/G'** Bright-field photographs corresponding to **F/G**. Arrowhead in **G/G'** points to lack of dorsal *vasa* expression. Abbreviations: 4 to 7 *vasa* expression in the dorsal segmental units four to seven; **5/6** *vasa* expression in the fused dorsal tissue (diplosegment) aligned with T5 and T6; **an** antenna; **L** left side of embryo; **md** mandible; **mx** maxilla; **R** right side of embryo; **T1-T2** first to third walking limb; **Y** yolk.

tinuous at the germ band's dorsal side (Fig. 1G'). This means that dorsal closure has not yet happened. The number of *vasa* stripes in the minor germ band suggests that the same number of segments have formed in the minor and the major germ band. Four stripes of *vasa* can be seen posterior to T3 in the minor germ band (Fig. 1F'/G'). These stripes appear to correspond to three stripes of *vasa* posterior to T3 in the major germ band (Figs 1A and S1A). How is this possible? In *G. marginata* dorsal segmental tissue corresponding to the ventral leg bearing segmental units T5 and T6 (and T7/ T8) first develops as separate haplosegmental units, but subsequently the dorsal units fuse to form the diplosegments (Janssen 2011b). Apparently, in the minor germ band this fusion did not happen, and consequently two separate stripes (instead of one fused stripe) of *vasa* corresponding to T5 and T6 (stripes 5 and 6 in Fig. 1F'/G') are still present. Since the development of ventral tissue is disturbed in the minor germ band, and dorsal fusion is apparently not taking place, the signal for dorsal fusion may thus originate from ventral tissue. In all hitherto described *G. marginata* ADEs, except one specimen, the posterior ends of the embryos are normally developed (Janssen 2013). In the ADE described here, however, the posterior end of the minor germ band is clearly malformed with no anus, no or fused anal valves, and no ventral tissue, or at most only reduced amounts of it.

Among all described G. marginata ADEs, this specimen is the only one that possibly developed two separate posterior ends from one posterior cumulus. In G. margi*nata* all segments posterior to T1 form from the SAZ that develops from the *cumulus*, and all segments anterior to (and including) T1 form from the blastoderm, the regio germinalis (Dohle 1964, Janssen et al. 2004). Thus the duplicated posterior germ band originates from the exact point where the *cumulus* was located prior to its transformation into the SAZ. The posterior pole of the minor germ band may thus represent a fraction of a single *cumulus* that split off early during development. This minor fraction was then only able to develop into the minor posterior germ band, and was not able to fully substitute for a complete *cumulus*/SAZ. Consequently, ventral derivatives have not been established properly. The position at which the minor germ band is connected to the major germ band supports the idea that its SAZ may represent a fraction of the major *cumulus*. The contact point of minor and major posterior germ bands is exactly at the transition of tissue from the anterior regio germinalis and tissue generated from the posterior cumulus/SAZ (Fig. S2C/D). In addition, the minor germ band connects to tissue within the major germ band, and not to the dorsal edge of the major germ band as would be the case if two separate *cumuli* were present (Figs S1C and S2A/B) (cf. Janssen 2013).

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Supplementary data

Figure S1. Expression of *vasa* (**A/B**) and a typical abnormally developed embryo (ADE) of *Duplicitas posterior* type (**C**). In all panels anterior is to the left. **A/B** Bright-field and corresponding DAPI-stained embryo. White arrowheads mark strong expression of *vasa* anterior to the anal valves. Red asterisk marks the position where the minor germ band is connected to the major germ band in the presented ADE (cf. Fig. 1). **C** Typical *D. posterior*-type embryo. Abbreviations: 1 to 7, expression of *vasa* in dorsal segmental units corresponding to ventral trunk segments one to seven; 5/6, first diplosegmental unit corresponding to ventral trunk segments five and six; **A** anterior pole (head); **P** posterior pole (anal valves).



Figure S2. Schematic representation of normal development (**A**), 'normal' *D. posterior* type development (**B**), and the rare modified case of *D. posterior* reported in this paper (**C**/**D**). Light grey: yolk; dark grey: (major) germ band; transverse black lines: segmental boundaries; dashed lines: future segmental boundaries; light blue: minor germ band. Asterisks mark the anterior pole. Red arrowhead point to the direction in which new segments are added from the segment addition zone (SAZ). Abbreviations: **an** antennal segment; **c** cumulus of minor germ band; **cu** cumulus of major germ band; **md** mandibular segment; **mx** maxillary segment; **p/c** posterior (p) end of minor germ band and cumulus (c); **pmd** premandibular segment; pmx, postmaxillary segment; **pre-an** pre-antennal area; **SAZ** segment addition zone; **T1-T3** first to third trunk segment.

RESEARCH ARTICLE



Morphometric measurements of dragonfly wings: the accuracy of pinned, scanned and detached measurement methods

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Abstract

Large-scale digitization of museum specimens, particularly of insect collections, is becoming commonplace. Imaging increases the accessibility of collections and decreases the need to handle individual, often fragile, specimens. Another potential advantage of digitization is to make it easier to conduct morphometric analyses, but the accuracy of such methods needs to be tested. Here we compare morphometric measurements of scanned images of dragonfly wings to those obtained using other, more traditional, methods. We assume that the destructive method of removing and slide-mounting wings provides the most accurate method of measurement because it eliminates error due to wing curvature. We show that, for dragonfly wings, hand measurements of pinned specimens and digital measurements of scanned images are equally accurate relative to slide-mounted hand measurements. Since destructive slide-mounting is unsuitable for museum collections, and there is a risk of damage when hand measuring fragile pinned specimens, we suggest that the use of scanned images may also be an appropriate method to collect morphometric data from other collected insect species.

Keywords

Digitization, entomological collections, morphometrics, museum collections, dragonflies

Introduction

Digitized imaging of museum collections is becoming increasingly commonplace. Large-scale imaging of biological collections, particularly those of insects and plants, are currently being undertaken at many museums (Beaman and Cellinese 2012). Digitized collections have many advantages: they make collections globally accessible; they decrease the risk of damage associated with accessing and handling specimens; and they last indefinitely. Many museums image individual specimens (Tegelberg et al. 2012; Flemons and Berents 2012) while others use whole-drawer imaging, especially of insect collections (Mantle et al. 2012; Bertione et al. 2012; Dietrich et al. 2012; Schmidt et al. 2012). The advantage of whole-drawer imaging over imaging and/or databasing individual specimens is the speed with which it can be done, thereby allowing rapid, large-scale digitization of whole collections. There is also no need to handle specimens that are sometimes very fragile and/or valuable.

If the method of digitization is appropriate, it might also be possible to use the images for the collection of morphometric data. The North Carolina State University GigaPan project images whole-drawers of insect collections but produces images with curvature and distortion around the edges, precluding their use in morphometric analyses (Bertone et al. 2012). There are two systems, however, that have overcome the distortion problem by using a camera that moves over the entire drawer, takes multiple scans and then stitches them together. The DScan is used by the Munich Zoologische Staatssammlung in Germany (Schmidt et al. 2012) and the SatScan system is used by both the Australian National Insect Collection (ANIC) and Natural History Museum, London (Mantle et al. 2012; Blagoderov et al. 2012). Both DScan and SatScan have the potential to create images that can be used for morphometric studies of insect specimens, but the accuracy of these systems has not been investigated to date. Validation is desirable, because there are obvious advantages to measuring scanned images rather than pinned specimens. Preserved insects can be extremely fragile and are easily damaged during handling, which is problematic because most museum specimens are very valuable and often irreplaceable. Consequently, hand measurements of pinned specimens are often restricted to highly experienced museum staff, thereby limiting the scope of studies undertaken.

Here we examine whether accurate morphometric measurements can be obtained from digital images collected during whole-drawer scans using the SatScan system. We selected dragonfly wings because they are particularly difficult insects to handle and pin. Furthermore, the wings may be set at an angle to the horizontal, or with slight curvature over the length of the wing; this preparation artifact could limit the usefulness of scanned images for morphometric analysis since the 2D images might systematically underestimate wing length (Mantle et al. 2012). We suggest that the most accurate method for measuring dragonfly wings is to remove them from specimens and mount them between microscope slides, thereby eliminating measurement error due to curvature. In this study, we used a collection of dragonflies, each of which we measured in four different ways. (1) We used calipers to hand measure the wing length of pinned specimens removed from their drawers; (2) we scanned specimen drawers and used the digitized images to measure the wings, and (3, 4) we removed wings from specimens and slide-mounted them in preparation for hand measuring (first with their identifier labels visible and then with their labels obscured). We then compared the measurements from slide-mounted specimens to those taken from pinned and scanned wings respectively.

Methods

We measured the right forewings of 71 assorted, unidentified specimens of dragonflies. Each wing was measured a total of twelve times with three repeated measures for each of four different methods: pinned specimens, scanned images, and two sets of measures on slide-mounted wings. The wing was measured from the first cross-vein (ax0; Bechly 1996) to the furthest point of the wing tip. For consistency, all measurements were made by a single researcher (LJ).

Pinned measurements

We successively removed sets of three pinned specimens from their collection drawer and pinned them on separate foam blocks. We measured the right forewing in situ, using the tips of the lower jaws of digital calipers, recording to an accuracy of 0.01mm. We took three measurements for each specimen by sequentially measuring each individual in the set of three so that no single individual was measured twice in a row. The calipers were closed and re-zeroed after each measurement.

Scanning

We scanned whole drawers of specimens using a SatScan[™] imaging system developed by SmartDrive Ltd. The system uses a Basler A631FC ½" CCD camera with a 0.16x telecentric lens that moves along rails positioned above the drawer (Mantle et al. 2012). This minimizes the distortion and provides images with no parallax artifacts. The camera captures 200-400 'tile' images at precise positions, and these are then 'stitched' together to produce a single high-resolution image of the entire drawer (see Mantle et al. 2012). External light is excluded with shields and a controlled light source is provided by internal fluorescent tubes (Mantle et al. 2012). Prior to scanning, the dragonflies were not repositioned within their drawer so that their wings were horizontal. The final image was analyzed using SigmaScan[™] software. Three measurements were made of each wing using a digital pointer to mark the end points of the measurement, recording to an accuracy of 0.01mm.

Slide measurements

After hand measuring then scanning the pinned specimens, we used fine forceps to remove the right forewing of each specimen under a 10x magnification microscope lens. The detached wing was placed between labeled glass slides with a drop of water for cushioning. We measured the flattened wings in the same way as the pinned specimens, using the same calipers, recording to an accuracy of 0.01mm.

Slide-blind measurements

We re-measured the slide-mounted wings but with the identifier label replaced by a random specimen number to ensure that no subconscious bias could affect the measurements. The wings were otherwise measured as described above.

Statistics

To compare the estimated means between the four measurement types we ran a mixed model with measurement type as a fixed factor and specimen identity as a random factor (to control for repeated measurements). We estimated repeatability for each measurement type using a one-way ANOVA and calculated the intra-class correlation (r_l) following the methods of Lessells and Boag (1987). All statistical tests were conducted using SPSS 19.0.

Results

The estimated mean forewing lengths obtained using the four different methods were (Mean ± SE (in mm): pinned: 29.38 ± 1.04; scanned: 28.77 ± 1.04; slide-mounted: 29.24 ±1.04; blind slide-mounted: 29.24 ±1.04; all n = 71) (Figure 1). There was a significant difference in estimated mean size among the four measurement types ($F_{3,778}$ = 58.16; P<0.001). All pair-wise differences were significant (Bonferonni tests, all P < 0.005) except for that between the two slide-mounted measures (i.e. regardless of whether the label was visible or hidden) (P = 0.88).

For all four measurement types, the three repeated measures for each specimen were highly repeatable (Lessells and Boag 1987) (pinned: $F_{2,68} = 15163.79$, P < 0.001, $r_1=0.999$; scanned: $F_{2,68} = 9630.54$, P < 0.001, $r_1=0.999$; slide-mounted: $F_{2,68} = 7389.77$, P < 0.001, $r_1=0.999$; blind slide-mounted: $F_{2,68} = 17882.37$, P < 0.001, $r_1=0.999$) (Figure 1).

Based on the assumption that slide-mounting gave the most accurate measure of wing length, we tested whether there was a significant difference in the extent to which measurements from pinned and scanned specimens, respectively, deviated from those



Figure 1. Estimated mean forewing lengths obtained using the four different measurement methods. Slide 1 = identifier visible; slide 2 = identifier obscured. The median, quartiles and range are shown.

obtained from slide-mounted specimens. To do this, we re-ran two separate mixed models, first comparing the treatments of slide-mounted and pinned, then comparing slide-mounted and scanned. For each model we then calculated the absolute value of the effect size (i.e. the standardized magnitude of the difference between the slide mounted and alternate treatment). The effect size *r* was calculated from the *F* statistic using a standard formula (Koricheva et al. 2013). We then compared the effect sizes using a standard test to compare two correlation coefficients (Zar 1984). There was no significant difference between the two effect sizes (Z = 0.543, P = 0.587). The pinned and scanned measurements showed equivalent degrees of variation compared to those from slide-mounted measurements.

Discussion

Slide-mounted wings were measured with their identifying labels visible (three measurements) and with their labels hidden (three measurements). These two sets of readings were statistically identical, and the measurements were highly repeatable. This suggests that the measurements on slide-mounted wings were extremely precise, and may be regarded as the most accurate method to measure size. By removing the wing and mounting it between microscope slides, the wing is flattened and the potential problems of curvature and wing angle are eliminated. This makes it easier to obtain an accurate measurement of maximum length. Unfortunately this is a very destructive method, and is unsuitable for most museum collections.

The two alternative methods for measuring dragonfly wings, hand measuring pinned specimens using calipers and digital measurement of (whole-drawer) scanned images, were also highly repeatable. In both cases, however, the estimated means for wing length differed from that for slide-mounted wings. The pinned specimens yielded the largest and the scanned images the smallest estimated mean. It is not surprising that scanned images resulted in smaller readings since the two dimensional image does not allow compensation for wing curvature or the angle at which the wings are set, relative to the insect's body. In addition, the angle at which specimens are positioned within drawers will lead to foreshortening if they are not set parallel to the camera lens. It is less clear, however, why pinned specimens produce larger measurements. It is difficult to measure dragonfly wings *in situ*: they are fragile and the calipers need to be moved very carefully to avoid touching the specimen. There might be a bias when measuring curved or angled wings to compensate for this problem, which results in a slight overestimation of wing length.

Given that the measurements from pinned specimens and those from scanned images were equally inaccurate compared to those of slide-mounted wings; we suggest that there is no advantage in measuring pinned specimens over scanned images. There is a cost, however, to measuring pinned specimens: the procedure is very time-consuming and has greater risk of damaging the specimens compared to the use of scanned images. We therefore suggest that scanned images are an appropriate way of measuring specimens, particularly those that are fragile like dragonflies.

It is important to note that we selected dragonfly wings for this study because they are fragile and most likely to show preparation artifacts that decrease measurement accuracy (e.g. wing curvature). Measuring sturdier structures like the elytra of beetles is likely to be more accurate, using both digital measures of scanned images and hand measuring pinned specimens. Pinned specimens might provide the more accurate estimate in such cases, because calipers can come into contact with the structure with less fear of damaging the specimen. This might reduce the risk of over measurement that we suspect affected our pinned specimen wing data. In addition, the inherent and random error arising from the angle at which specimens are secured within drawers is eliminated.

Despite these potential advantages, however, repeated handling of specimens will inevitably lead to damage via breakages or the removal or abrasion of fine structures (e.g. antennae). Accordingly, the relative risks of the handling specimens must be considered in the context of measurement error when choosing appropriate study methods. Our study shows that the use of scanned images is a better method in the case of fragile specimens and should be routinely considered as a technique in any museum study.

Conclusion

Measuring detached, slide-mounted dragonfly wings is the most accurate method for morphometric studies but is obviously unusable for museum specimens. Here we show that, for dragonfly wings, hand measurements of pinned specimens and digital measurements of scanned images are equally accurate relative to slide-mounted measurements. Hand-measuring pinned specimens carry a risk of damaging the insects. We therefore suggest that the use of whole-drawer scanned images is an appropriate method to collect morphometric data on dragonfly wings. For other collected insects, we suggest this method should be considered as an alternative to hand measuring pinned specimens when the measurement precision required and the fragility of the specimens are taken into account.

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Appendix

Morphometric measurements of dragonfly wings. (doi: 10.3897/zookeys.276.4207. app) File format: Microsoft Axcell document (xls).

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RESEARCH ARTICLE



Alburnoides manyasensis (Actinopterygii, Cyprinidae), a new species of cyprinid fish from Manyas Lake basin, Turkey

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Abstract

Alburnoides manyasensis, **sp. n.**, is described from the Koca Stream (Lake Manyas drainage, Marmara Sea basin) in Anatolia. It is distinguished from all species of *Alburnoides* in Turkey and adjacent regions, *Alburnoides tzanevi* (Rezovska [Rezve], Istranca and Terkos streams in the western Black Sea drainage), *Alburnoides cf. smyrnae* (Banaz Stream, a drainage of Büyük Menderes River, Aegean Sea basin), *Alburnoides fasciatus* (streams and rivers in the eastern Black Sea drainage) and *Alburnoides eichwaldii* (Kura and Aras rivers [a drainage of Kura River], Caspian Sea basin) by a combination of the following characters (none unique to the species): marked hump at nape, especially in specimens larger than 60 mm SL; partly developed ventral keel between pelvic fin and anal fin, scaleless 1/2 to 2/3 its length; body depth at dorsal-fin origin 29–32% SL; caudal peduncle depth 11–12% SL; 45–52+ 2–3 lateral-line scales; 9–12 scale rows between lateral line and dorsal-fin origin; 4–5 scale rows between lateral line and anal-fin origin, 10½–12½ branched anal-fin rays; 40–42 total vertebrae.

Keywords

Anatolia, Cyprinidae, taxonomy, Alburnoides, new species

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Introduction

The genus Alburnoides is characterized by small black spots near the pores located on each side of the lateral line outlining the canal at least along its anterior portion (Bogutskaya and Coad 2009). Three species of Alburnoides had been recognized as valid species before 2007. These were Alburnoides oblongus Bulgakov, 1923 [Chirchik River, Aral Sea basin], Alburnoides taeniatus (Kessler, 1874) [Tashkent, Aral Sea basin], and Alburnoides bipunctatus (Bloch, 1782) [France through Europe north of the Alps eastwards to the Black, Caspian and Aral Sea basins] (Berg 1949; Bogutskaya and Naseka 2004). Furthermore, 10 subspecies and local forms were described or reported within the Alburnoides bipunctatus complex: A. bipunctatus armeniensis Dadikyan, 1972 [Aras River, Kura River Drainage, Caspian Sea basin], A. bipunctatus eichwaldii De Filippi, 1863 [Kura River, Caspian Sea basin], A. bipunctatus rossicus Berg, 1924 [Dnieper River, Black Sea basin and Volga River, Caspian Sea basin], A. bipunctatus rossicus natio kubanicus Berg, 1932 [Kuban River, Sea of Azov basin], A. bipunctatus ohridanus Karaman, 1928 [Lake Ohrid, Adriatic Sea basin], A. bipunctatus var. prespensis Karaman, 1924 [Lake Prespa], A. bipunctatus var. smyrnae Pellegrin, 1927 [Melel Stream (near İzmir), Aegean Sea basin], A. bipunctatus strymonicus Chichkoff, 1940 [Struma River, Aegean Sea Basin], A. bipunctatus tzanevi Chichkoff, 1933 [Rezovska River (ancient Riesova River as mentioned by Chichkoff and Rezve in Turkish)], Black Sea basin], and A. bipunctatus subsp. (Berg 1949) [Kuma, Terek, Sulak rivers, Caspian Sea basin] (Berg 1949; Bogutskaya and Coad 2009). Besides above mentioned subspecies and local forms of Alburnoides bipunctatus, Aspius fasciatus Nordmann, 1840 [rivers of the western Transcaucasia, Black Sea basin] and Alburnoides maculatus Kessler, 1859 [Salgir River, Sea of Azov basin] have also been synonymized as Alburnoides bipunctatus.

Kottelat and Freyhof (2007) reported Alburnoides bipunctatus ohridanus and Alburnoides bipunctatus var. prespensis as valid species. Later, A. bipunctatus rossicus, A. bipunctatus rossicus natio kubanicus, A. bipunctatus fasciatus, Alburnoides maculatus and A. *bipunctatus eichwaldii* were reported as a valid species by Coad and Bogutskaya (2009) and Bogutskaya and Coad (2009). In addition to these, following 10 new species were described: Alburnoides devolli Bogutskaya, Zupančič et Naseka, 2010 [Seman River system, Adriatic Sea basin], A. fangfangae Bogutskaya, Zupančič et Naseka, 2010 [Seman River system, Adriatic Sea basin], A. gmelini Bogutskaya et Coad, 2009 [Sunzha River, Terek River drainage, Caspian Sea basin], A. holciki Coad et Bogutskaya, 2012 [Hari (Tedzhen) River, endorheic (historically Aral Sea basin)], A. idignensis Bogutskaya et Coad, 2009 [Bid Sorkh River, Gav Masiab River system, Tigris River drainage, Persian Gulf basin], A. namaki Bogutskaya et Coad, 2009 [Qanat at Taveh, Namak Lake basin], A. nicolausi Bogutskaya et Coad, 2009 [Simareh River in Karkheh River system, Tigris River drainage, Persian Gulf basin], A. petrubanarescui Bogutskaya et Coad, 2009 [Qasemlou Chay, Orumiyeh Lake basin], A. qanati Coad et Bogutskaya, 2009 [qanat in the Pulvar River drainage, Kor River basin], and A. varentsovi Bogutskaya et Coad, 2009 [Ashkhabadka River, endorheic (historically Aral Sea basin)] (Coad and Bogutskaya 2009, 2012; Bogutskaya and Coad 2009, Bogutskaya et al. 2010).

The genus *Alburnoides* is widely distributed in Turkey in rivers and streams of basins of the Marmara, Black and Aegean seas from tributaries of Büyük Menderes River in the west, Euphrates and Tigris river drainages in the east and south-east, and Kura River drainage in the east, being absent only from the Mediterranean Sea basin (Kuru 1975, Erk'akan 1983, Kutrup 1994, Turan 2003, Kuru 2004, Geldiay and Balık 2009, our data). The populations of *Alburnoides* from streams and rivers in the eastern Black sea coast of Turkey were identified as *A. fasciatus*, and populations from Kura as *A. eichwaldii* (Bogutskaya et al. 2010).

In order to understand the *Alburnoides* diversity in Turkey, we sampled at 105 localities throughout the country between 2004 and 2012. In this paper we shall only discuss *Alburnoides* distributed in the Manyas Lake drainage in Marmara sea basin of Turkey (Fig. 1). After comparison with the other *Alburnoides* species of Turkey, including Kura River (Caspian Sea basin), Menderes River (Aegen Sea basin), also rivers Terkos, Istranca, Çoruh and İyidere (Black Sea basin), we concluded it is a distinct unnamed species which we describe herein as *A. manyasensis*.

Materials and methods

Fish were caught by pulsed DC electrofishing equipment and killed by over overanestization, fixed in formaldehyde and stored in ethanol. Material is deposited in: FFR, Recep Tayyip Erdoğan University Zoology Museum of the Faculty of Fisheries (Former Fisheries Faculty of the city of Rize). Counts and measurements follow Hubbs and Lagler (1947) except as follows. Head width₁: the distance between the anterior eye margins; head width₂: the distance between the posterior eye margins; head width₃: the head width at the nape; head depth₁: the head depth through the eye; head depth₂: the



Figure 1. Distribution of named *Alburnoides* species in Turkey: *A. manyasensis* (Δ), *A.* cf. *smyrnae* (\square) *A. tzanevi* (**a**), *A. fasciatus* (+), and *A. eichwaldii* (\square).

head depth at the nape; snout width: measured at level of the nostrils. The lateral-line scales are counted from the anteriormost scale (the first one to touch the shoulder girdle) to the end of the hypural complex. The scales on the caudal fin itself are indicated by '+'. The last two branched dorsal and anal rays articulating on a single pterygiophore are counted as 1½. The number in parentheses after a count indicates the frequency of occurrence of the count. Vertebral counts were obtained from radiographs and counted as total, predorsal, abdominal and caudal vertebrae following Bogutskaya and Coad (2009). Predorsal vertebrae include the Weberian vertebrae and abdominal vertebrae anterior to the first dorsal-fin pterygiophore. Abdominal vertebrae were counted from the first Weberian vertebra to the one just anterior the first caudal vertebra. The first caudal vertebra is that with its haemal spine fully developed (Fig. 2). The count of total and caudal vertebrae includes the last complex vertebra bearing hypurals.

The morphometric characters of the five species of *Alburnoides* from Turkey were compared by Principal Component Analysis (PCA) using a covariance matrix on log-transformed measurements and counts with the software package PAST version 1.8 (Hammer et al. 2001).

Results

Alburnoides manyasensis sp. n.

urn:lsid:zoobank.org:act:9A720EDC-D057-4EBB-949C-C298544FE46A http://species-id.net/wiki/Alburnoides_manyasensis Fig. 2, 3

Holotype. FFR 01069. Female. 82 mm SL; Turkey, Balıkesir Prov., Koca Stream at outlet of Manyas Dam Lake, Lake Manyas drainage; 39°59'26"N, 27°47'58"E, 11 July 2007, coll. D. Turan and R. Buyurucu.

Paratypes. FFR 01073, 24, 54–92 mm SL; same data as holotype.

Diagnosis. *Alburnoides manyasensis* is distinguished from all the species of *Alburnoides* in Turkey and adjacent areas by a combination of the following characters (none unique to the species): partly or slightly developed ventral keel between pelvic fin and anal fin, scaleless about 1/2 to 2/3 its length; upper body profile markedly convex, with marked hump at nape, especially in specimens larger than 60 mm SL; upper head profile straight or slightly convex in interorbital area, slightly convex on snout; corner of mouth reaching vertical through anterior margin of pupil; snout with slightly pointed tip; interorbital width 7–8% SL; dark grey stripe indistinct or slightly distinct in anterior part of body but distinct in posterior body; pigmentation of lateral line slightly distinct in anterior spart of body but indistinct in posterior part of body (Fig. 3) in most of specimens; 45–52+2–3 lateral-line scales, 9–12 scale rows between lateral line and dorsal-fin origin, 4–5 scale rows between lateral line and anal-fin origin, 10½–12½ branched anal-fin rays; pharyngeal teeth 4.2–2.4, markedly hooked; total vertebrae 40–42: 20–22, with mode of 21, abdominal and 19–21, with mode of 20, caudal vertebrae.



Figure 2. *Alburnoides manyasensis* sp. n. Radiograph of a paratype, FFR 01073, 74 mm SL. Arrow shows first caudal vertebra.



Figure 3. *Alburnoides manyasensis*; Turkey: Balıkesir Province: Koca Stream, Lake Manyas drainage, holotype, FFR 01069, female, 82 mm SL.

Description. Maximum known size 92 mm SL. General appearance shown in Fig. 3; morphometric and meristic data given in Tables 1 and 3. Body deep, its depth at dorsal-fin origin 29–32% SL, mean 29.4, at anal-fin origin 22–27% SL, mean 24.4, and markedly compressed. Dorsal profile markedly convex with marked hump at nape in specimens larger than 60 mm SL, ventral profile less convex than dorsal profile. Predorsal length 52–58% SL, mean 54.2. Caudal peduncle deep, its depth 11–12% SL, mean 11.5. Head short, its length 25–27% SL, mean 26.0, approximately 0.8–0.9 times body depth at dorsal fin origin, dorsal profile straight or slightly convex at interorbital area, slightly convex at snout. Snout short, slightly pointed, its length 6–8% SL, mean 6.8, shorter than both eye diameter (eye diameter 7–9% SL, mean 8.2) and interorbital width (interorbital width 7–8 %SL, mean 7.7). Mouth terminal, with very slightly marked chin, its corner reaching vertical through anterior margin of pupil.

Lateral line with 45-52 + 2-3 scales; (9)10–12 scales rows between lateral line and dorsal-fin origin; 4–5 scales between lateral line and anal-fin origin. Gill rakers 8–10: 2–3 + 6–7 on outer side of first gill arch. Dorsal fin with 3 simple and 8½, rarely 7½ or 9½, branched rays; its depth 21–27% SL, outer margin straight or slightly concave. Pectoral fin long, not reaching pelvic-fin origin in both sexes, its length 20–24% SL, outer margin slightly convex, with 12–13 branched rays. Pelvic fin rounded, reaching

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	A. manyasensi.	s, n=24		A. cf. smyrnae, n	=8	A. tzanevi, n=	10	A. tzanevi, n=1	0
Basin	Marmara	Sea		Aegean Sea		Black Sea		Black Sea	
River or stream	Koca			Büyük Mender	es	Terkos		Istranca	
	Range	SD	Holo- type	Range	SD	Range	SD	Range	SD
Standard length (mm)	54-92		80	58-77		63–81		63–94	
In percents of standard length									
Head length	24.5-27.3 (26.0)	0.68	25.2	25.7-27.8 (26.7)	0.71	26.0-27.7 (26.6)	0.58	24.8-26.8 (25.6)	0.71
Body depth at dorsal fin origin	28.8-31.9 (29.4)	1.14	30.0	27.8-29.5 (28.6)	0.64	24.5-27.2 (25.9)	0.95	23.7-26.0 (24.9)	0.83
Body depth at anal fin origin	22.3-26.8 (24.4)	1.26	25.5	23.2-25.2 (24.3)	0.64	21.0-22.9 (22.0)	0.62	20.4-21.8 (21.0)	0.52
Caudal peduncle depth	10.7-12.2 (11.5)	0.42	11.8	10.8-12.3 (11.8)	0.47	10.2-11.0 (10.5)	0.24	8.8-10.3 (9.4)	0.49
Predorsal length	52.4-57.8 (54.2)	1.31	52.7	50.7-55.1 (53.0)	1.29	52.9-54.3 (53.6)	0.48	51.0-53.9 (52.5)	1.00
Prepelvic length	44.4-49.7 (46.8)	1.33	46.9	46.0-47.9 (46.8)	0.71	46.1-48.9 (47.5)	0.87	44.8-48.0 (46.2)	1.23
Preanal length	61.4-67.2 (64.5)	1.54	66.4	63.2-67.7 (65.2)	1.34	64.0-68.8 (66.8)	1.45	65.4-68.0 (66.5)	0.99
Pectoral-fin origin to anal fin	38.1-44.2 (41.3)	1.36	44.2	38.3-42.9 (40.8)	1.73	38.4-44.5 (42.7)	1.87	40.2-44.3 (42.5)	1.38
Pectoral-fin origin to pelvic fin	20.5-24.5 (22.9)	0.94	23.7	19.3–25.0 (22.2)	1.90	21.3-24.6 (22.9)	1.11	20.1-24.4 (22.1)	1.34
Pelvic-fin origin to anal fin	16.7-21.2 (18.6)	1.14	21.2	17.1-20.3 (18.7)	1.10	18.0-21.9 (20.2)	1.16	20.4-22.8 (21.3)	0.83
Caudal peduncle length	20.4-25.0 (22.2)	1.20	22.3	20.7-26.2 (23.7)	2.31	18.2–21.0 (19.5)	1.02	18.1-23.1 (20.4)	1.53
Dorsal fin depth	21.3-27.3 (24.4)	1.64	23.3	21.7-27.9 (24.6)	1.94	20.6-23.4 (21.8)	0.99	20.7-25.6 (22.0)	1.38
Pectoral fin length	20.1-23.6 (21.3)	0.83	20.7	18.6-23.6 (20.6)	2.09	19.2–21.7 (20.2)	0.91	18.4–21.7 (19.9)	0.99
Pelvic fin length	14.5-18.5 (16.8)	0.80	16.5	17.3–21.0 (19.2)	1.18	13.5-17.0 (15.9)	0.99	15.7–17.1 (16.5)	0.47
Anal fin length	15.9-20.9 (18.7)	1.98	18.0	18.4-21.3 (20.0)	1.03	16.9–18.4 (17.5)	0.41	17.3-19.0 (18.1)	0.52
Upper caudal-fin lobe	21.2-27.2 (24.5)	1.73	23.9	27.9-31.3 (29.1)	1.07	21.5-24.4 (22.9)	0.97	22.4–26.8 (23.1)	1.54
Middle caudal-fin lobe	12-15.9 (14.4)	0.99	14.7	14.3-17.3 (16.0)	1.09	13.3–14.7 (14.1)	0.54	12.4 -14.5 (13.4)	06.0
Head width,	7.6–9.7 (8.8)	0.64	9.5	8.9-10.3 (9.9)	0.49	8.5–9.7 (9.2)	0.39	7.9–9.6 (9.1)	0.44
Head width ₂	11.5-13.6 (12.7)	0.54	12.8	13.3-15.3 (14.0)	0.58	11.2-12.5 (11.9)	0.44	11.6-12.4 (12.1)	0.32

	A. manyasensi	s, n=24		A. cf. smyrnae, n	=8	A. tzanevi, n=	10	A. tzanevi, n=1	0
Basin	Marmara	Sea		Aegean Sea		Black Sea		Black Sea	
River or stream	Koca			Büyük Mender	es	Terkos		Istranca	
	Range	SD	Holo- type	Range	SD	Range	SD	Range	SD
Head width $_3$	12.4-15.9 (13.6)	0.70	13.8	14.2-17.7 (15.0)	0.52	12.2-13.2 (12.8)	0.35	12.4–14.6 (13.1)	0.60
Head depth ₁	13.2-15.0 (14.1)	0.56	14.4	14.4-16.0 (15.2)	0.53	13.8-14.9 (14.3)	0.37	12.3-14.5 (13.6)	0.66
Head depth ₂	18.0-20.4 (19.2)	0.80	19.2	19.8-20.8 (20.3)	0.42	18.0-19.1 (18.7)	0.28	16.5-18.8 (17.5)	0.73
Eye diameter	7.3-9.1 (8.2)	0.58	7.6	8.1–9.3 (8.7)	0.48	7.0–7.7 (7.4)	0.24	6.6-8.9 (7.7)	0.71
Snout length	6.0-7.7 (6.8)	0.49	6.2	6.4-8.0 (7.0)	0.49	6.4-7.3 (6.8)	0.24	6.3-7.6 (6.9)	0.42
Interorbital width	7.1-8.4 (7.7)	0.36	8.0	8.4-9.5 (8.9)	0.39	6.9-8.0 (7.3)	0.42	6.3-7.5 (6.9)	0.33
Snout width at nostrils	6.8–9.8 (8.3)	0.96	9.4	7.8–9.9 (8.6)	0.68	9.2-10.3 (9.6)	0.36	8.7-10.7 (9.4)	0.35

or slightly behind anus, with 1 simple and 7 branched rays. Anal fin with 3 simple and 10¹/₂-12¹/₂ branched rays, outer margin concave. Caudal fin forked, lobes slightly pointed.

Pharyngeal teeth 4.2–2.4, markedly hooked. Total vertebrae 40–42; predorsal vertebrae 13–15 with mode of 14; number of abdominal vertebrae 20–22 with mode of 21, and that of caudal vertebrae 19–21 with mode of 20 (frequency of occurrence of character states given in Table 3). Abdominal region longer than caudal region, rarely regions equal, and difference between abdominal and caudal counts varying from 2 to -1; most common vertebral formula 21+20.

Sexual dimorphism. There are small tubercles on rays of anal fins in male. The length of the paired fins does not display any statistically significant difference in males and females as it often occurs in other *Alburnoides* species.

Coloration. Formalin preserved adults and juveniles brownish on back and upper part of flank, yellowish on lower part of flank and belly. Caudal and dorsal fins light grey; pectoral, pelvic and anal fins yellowish. Spots along lateral line above and below pores slightly distinct in anterior part of body but indistinct in posterior part. Dark grey stripe (its width approximately equal to eye diameter) on upper part of flank from posterior margin of operculum to caudal peduncle, slightly distinct in anterior body part but clearly distinct in posterior part. No or few dark pigment dots on each scale pocket below lateral stripe.

Distribution and notes on biology. *Alburnoides manyasensis* is known only from the Koca Stream, drainage of Lake Manyas, Marmara Sea basin (Fig. 1). It inhabits clear fast running water with cobble and pebble substrates. *Capoeta tinca* (Heckel, 1843), *Barbus oligolepis* Battalgil, 1941, *Squalius cii* (Richardson, 1857), *Vimba vimba* (Linnaeus, 1758), *Chondrostoma* sp., *Rhodeus amarus* (Bloch, 1782), *Oxynoemacheilus* sp. and *Alburnus* sp. were collected together with *A. manyasensis*.

Etymology. The name of the species, an adjective, is derived from the name of Lake Manyas.

Discussion

We compared the material from the Koca Stream in the Marmara Sea basin with *Alburnoides fasciatus* from streams and rivers in the eastern Black Sea basin, *Alburnoides eichwaldii* from Kura and Aras rivers (Kura River drainage) and *Alburnoides tzanevi* from Rezovska (Rezve), Istranca and Terkos streams in the western Black Sea basin.

No specimens were collected from the type locality of *A. bipunctatus* var. *smyrnae* although we checked it (Melel Stream, Aegean Sea basin) as well as some streams and rivers near İzmir (ancient Smyrna, Aegean Sea basin, Turkey). Thus, we failed to catch any specimens from the population which is known to exist quite sparsely in the province of İzmir where the habitat is heavily degraded. Instead, we examined 8 specimens of *Alburnoides* from Banaz Stream, a tributary of Büyük Menderes River, Aegean Sea basin. The Banaz Stream population exibits character states similar to those

known in *A. bipunctatus* var. *smyrnae* such as the numbers of lateral-line scales and anal-fin branched rays. They have 41–46 total lateral line scales according to Pellegrin (1928: 86) and 42–47 in our material, and 13–15 branched anal–fin rays according to Pellegrin (1928: 86) and 12½–14½ in our material. The population from the Büyük Menderes River is most probably conspecific with *A. bipunctatus* var. *smyrnae*. Therefore we identify them as *Alburnoides* cf. *smyrnae* (Fig. 4) and suppose it is a distinct valid species. It is distinguished from all species of *Alburnoides* in Turkey and adjacent watersheds by fewer total lateral-line scales (42–47, vs. 47–57, except for *A. tzanevi*) and a longer caudal fin (length of the upper caudal-fin lobe 28–31% SL, vs. 21–28, see Table 1). Besides characters mentioned, *Alburnoides* cf. *smyrnae* differs from *A. tzanevi* by having a deeper body (28–30% SL, mean 28.6, vs. 24–27, mean 25.4).

Alburnoides manyasensis can be distinguished from Alburnoides cf. smyrnae by having fewer branched anal-fin rays $(10\frac{1}{2}-12\frac{1}{2})$, vs. $12\frac{1}{2}-14\frac{1}{2})$, a narrower interorbital distance (7–8% SL, mean 7.7, vs. 8–10, mean 8.9), the presence of a hump at nape in specimens larger than 60 mm SL (vs. absent), the ventral keel scaleless about 1/2 to 2/3 of its length (vs. almost entirely scaled) and the upper profile of head slightly convex at level of nostrils (Fig. 3) (vs. markedly convex, see Fig. 4).

The type locality of *Alburnoides bipunctatus tzanevi* is Rezovska River in Bulgaria, Black Sea drainage. We consider it to be a valid species because it can be easily distinguished from all species of *Alburnoides* in Turkey and adjacent area by a more slender body (the body depth at dorsal-fin origin about equal to the head length, vs. the body depth at dorsal-fin origin commonly greater than the head length), a considerably pointed snout (vs. slightly pointed or rounded). The detailed metric and meristic characters of *A. tzanevi* are given in Tables 1 and 3.

Besides the differences given above, *Alburnoides manyasensis* is distinguished from *A. tzanevi* by the presence of a hump at nape in specimens larger than 60 mm SL (vs. absent) and a deeper caudal peduncle (11-12% SL, mean 11.5, vs. 9–11, mean 9.9). In *A. manyasensis*, pigmentation of the lateral line is slightly distinct in anterior part of the body but indistinct in posterior part of body (Fig. 3) and the snout length is markedly shorter than interorbital distance in contrast to *A. tzanevi* (Fig. 5) with the lateral line clearly distinct in both the anterior and posterior parts of the body and the snout length about equal to the interorbital distance.

Alburnoides manyasensis differs well from A. fasciatus by the presence of a hump at nape in specimens larger than 60 mm SL (vs. absent) and in having fewer branched anal-fin rays $(10\frac{1}{2}-12\frac{1}{2})$, vs. $13\frac{1}{2}-15\frac{1}{2}$) and fewer predorsal vertebrae (13-14, mode14, vs. 14–15, mode 15). It is further distinguished from A. fasciatus by a more slender body (29–32% SL, mean 29.4, vs. 25–30, mean 27.8), a narrower head (head width at the anterior eye margin 8–10% SL, mean 8.8, vs. 10–11, mean 10.1) and a longer caudal peduncle (20–25% SL, mean 22.2, vs. 17–21, mean 19.1). In A. manyasensis, the eye diameter is longer than both the snout length and the interorbital width, while in A. fasciatus the eye diameter is smaller than both the snout length and the interorbital width (Table 2). In A. manyasensis, pigmentation of the lateral line is slightly distinct in the anterior part of the body but indistinct in the posterior part (Fig 3) in



Figure 4. *Alburnoides* cf. *smyrnae*; Turkey: Uşak Province: Banaz Stream, Büyük Menderes River drainage, FFR 1110, female, 75 mm SL.



Figure 5. Alburnoides tzanevi; Turkey: İstanbul Province: Terkos Stream, FFR 1066, female, 77 mm SL.



Figure 6. *Alburnoides fasciatus*, Turkey: Artvin Province: Aralık Stream, Çoruh River drainage, FFR 1003, female, 75 mm SL.

contrast to *A. fasciatus* (Fig. 6) with the lateral line clearly distinct in both the anterior and posterior parts of the body.

Alburnoides manyasensis is easily distinguished from A. eichwaldii by the presence a hump at nape in specimens larger than 60 mm SL (vs. absent), It further differs from A. eichwaldii by a more slender body (body depth at dorsal fin origin 29–32% SL, mean 29.4, vs. 25–30, mean 27.5). In Alburnoides manyasensis, the eye diameter is longer than the snout length and the interorbital width, while in A. eichwaldii the

	A. fasciatus, n=	[4	A. fasciatus, n=	10	A. eichwaldii, n=	=15	A. eichwaldii, n=	10
Basin	Black Sea		Black Sea		Caspian Sea		Caspian Sea	
River or stream	Çoruh		İyidere		Aras		Kura	
	Range	SD	Range	SD	Range	SD	Range	SD
Standard length (mm)	60-77		52-67		55-107		55-87	
In percents of standard length								
Head length	25.5-27.5 (26.7)	0.55	24.5-28.3 (26.4)	1.57	24.3–27.7 (25.8)	1.16	25.8-27.6 (26.7)	0.68
Body depth at dorsal fin origin	25.7-29.3 (27.8)	1.14	25.4-29.7 (27.9)	1.97	25.0-29.6 (27.5)	1.28	25.7-30.1 (27.7)	1.90
Body depth at anal fin origin	22.6-25.6 (24.3)	0.91	22.3-24.2 (23.3)	0.81	21.7-24.4 (23.0)	0.86	21.1-25.3 (23.3)	1.22
Caudal peduncle depth	10.8-12.0 (11.4)	0.40	11.0-12.2 (11.5)	0.46	11.4-13.2 (12.1)	0.48	11.2-12.6 (11.9)	0.41
Predorsal length	53.0-55.6 (54.3)	0.76	52.8-56.1 (54.7)	0.99	50.6-54.6 (52.9)	1.09	52.8-56.3 (54.4)	1.25
Prepelvic length	45.9-49.2 (47.3)	0.99	45.8-50.0 (48.7)	1.27	45.6-48.8 (47.2)	0.85	46.3-50.1 (48.1)	1.34
Preanal length	64.2-68.4 (66.0)	1.25	65.2-69.1 (66.9)	1.19	63.3-66.2 (65.0)	0.83	64.1-69.2 (65.7)	1.60
Pectoral-fin origin to anal fin	40.4-44.3 (41.9)	1.25	41.7-45.9 (43.0)	1.26	39.4-44.2 (41.4)	1.37	39.5-46.1 (41.5)	2.13
Pectoral-fin origin to pelvic fin	20.9–23.9 (22.8)	0.66	22.6-26.3 (24.4)	1.08	21.5-26.6 (22.9)	1.29	22.1-26.2 (23.6)	1.30
Pelvic-fin origin to anal fin	16.7-20.5 (18.8)	1.09	17.9-20.6 (19.0)	0.78	16.9-20.1 (18.6)	0.98	16.2-21.0 (18.3)	1.60
Caudal peduncle length	18.1–20.6 (19.6)	0.68	16.9-20.0 (18.5)	0.96	19.6-23.3 (21.4)	0.97	19.2-21.3 (20.5)	0.75
Dorsal fin depth	23.0-25.7 (24.0)	0.74	22.3-25.7 (23.7)	1.04	20.1-25.2 (23.0)	1.44	21.4-26.0 (23.6)	1.39
Pectoral fin length	20.8–22.7 (21.6)	0.61	19.9–23.6 (21.9)	1.19	19.3–22.5 (20.7)	1.06	19.6-22.9 (21.5)	1.24
Pelvic fin length	16.6-18.3 (17.1)	0.47	15.9-19.4 (17.6)	1.18	15.7–18.5 (16.8)	0.92	15.7-18.8 (17.2)	0.94
Anal fin length	17.4-20.2 (18.2)	0.75	17.3-19.6 (18.1)	0.86	15.0-19.1 (16.8)	1.02	15.8-19.2 (17.4)	1.02
Upper caudal-fin lobe	21.9–26.6 (24.8)	0.14	23.9–27.6 (25.0)	1.21	20.5-27.3 (24.0)	2.25	22.2-27.0 (24.0)	1.32
Middle caudal-fin lobe	14.1–15.7 (14.8)	0.55	14.8-16.6 (15.8)	0.56	13.4–16.8 (15.1)	1.08	13.1–16.4 (15.2)	1.05
Head width ₁	9.5-10.7 (10.1)	0.29	9.5-10.5 (9.9)	0.39	9.2-10.7 (10.0)	0.47	9.1-10.2 (9.7)	0.31
Head width ₂	12.4–13.4 (13.0)	0.26	11.8-14.3 (12.9)	0.70	11.9–13.1 (12.6)	0.42	11.4-13.4 (12.6)	0.65
Head width ₃	13.3–14.6 (14.0)	0.42	12.7-14.1 (13.3)	0.47	13.1–15.0 (14.0)	0.66	12.4–14.7 (13.5)	0.67

Table 2. Morphometric characters in *Alburnoides fasciatus* and *A. eichwaldii*. Mean values are given in parentheses.

	A. fasciatus, n=	14	A. fasciatus, n=1	0	A. eichwaldii, n=	=15	A. eichwaldii, n=	10
Basin	Black Sea		Black Sea		Caspian Sea		Caspian Sea	
River or stream	Çoruh		İyidere		Aras		Kura	
	Range	SD	Range	SD	Range	SD	Range	SD
Head depth,	14.4-16.3 (15.2)	0.48	13.7-15.9 (14.8)	0.71	13.3-15.0 (14.4)	0.45	14.3-15.5 (14.9)	0.31
Head depth ₂	18.8-20.8 (19.7)	0.45	17.5-20.3 (19.1)	0.85	18.0-20.6 (19.4)	0.66	18.0-20.2 (19.4)	0.63
Eye diameter	7.0-8.1 (7.6)	0.33	7.3-8.0 (7.7)	0.23	5.9-7.3 (6.7)	0.47	6.5-8.1 (7.4)	0.61
Snout length	7.5–8.1 (7.7)	0.19	7.7–8.2 (7.8)	0.18	7.2–8.5 (7.8)	0.38	7.0-8.0 (7.6)	0.38
Interorbital width	8.7-9.8 (9.2)	0.32	8.0-9.4 (8.9)	0.44	7.8-8.8 (8.4)	0.31	7.4–9.5 (8.3)	0.59
Snout width at nostrils	9.1–10.6 (9.9)	0.39	9.4-10.8 (10.2)	0.55	9.6-10.7 (10.2)	0.29	10.0-11.3 (10.5)	0.40

]	Late	eral	-liı	ne s	cales							
	4	2 4	í3	44	45	46	47	48	49) 5	50	51	52	53	54	55	50	5 5	7	Mean
A. manyasensis, n=25	-		-	-	_	-	2	3	1		3	5	5	4	-	2			_	50.9
A. cf smyrnae, n=8		1	3	1	1	1	1	-	-		-	-	-	_	-	-	-		_	44.3
A. tzanevi, n=17	-	-	1	1	_	3	4	1	-		4	1	2	_	-	-			_	48
A. fasciatus, n= 30	-		-	-	_	-	1	4	8	1	7	3	6	_	1	-	-		_	50
A. eichwaldii, n= 38	-		-	-	_	-	-	5	3		2	5	8	8	2	3	_		1	51.7
	Sca	les a	bov	re lat	tera	l lin	e	Sca lat	les tera	bel 1 lii	ow ne	7		Bra	nch	ed a	nal	fin	ra	ys
	9	10	11	12	2 N	Mean	n 4	5		6	M	ean	10	11	12	13	14	1	5	Mean
A. manyasensis, n=25	1	8	14	2		10.7	' 5	20) -	-	4	.2	2	9	14	-	-	-	-	11.5
A. cf smyrnae, n=8	3	5	-	-		9.6	8	-	-	-	8	8	-	_	1	4	2	-	-	13
A. tzanevi, n=17	16	1	-	-		9.1	17	′ –	-	-	2	4	-	6	11	-	-	-	-	11.6
A. fasciatus, n=30	1	24	5	_		10.1	3	27	7 -	_	4	.9	_	_	_	16	12		2	13.5
A. eichwaldii, n=38	11	23	4	-		9.8	4	32	2 1	2	4	.9	-	3	20	13	2	-	-	12.4
		,	Tota	ıl ve	rteł	orae		Al	odo	mir	ıal	ver	tebra	e	C	Cauc	lal v	erte	ebr	ae
	4	0	41	42	4	3 1	Mean	2	0	21	2	22	Mear	n 1	9	20	21	2	2	Mean
A. manyasensis, n=10	1	3	5	2	-	-	40.9	1		8	1	1	21	2	2	6	2	-	-	20
A. cf smyrnae, n=8	-	-	6	2	-	-	41.3	3		5	-	-	20.6	-	-	6	2	-	-	20.3
A. tzanevi, n=9	1	l	3	5	-	-	41.4	2		5	2	2	21	-	-	6	2	1		20.4
A. fasciatus, n=10	-	-	4	5	1		41.7	-		5	-	5	21.5	2	2	4	4	-	-	20.2
A. eichwaldii, n=10	-	- T	-	10	-	-	42	-		10	-	-	21	-	-	-	10	-	-	21

Table 3. Frequency of occurrence of meristic characters in five Alburnoides species distributed in Turkey.



Figure 7. *Alburnoides eichwaldii*, Turkey: Ardahan Province: Hanak Stream, Kura River drainage, FFR 1047, female, 84 mm SL.

eye diameter is shorter than the snout length and the interorbital width (see Table 1, 2). In *Alburnoides manyasensis*, pigmentation of the lateral line is slightly distinct in the anterior part of the body but indistinct in the posterior part, while in *A. eichwaldii* (Fig. 7) the dots along the lateral line are distinct in both the anterior and posterior parts of the body.

Five Alburnoides species from Turkey (A. manyasensis, A. cf. smyrnae, A. tzanevi, A. fasciatus and A. eichwaldii) were compared by Principal Component Analysis (PCA). The



Figure 8. A scatter plot of the scores of the first two principal components (PC I, PC II) for 57 specimens of the five *Alburnoides* species (*A. manyasensis* (Δ), *A. cf. smyrnae* (\Box) *A. tzanevi* (\blacksquare), *A. fasciatus* (+) and *A. eichwaldii* (\Box), based on 26 morphometric characters.

Morphometric features (% SL)	PC I	PC II
Head length	-0.008	0.064
Body depth at dorsal–fin origin	0.009	0.122
Body depth at anal–fin origin	-0.056	0.118
Caudal peduncle depth	-0.175	0.142
Head width, (ant. margin of eye)	-0.358	0.066
Head width, (post. margin of eye)	-0.055	0.177
Head width ₃ (at opercle)	-0.135	0.173
Head depth, at interorbital region	-0.161	0.079
Head depth, (at nape)	-0.098	0.112
Eye diameter	0.353	0.311
Snout length	-0.322	0.165
Interorbital width	-0.355	0.275
Snout width at nostrils	-0.554	-0.158
Predorsal length	0.015	0.047
Prepelvic length	-0.018	0.000
Preanal length	-0.032	-0.031
Pectoral–fin origin to anal fin	-0.036	-0.098
Pectoral–fin origin to pelvic fin	-0.021	-0.080
Pelvic–fin origin to anal fin	-0.027	-0.161
Caudal-peduncle length	0.133	0.107
Dorsal–fin depth	0.144	0.356
Pectoral–fin length	0.035	0.248
Pelvic-fin length	0.003	0.224
Anal–fin length	0.182	0.245
Upper caudal–fin lobe	-0.068	0.213
Middle caudal–fin lobe	0.022	0.375

Table 4. Character loading on principal components I–II for 26 measurements taken on 96 specimens of five *Alburnoides* species (*A. manyasensis, A.* cf. *smyrnae, A. tzanevi, A. fasciatus* and *A. eichwaldii*).

PCA was performed in using twenty-six morphometric characters of the five *Alburnoides* species. The PCA separated *A. manyasensis* from *A. cf. smyrnae*, *A. tzanevi*, *A. fasciatus* and *A. eichwaldii* (Fig. 8). Also, there was only marginal overlap between *A. fasciatus* and *A. eichwaldii* (Fig. 8). Variables loading on the first metric PC I–II are given in Table 4.

Comparative material

- Alburnoides eichwaldii: FFR 1013, 3, 60–82 mm SL; Turkey: Ardahan Prov.: Aşıkzülal Stream, Kura River drainage; D. Turan & R. Buyurucu, 02 Sep. 2006. - FFR 1019, 2, 75-87 mm SL; Turkey: Ardahan Prov.: Susuz Stream, Aras River, Kura River drainage; D. Turan & R. Buyurucu, 23 June 2006. - FFR 1022, 112, 39-88 mm SL; Turkey: Ardahan Prov.: Kura River drainage; D. Turan & R. Buyurucu, 20 Sep. 2004. - FFR 1038, 6, 48-63 mm SL; Turkey: Kars Prov.: Selim Stream, Aras River, Kura River drainage; D. Turan & R. Buyurucu, 04 July 2004. – FFR 1039, 8, 47–87 mm SL; Turkey: Kars Prov.: Kars Stream, Aras River, Kura River drainage; D. Turan & R. Buyurucu, 19 Aug. 2007. - FFR 1047, 38, 50-107 mm SL; Turkey: Ardahan: Hanak Stream, Kura River drainage; D. Turan & R. Buyurucu, 12 June 2005. – FFR 1063, 67, 57–106 mm SL; Turkey: Kars Prov.: Boyalı Stream, Aras River, Kura River drainage; D. Turan & R. Buyurucu, 05 July 2007. - FFR 1071, 29, 31-103 mm SL; Turkey: Kars Prov.: Sarıkamış Stream, Aras River, Kura River drainage; D. Turan & R. Buyurucu, 03 Sep. 2006.- FFR 1082, 24, 33–94 mm SL; Turkey: Kars Prov.: Kızılçubuk Stream, Aras River, Kura River drainage; D. Turan & R. Buyurucu, 03 Sep. 2006. - FFR 1084, 7, 34-75 mm SL; Turkey: Ardahan: Göle Stream, Kura River drainage; D. Turan & R. Buyurucu, 06 Sep. 2006. - FFR 1085, 32, 41-89 mm SL; Turkey: Ardahan Prov.: Çıldır Lake, Aras River, Kura River drainage; D. Turan, C. Kaya & E. Doğan, 14 July 2012. – FFR 1087, 2, 63–78 mm SL; Turkey: Iğdır Prov.: Perçekkale Stream, Aras River, Kura River drainage; D. Turan, C. Kaya & E. Doğan, 16 July 2012. – FFR 1088, 37, 65–113 mm SL; Turkey: Kars Prov.: Selim Stream, Aras River, Kura River drainage; D. Turan, C. Kaya & E. Doğan, 15 July 2012. - FFR 1089, 7, 82–112 mm SL; Turkey: Ardahan Prov.: Yalnızçam Stream, Kura River drainage; D. Turan, C. Kaya & E. Doğan, 19 July 2012. - FFR 1090, 10, 39-78 mm SL; Turkey: Iğdır Prov.: Aras River, Kura River drainage; D. Turan, C. Kaya & E. Doğan, 17 July 2012. – FFR 1091, 18, 61–96 mm SL; Turkey: Ardahan Prov.: Göle Stream, Kura River drainage; D. Turan, C. Kaya & E. Doğan, 14 July 2012. – FFR 1092, 14, 52–91 mm SL; Turkey: Ardahan Prov.: Hanak Stream, Kura River drainage; D. Turan, C. Kaya & E. Doğan, 14 July 2012. - FFR 1093, 19, 63-85 mm SL; Turkey: Kars Prov.: Digor Stream, Aras River, Kura River drainage; D. Turan, C. Kaya & E. Doğan, 17 July 2012.
- Alburnoides fasciatus: FFR 1000, 16, 28–57 mm SL; Turkey: Artvin Prov.: Hopa Stream; D. Turan, C. Kaya & E. Doğan, 11 Nov. 2011. – FFR 1003, 30, 62–73 mm SL; Turkey: Artvin Prov.: Aralık Stream, Çoruh River drainage; D. Turan, C.

Kaya & E. Doğan, 15 July 2011. – FFR 1004, 6, 52–81 mm SL; Turkey: Artvin Prov.: Hopa Stream; D. Turan & R. Buyurucu, 23 June 2007. – FFR 1006, 9, 59–91 mm SL; Turkey: Rize Prov.: İyidere Stream; D. Turan & R. Buyurucu, 3 Jan. 2007. – FFR 1007, 3, 46–78 mm SL; Turkey: Rize Prov.: İyidere Stream; D. Turan & R. Buyurucu, 3 May 2009. – FFR 1008, 2, 55–64 mm SL; Turkey: Giresun Prov.: Aksu Stream; D. Turan & R. Buyurucu, 6 Sep. 2004. –FFR 1009, 43, 37–98 mm SL; Turkey: Rize Prov.: İyidere Stream; D. Turan & R. Buyurucu, 19 May 2008. – FFR 1011, 16, 67–87 mm SL; Turkey: Rize Prov.: Büyükçay Stream; D. Turan & R. Buyurucu, 10 Sep. 2004. – FFR 1024, 2, 67–72 mm SL; Turkey: Rize Prov.: Güneysu Stream; D. Turan & R. Buyurucu, 27 July 2006. – FFR 1046, 60, 41–88 mm SL; Turkey: Artvin Prov.: Aralık Stream, Çoruh River drainage; D. Turan & R. Buyurucu, 20 July 2007. – FFR 1081, 41, 57–89 mm SL; Turkey: Rize Prov.: Büyükçay Stream; D. Turan & R. Buyurucu, 29 July 2006. *Alburnoides* cf. *smyrnae*: FFR 1110, 8, 58–77 mm SL; Turkey: Uşak Prov.: Banaz

- Stream, Menderes River drainage; S. S. Güçlü, 7 Sep. 2012.
- Alburnoides tzanevi: FFR 1049, 3, 48–94 mm SL; Turkey: İstanbul Prov.: Istranca Stream; D. Turan & R. Buyurucu, 15 Aug. 2005. FFR 1052, 9, 33–80 mm SL; Turkey: İstanbul Prov.: Karamandere Stream; D. Turan & R. Buyurucu, 10 July 2007. FFR 1066, 10, 63–81 mm SL; Turkey: İstanbul Prov.: Terkos Stream; D. Turan & R. Buyurucu, 10 July 2007. FFR 1068, 17, 63-96 mm SL; Turkey: İstanbul Prov.: Istranca Stream; D. Turan & R. Buyurucu, 15 Aug. 2005.

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