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The Ashtamudi Lake short-neck clam: re-assigned to the genus *Marcia* H. Adams & A. Adams, 1857 (Bivalvia, Veneridae)

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Abstract

The economically valuable bivalve mollusc, known as the short-neck clam, is the major fishery resource of the brackishwater Ashtamudi Lake in Kerala, India. This fishery carries a Marine Stewardship Council certification for sustainability wherein it and all hitherto published reports identify the short-neck clam or yellow-foot clam as *Paphia malabarica* (Dillwyn, 1817). It is noted that this name does not conform with current nomenclature and is now correctly referred to *Protapes gallus* (Gmelin, 1791). Furthermore, it is shown that the identification is also incorrect. Comparative shell morphology of venerid clams of the subfamily Tapetinae from the south Indian coast demonstrates that the short-neck clam in Ashtamudi Lake is *Marcia recens* (Holten, 1802). Small numbers of *M. opima* (Gmelin, 1791) were found in Ashtamudi Lake but appear not to be part of, or contribute significantly to, the fishery. The venerid clams *Protapes gallus* and *P. ziczac* (Linnaeus, 1758) are not found in Ashtamudi Lake but are inhabitants of the shallow coastal waters of south India. Descriptions of the four confused species *M. recens, M. opima, P. gallus,* and *P. ziczac* are given. On the basis of this study, the species involved in Marine Stewardship Council (MSC) certification may be better considered at the generic level of *Marcia* or at the species level as *Marcia recens*, the most dominant species in the Ashtamudi Lake clam fishery zone.

Keywords

Fisheries management, India, *Marcia*, MSC certification, *Paphia*, *Protapes*, Venerid clam, Veneridae

Introduction

India supports extensive bivalve fisheries, notably for mussels, oysters, and clams, with an estimated annual production of 84,483 tonnes (CMFRI 2017). Clams form a subsistence fishery in Indian coastal waters, lakes, and estuaries, with a potential yield of 113,189 tonnes and the export from India is dominated by the short-neck or yellowfoot clam. A major part of this export is sourced from the Ashtamudi Lake in Kerala state, a designated Ramsar wetland on the southwestern coast of India. The Ashtamudi Lake is a large, basin-shaped estuary, some 62 km^2 in area and discharging into the Laccadive Sea through a narrow channel less than 300 m wide (Mohamed et al. 2013). This estuary provides livelihoods for hundreds of people involved in clam fishing, preparation and packing (CMFRI 1988, 2015, 2017, Appukuttan 1993, 2016, Appukuttan et al. 1999, Mohamed et al. 2013). With proper management interventions the sustainability of the Ashtamudi clam fishery has been ensured (Mohamed et al. 2013, Appukuttan 2016) and has, since 2014, been certified under the eco-labelling scheme of the Marine Stewardship Council (Wakamatsu and Wakamatsu 2017). All published reports of this clam, from the Ashtamudi Lake, refer to it as *Paphia malabarica* (Dillwyn, 1817), (Achari 1986, Kripa et al. 2006, CMFRI 2011, 2015, 2017, Appukuttan 2016). This name continues to be used despite the fact that it is a junior synonym of *Protapes gallus* (Gmelin 1791) (MolluscaBase 2018a).

During a bivalve training workshop in Kochi in 2016 (Nandan et al. 2016), further suspicions were raised about the taxonomy of clams brought from Ashtamudi Lake. The specimens at hand were supplied as short-neck clams but the shape and pallial sinus suggested that they did not belong to the genera *Paphia* or *Protapes* but to a different genus of the Tapetinae. This paper reports on a morphological analysis of the clams fished from the Ashtamudi Lake, the subsequent comparison of the shell morphologies of southern Indian Tapetinae and the correct identification of the Ashtamudi Lake short-neck clam.

Materials and methods

In order to record the species diversity represented in clam fisheries, surveys were conducted in the clam fishing zones of Ashtamudi Lake (8°56'N, 76°30'E), during 2015–2017 (Figure 1). Specimens were collected by fishermen using hand dredge nets and hand picking (Figure 2). Over 200 specimens were procured in order to assess the variation and species diversity. Specimens were also collected from the shallow waters of the Tuticorin (Thoothukudi) coast, Tamil Nadu (Figure 1), which is the type locality for *Marcia recens* (Holten, 1802). Shallow offshore sampling on both southwestern and southern-eastern coasts of India was undertaken to collect clams of the genus *Protapes*. The specimens were collected by bottom trawlers at an average depth off 15–30 m off the Kollam and Kannur coastal regions of Kerala, India (Figure 1). The voucher specimens are deposited in the museum of Department of Aquatic Biology and Fisheries, University of Kerala, Trivandrum, Kerala, India (DABFUK).

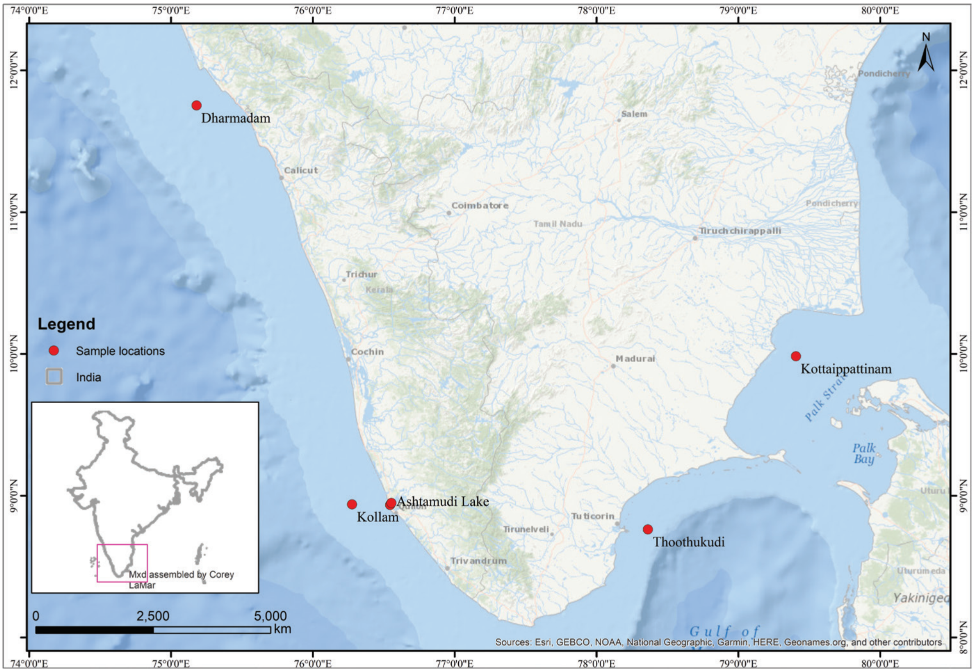

Figure 1. Sampling locations of venerid clams from the coast of southern India.

An initial review was undertaken by examining literature, primarily that of Subba Rao (2017), but also of Huber (2010), for Tapetinae known from southern India.

The nomenclature was reviewed from all original sources including Gmelin (1791), Chemnitz (1795), Holten (1802), Dillwyn (1817), and Lamarck (1818). The taxonomic identification of the specimens was carried out using Fischer-Piette and Metivier (1971), Oliver (1992), Oliver and Glover (1996), Huber (2010), Ramakrishna and Dey (2010), and Subba Rao (2017). Synonyms were accepted from MolluscaBase (2018) (http://www.molluscabase.org).

Shell measurements such as shell length (maximum distance from anterior to posterior margin), shell height (maximum distance from dorsal to ventral margin), and shell breadth (maximum inflation of the valves when joined) were recorded based on Oliver and Glover (1996), to the nearest 0.1 mm using a digital Vernier calliper.

Institutional abbreviations

CMFRI Central Marine Fisheries Research Institute, India

DABFUK Department of Aquatic Biology and Fisheries, University of Kerala, Trivandrum, Kerala, India

MHNG Geneva Museum of Natural History

NMW National Museum of Wales, Cardiff

Figure 2. Small scale clam fishery in Ashtamudi Lake, Kerala, India **A** collecting by hand picking **B** collecting using a dredge net **C, D** a typical catch of clams.

Results

Identity of the Ashtamudi clam

Subba Rao (2017) records 17 species of Tapetinae from Indian waters but only two species were collected from the Ashtamudi Lake. Both species have a shell with no radial sculpture and this excludes the genera *Ruditapes*, *Venerupis,* and *Irus*. The outline is subovate with rounded lateral margins and this excludes the rhomboidal form of *Tapes* species that occur in India, as well as the trigonal *Macridiscus*. The pallial sinus in both Ashtamudi species is horizontally aligned and this excludes the genera *Paphia* and *Protapes*. The Ashtamudi clams therefore fall into the genus *Marcia*. Subba Rao (2017) records four species of *Marcia* from Indian waters, two with weak commarginal sculpture (*M. recens* Holten, 1802 and *M. opima* Gmelin, 1791) and two with prominent commarginal riblets (*M. hiantina* Lamarck, 1818 and *M. japonica* Gmelin, 1791) Both Ashtamudi clams have a weak commarginal sculpture and can be identified as *M. recens* and *M. opima*. Specimens collected from the coast at Tuticorin can also be identified as *M. recens*.

No specimens referable to the genera *Paphia* or *Protapes* were found among the Ashtamudi Lake samples, but were collected from the offshore sampling. Subba Rao (2017) recorded two species of *Protapes* but Huber (2010) noted a third under the name of *P. ziczac* (Linnaeus, 1758). Both *P. ziczac* and *P. gallus* (Gmelin, 1791) were collected from offshore sampling. As detailed below, the comparative shell morphology demonstrates that the Ashtamudi clam fishery is not based on *Paphia malabarica* (= *Protapes gallus*), but primarily on *Marcia recens*. *Protapes* species are present around southern India but are absent from the Ashtamudi Lake, preferring open coastal waters. *Marcia recens*, by contrast, is widely distributed in estuarine and backwater habitats on both east and west coasts of India along with *M. opima*. Given the historical confusion we describe the species of *Marcia* in detail and give comparative descriptions of *Protapes gallus* and *P. ziczac*.

Descriptions

Family Veneridae Rafinesque, 1815
Subfamily Tapetinae Gray, 1851

Genus *Marcia* H. Adams & A. Adams, 1857

Type species. *Venus opima* Gmelin, 1791

Description. Moderately sized, outline triangular-ovate to elongate-ovate. Hinge with three cardinal teeth in each valve; posterior and middle cardinal bifid in left valve, middle cardinal bifid in right valve; laterals absent. Ligament external, elongate. Pallial sinus moderately deep, horizontally aligned. Sculpture variable from smooth to commarginal lines to weak commarginal ridges. Often highly and variably patterned externally with bold geometric blotches and radial rays. Inner shell margins smooth.

Remarks. The species within the genus *Marcia* are rather variable in form with the sculpture varying from almost smooth (*M. opima*) to finely ridged (*M. japonica* and *M. hiantina*). Huber (2010) notes this variability and discusses, but rejects, the use of *Hemitapes*, Römer, 1864 for these more coarsely sculptured forms. All have a horizontally aligned pallial sinus and this contrasts with the steeply ascending orientation seen in *Protapes*. Furthermore in *Protapes* the sculpture is stronger with commarginal raised ridges; the posterior margin is obliquely truncated and the anterior pronounced with a depressed lunule.

Marcia opima (Gmelin, 1791)
Figure 3

Original combination. *Venus opima* Gmelin, 1791

Synonyms. (from MolluscaBase 2018b) *Venus pinguis* Chemnitz, 1782 (unavailable), *Venus nebulosa* Gmelin, 1791; *Venus triradiata* Gmelin, 1791; *Venus gravida* Röding, 1798; *Tapes ceylonensis* G. B. Sowerby II, 1852.

Type locality. As the name *Venus pinguis* Chemnitz, 1782 is unavailable, this species takes the name of *Venus opima* Gmelin, 1791, both names referring to Chemnitz, 1782 tab. 34, figs 355–357. The type locality is given as East Indian Seas by Chemnitz (1782) but as India by Gmelin (1791).

Material examined. Ashtamudi Lake, Kerala, 21 live collected specimens + 26 articulated conjoined valves.

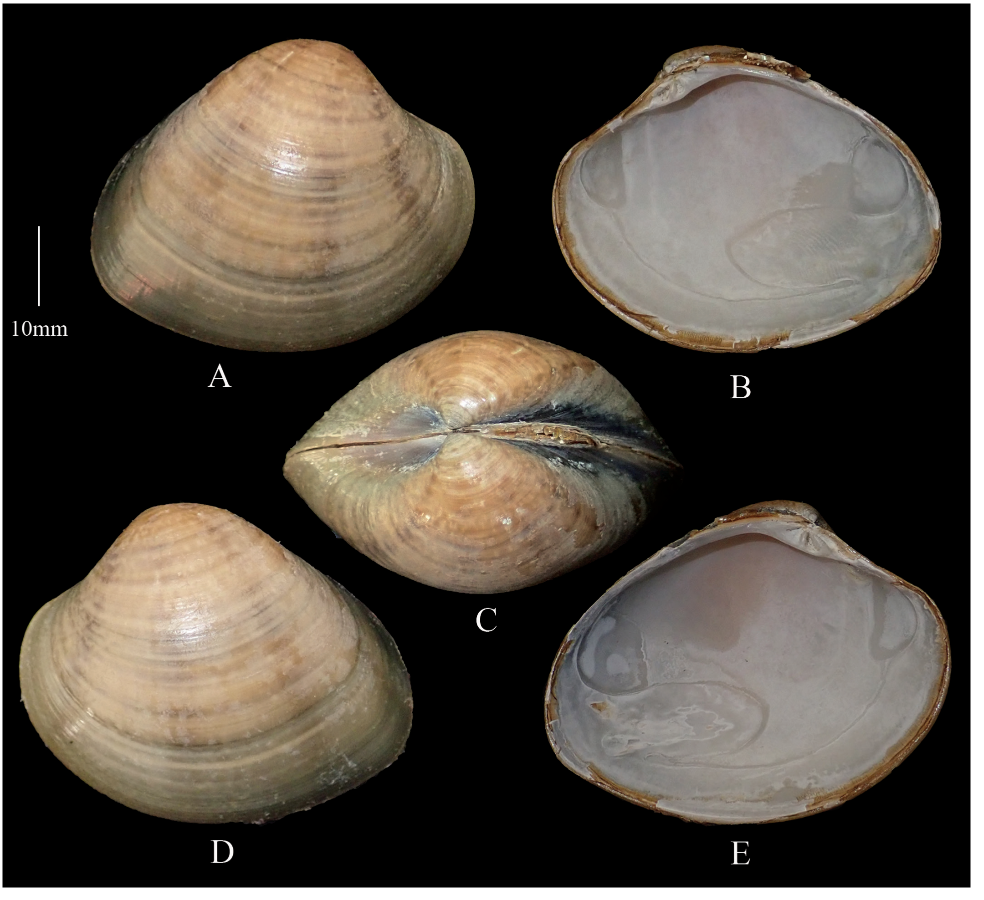

Figure 3. *Marcia opima* **A** right valve dorsal **B** right valve ventral **C** dorsal margin **D** left valve dorsal **E** left valve ventral (DABFUK), Ashtamudi, Kerala.

Measurements. Length 30.4–48.6 mm, mean L/H = 1.3, mean L/B = 1.6.

Description. Shell equivalve, relatively thin; inflated, umbos prominent. Outline triangularly subovate, inequilateral, beaks slightly in front of midline. Lunule well defined, prominent, flattened, and broad. Escutcheon weakly defined. Shell surface smooth, glossy with faint growth lines. Adductor muscles of equal size. Pallial sinus horizontally aligned, broadly rounded, extending to midline of shell. External colouration variable and variously patterned, shades of brown, cream and dark grey with 3–4 radial darker bands. Internal colouration white.

Distribution. *Marcia opima* is distributed throughout the Indian Ocean from the Red Sea to Indonesia. Authentic records are from East Africa, Kenya, Djibouti, Yemen, Arabian Gulf, Oman, Pakistan, India, Sri Lanka, Myanmar, Andaman Sea, West Malaysia, Penang, and Sulawesi (Huber 2010).

Remarks. *Marcia opima* was originally described from India and it has a wide distribution on the east and west coasts of India including the Andaman-Nicobar and Lakshadweep islands (Ramakrishna and Dey 2010, Subba Rao 2017). A fishery for this species in the Ashtamudi Lake was reported by Appukuttan et al. (1985) but we cannot confirm the actual identity of the species involved. Other fisheries of this species are recorded by Subba Rao (2017), in particular at Ratnagiri (west coast) and Adyar River (east coast).

Marcia recens (Holten, 1802)

Figures 4–9

Original combination. *Venus recens* Holten, 1802

Synonyms. (from MolluscaBase 2018c) *Venus marmorata* Lamarck, 1818; *Venus interrupta* Koch in Philippi, 1849; *Tapes laterisulca* G. B. Sowerby II, 1852; *Tapes bicolorata* Reeve, 1864; *Tapes ferruginea* Reeve, 1864; *Tapes occidentalis* Reeve, 1864; *Tapes orientalis* Reeve, 1864; *Tapes sinensis* Reeve, 1864; *Hemitapes dohrni* Römer, 1870; *Tapes exserta* Römer, 1872.

Type locality. Chemnitz (1795: 229) gives the type locality as Tuticorin on the Coromandel coast.

Material examined. Tuticorin, 42 live collected specimens: Ashtamudi Lake, 217 live collected specimens: Mumbai (Bombay), Maharashtra, 6 empty articulated shells, as *Tapes marmorata* Lamarck, leg. J. C. Melvill, NMW 1955.158: Thalassery (Tellicherry), Northern Kerala, 4 empty articulated shells, as *Hemitapes marmorata* Lamarck, coll. H. C. Winckworth, 1931, NMW. 1955.158

Measurements. Shells from Ashtamudi Lake and Tuticorin ranged in length from 12 to 51 mm. More detailed measurements are given for the morphotypes described below.

Description. Shell robust, moderately thick, moderately inflated. Outline elongate subovate, inequilateral, beaks in front of midline. Lunule flattened, not well defined. Escutcheon weakly defined. Shell surface slightly glossy; sculpture commarginal, of weak lines and growth stops, some with more defined ridges especially over anterior area. Muscle scars weakly heteromyarian, posterior larger. Pallial sinus horizontally aligned, broadly rounded extending to one third of shell length. External colouration highly variable and variously patterned, cream, red, white or brown and patterned with 3–4 black radiating rays, or darker trigonal blotches over a light ground or with anastomosing narrow radial rays. Internal colouration white, some with pinkish umbonal cavity.

Variability The type locality of *M. recens* is given as Tuticorin but without any further precision. Shells collected for this study from Tuticorin can be considered to come from the type locality and are given topotype status.

Topotypes (Figure 4) Outline ovate-elongate. Yellowish brown with darker radial bands and umbonal blotching. Sample size 30 shells. Shell length range 31.2–54.4 mm, mean L/H = 1.3, mean L/B = 2.1.

Shells from Ashtamudi Lake show considerable variation in shell colour and pattern and these are defined as follows.

Morphotype 1 (Figure 5). Outline ovate–elongate. Reddish brown to light brown shells with dark brown to black radial rays. Sample size 82 shells. Shell length 15.4–45.8 mm, mean L/H = 1.4, mean L/B = 2.3.

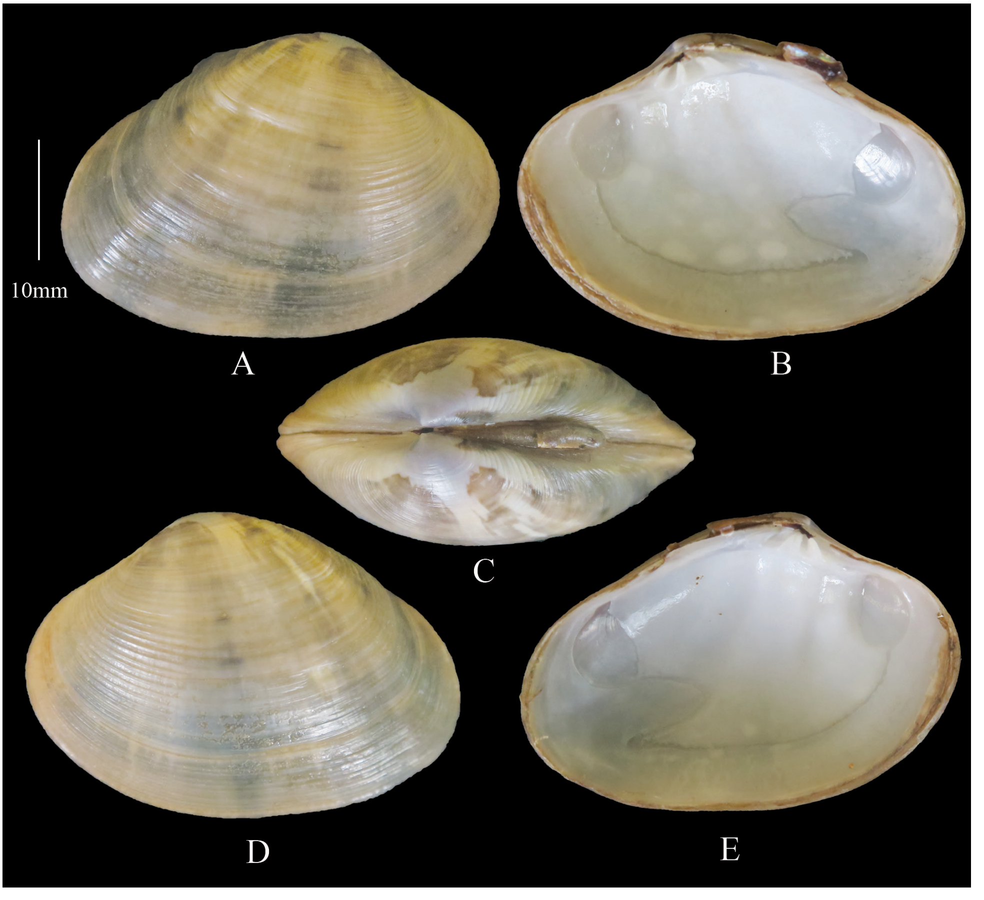

Figure 4. *Marcia recens* Topotype **A** right valve dorsal **B** right valve ventral **C** dorsal margin **D** left valve dorsal **E** left valve ventral (DABFUK), Tuticorin, Tamil Nadu.

Morphotype 2 (Figure 6). Outline ovate–elongate. White to cream shells with sparse blotching, lacking dark radial rays Sample size 75 shells. Shell Length 16.0–51.0 mm mean L/H = 1.4, mean L/B = 2.4.

Morphotype 3 (Figure 7). Outline trigonal–ovate, inflated. Yellowish brown shells with irregular sparse blotching. Sample size 7 shells. Shell Length 29.6–38.1 mm mean L/H = 1.4, mean L/B = 2.0

Morphotype 4 (Figure 8). Outline ovate–elongate. White or cream shells with black blotches over lunule and escutcheon. Sample size 75 shells. Shell Length 20.7–39.3 mm, mean L/H = 1.4 , mean L/B = 2.4 .

Morphotype 5 (Figure 9). Outline ovate-elongate. Cream to beige shells with prominent darker anastomosing radial zigzag streaks. Sample size 38 shells. Shell Length 12.4–43.2 mm, mean L/H = 1.4, mean L/B = 2.4.

Distribution. The type locality is recorded as Tuticorin on the Coromandel coast (Chemnitz 1795). The species was subsequently recorded in various localities from

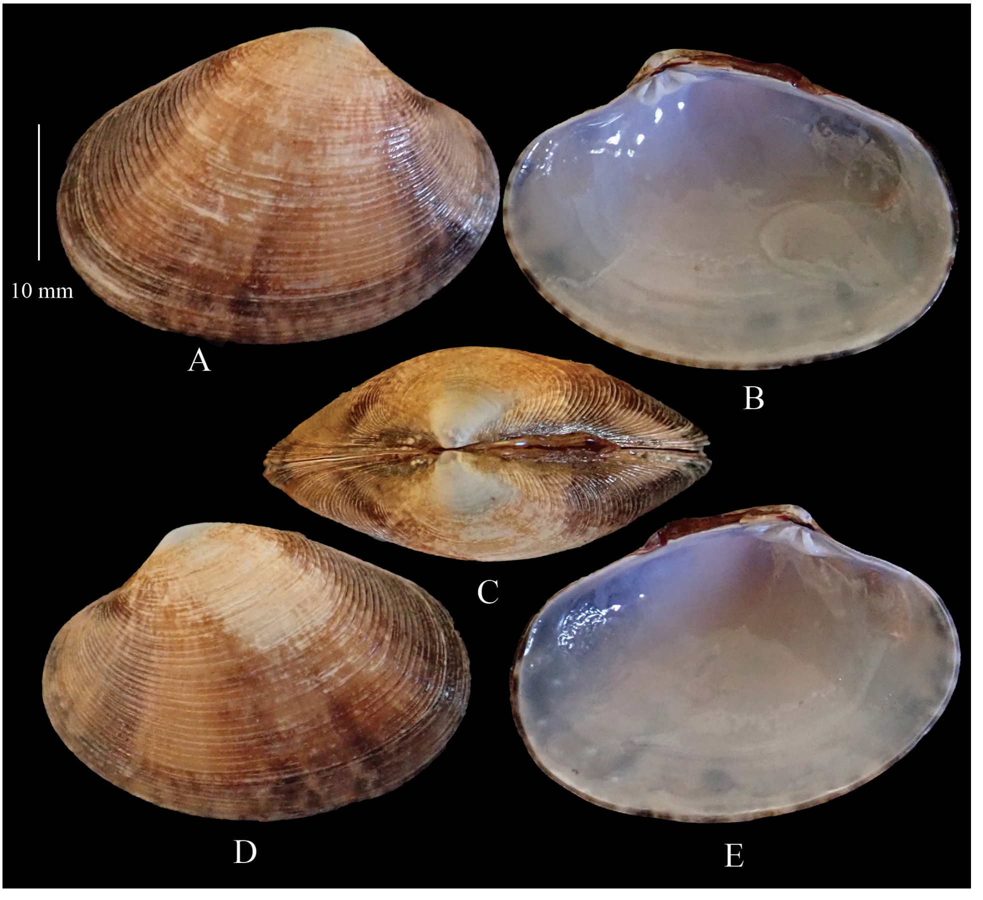

Figure 5. *Marcia recens* Morphotype 1 **A** right valve dorsal **B** right valve ventral **C** dorsal margin **D** left valve dorsal **E** left valve ventral (DABFUK), Ashtamudi Lake, Kerala.

Karachi to the Philippines (Ray 1948). Huber (2010) records this species from the east and west coasts of India, Andaman Sea, Indonesia, Philippines, South China, Singapore, Thailand, and Hainan. Records from the northern Arabian Sea may be *Marcia cordata* (Forsskål in Niebuhr, 1775) and the most easterly confirmed records are from Gujarat. In India *Marcia recens* is recorded from the states of Goa, Gujarat, Karnataka, Kerala, Maharashtra, Odisha, and Tamil Nadu (Ramakrishna and Dey 2010, Subba Rao 2017) as a commonly available, commercially exploited edible clam (Alagarswami and Narasimham 1973, Durve 1975, Narasimham 1991). The presence of this species in estuaries was recorded by Ray (1948), Huber (2010), and Pati and Panigrahy (2013).

Remarks. The species was originally described by Chemnitz (1795) and made available as *Venus recens* by Holten (1802). *Venus marmorata* Lamarck, 1818 is generally regarded as a synonym (Fischer-Piette and Metivier 1971; Huber 2010) despite the type locality given by Lamarck as 'southern Europe'. Examination of the type material in the Geneva Museum of Natural History (MHNG-MOLL-504213) supports the synonymy.

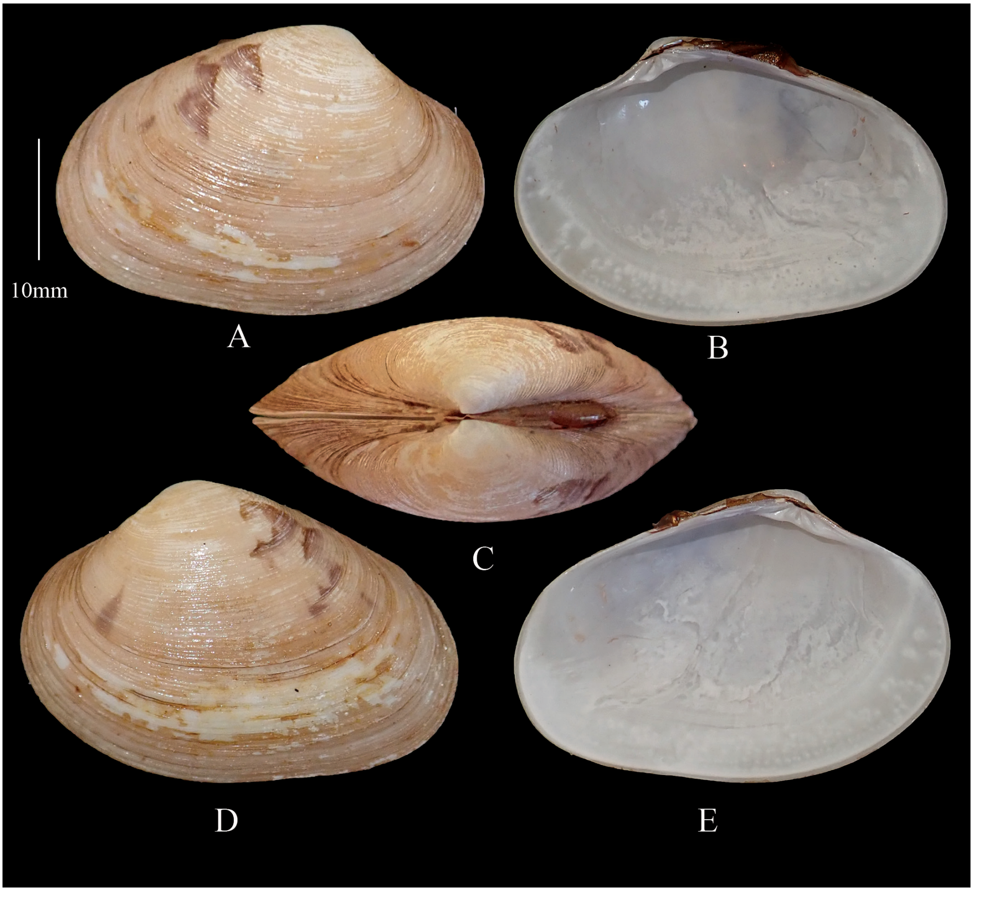

Figure 6. *Marcia recens* Morphotype 2 **A** right valve dorsal **B** right valve ventral **C** dorsal margin **D** left valve dorsal **E** left valve ventral (DABFUK), Ashtamudi Lake, Kerala.

The morphotypes differ primarily in colour pattern with some variation in relative timidity as shown by the L/B ratios that vary from 2.0 to 2.4. This ratio is distinctly different from the 1.6 for *M. opima*. The sampling regime was not precise enough to distinguish if there was any relationship between morphotype and distribution.

Genus *Protapes* Dall, 1902

Type species. *Venus gallus* Gmelin, 1791

Description. Moderately large, outline triangular ovate to oval, often posteriorly truncated and pronounced anteriorly; lunule margin excavated. Hinge with three cardinal teeth in each valve. Ligament external, opisthodetic. Pallial sinus steeply ascending towards the umbonal cavity. External sculpture strong, of raised commarginal ridges. External patterns predominantly of interrupted zig-zag lines.

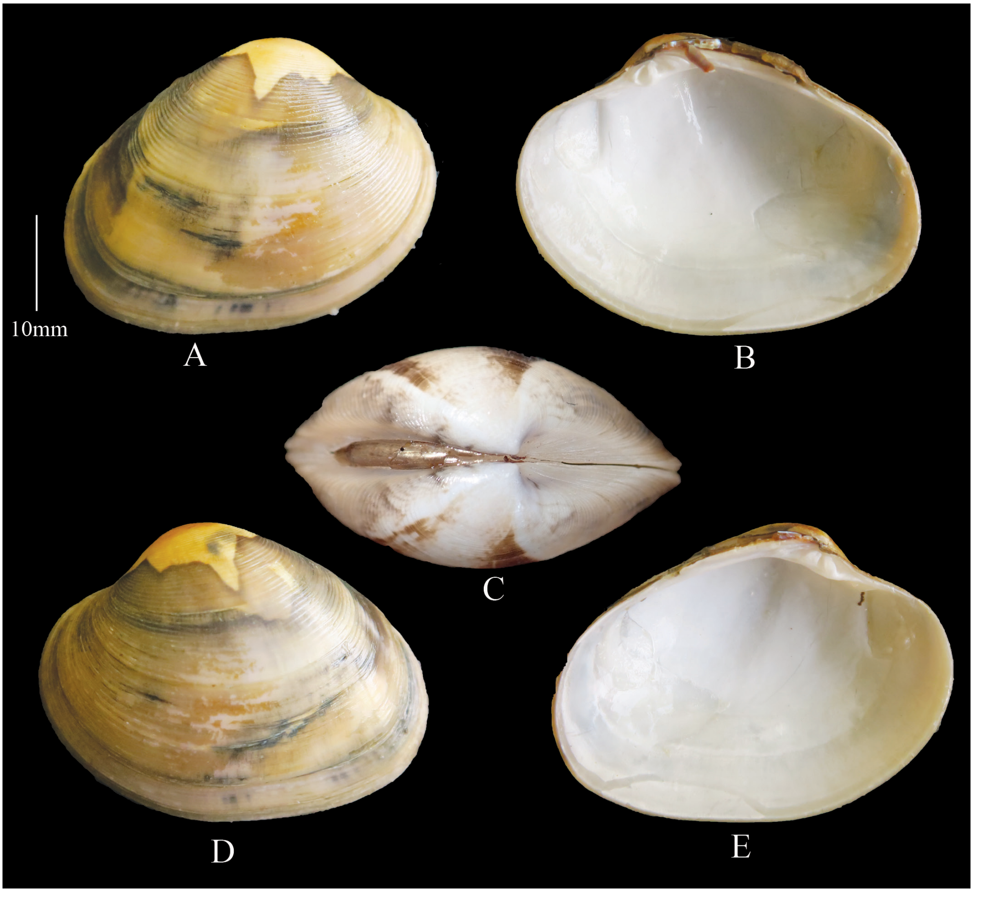

Figure 7. *Marcia recens* Morphotype 3 **A** right valve dorsal **B** right valve ventral **C** dorsal margin **D** left valve dorsal **E** left valve ventral (DABFUK), Ashtamudi Lake, Kerala.

Remarks. The genera *Protapes*, *Paphia,* and *Paratapes* all share the character of the ascending pallial sinus. *Paphia* and *Paratapes* differ in outline and sculpture in being elongate, distinctly longer than high, and having a smooth shell.

Three species of *Protapes* are recorded from Indian waters, *P. gallus* (Gmelin, 1791), *P. ziczac* (Linnaeus, 1758), and *P. monstrosus* (Römer, 1870), and all are well illustrated by Huber (2010). Only *P. gallus* and *P. ziczac* were collected in this study.

***Protapes gallus* (Gmelin, 1791)**
Figure 10

Original combination. *Venus gallus* Gmelin, 1791

Synonyms. (from MolluscaBase 2018a) *Venus malabarica* Dillwyn, 1817; *Venus rhombifera* Bory de Saint-Vincent, 1827; *Tapes lentiginosa* Reeve, 1864.

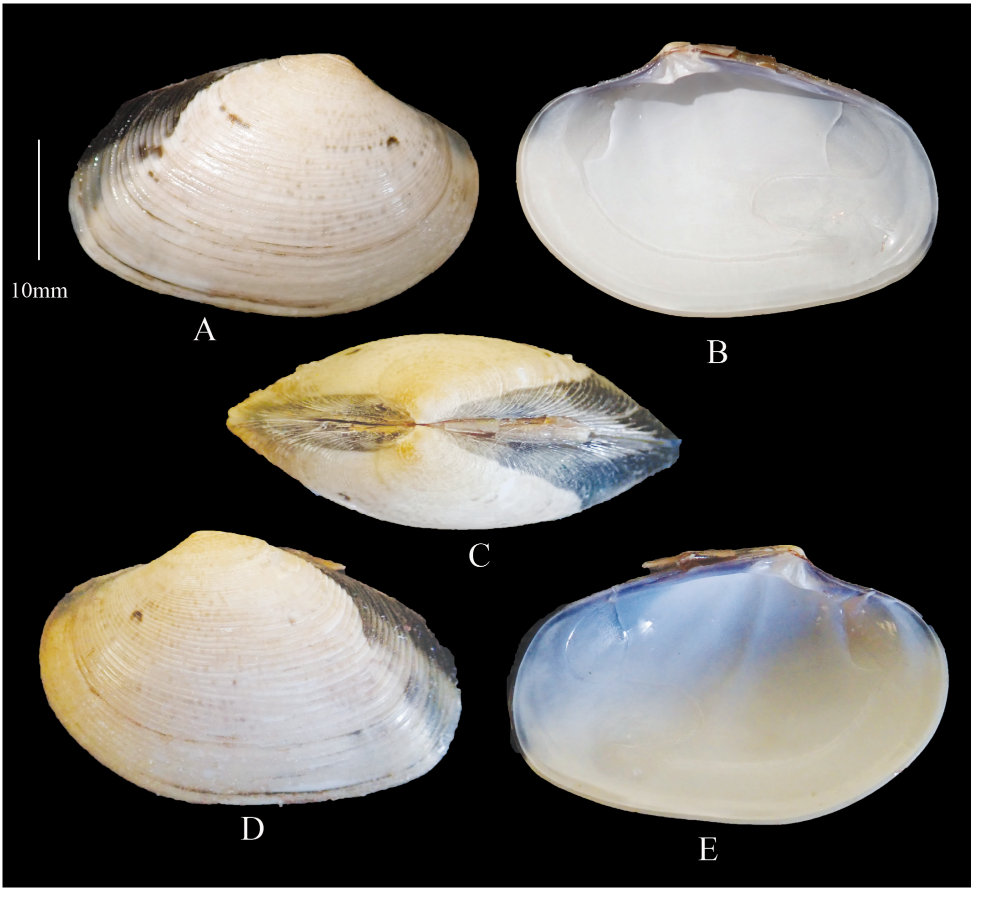

Figure 8. *Marcia recens* Morphotype 4 **A** right valve dorsal **B** right valve ventral **C** dorsal margin **D** left valve dorsal **E** left valve ventral (DABFUK), Ashtamudi Lake, Kerala.

Type locality. As the name *Venus malabarica* Chemnitz, 1782 is unavailable this species takes the name of *Venus gallus* Gmelin, 1791, both names referring to Chemnitz, 1782 tab. 31, figs 324–325. The type locality is given as the Malabar coast by Chemnitz (1782), which largely equates with the coast of modern Kerala.

Material examined. Neendakara, Kollam, 5 live collected specimens + 10 empty articulated shells; Dharmadam, Kannur, 6 live collected specimens + 4 empty articulated shells.

Description. Shell to 60 mm in length, solid, compressed, inequilateral, beaks slightly to the anterior. Outline trigonal-subovate, lunule margin impressed, anterior margin pronounced, posterior ventral margin weakly truncated, posterior dorsal margin sloping steeply. Lunule lanceolate, demarcated by shallow groove. Escutcheon long, narrow, weakly striated. Sculpture of evenly sized, rounded, closely spaced, commarginal ribs separated by narrow grooves. Pallial sinus wide, deep, ascending steeply toward umbonal cavity. External colouration light brown with narrow and light zigzag

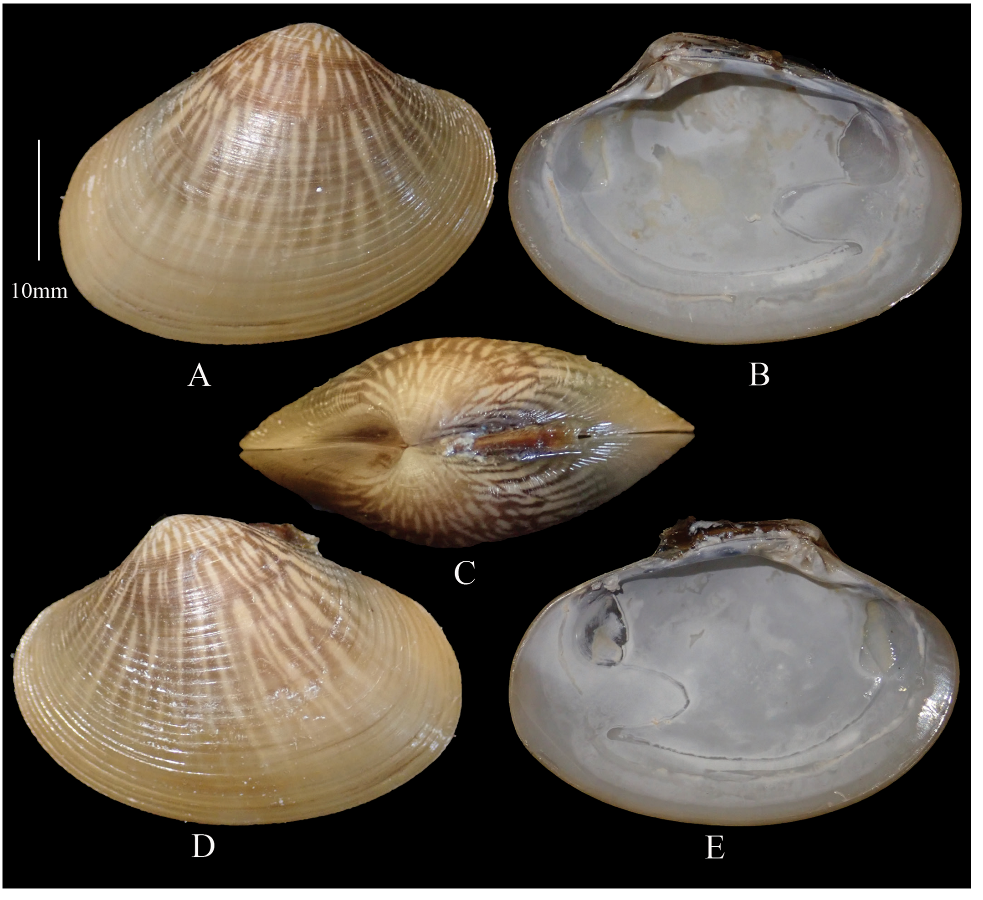

Figure 9. *Marcia recens* Morphotype 5 **A** right valve dorsal **B** right valve ventral **C** dorsal margin **D** left valve dorsal **E** left valve ventral (DABFUK), Ashtamudi Lake, Kerala.

or chevron streaks with four distinct brown rays radiating from the beak to the ventral margin. Shell interior white with yellowish tinge on the umbonal cavity.

Distribution. *Protapes gallus* has an Indo-West Pacific distribution extending from India to China (Huber 2010) but Chen et al. (2014) suggests that cryptic species may also be present.

Remarks. This species was described as *Venus malabarica* by Chemnitz (1782, figs. 324, 325) with the type locality of the Malabar coast in southwest India. Using Chemnitz's (1782) figures, Gmelin (1791) erected the name *Venus gallus* and repeated the type locality of the Malabar coast. No type material could be located in Copenhagen or St Petersburg collections, consequently all nomenclature is based on the figures in Chemnitz. These figures are sufficient to place this taxon in the genus *Protapes* and this taxon was adopted as the type of the genus by Dall (1902). Although Chemnitz's name is invalid for nomenclatural purposes, it was still being used in the late twentieth century by Fischer-Piette and Metivier (1971).

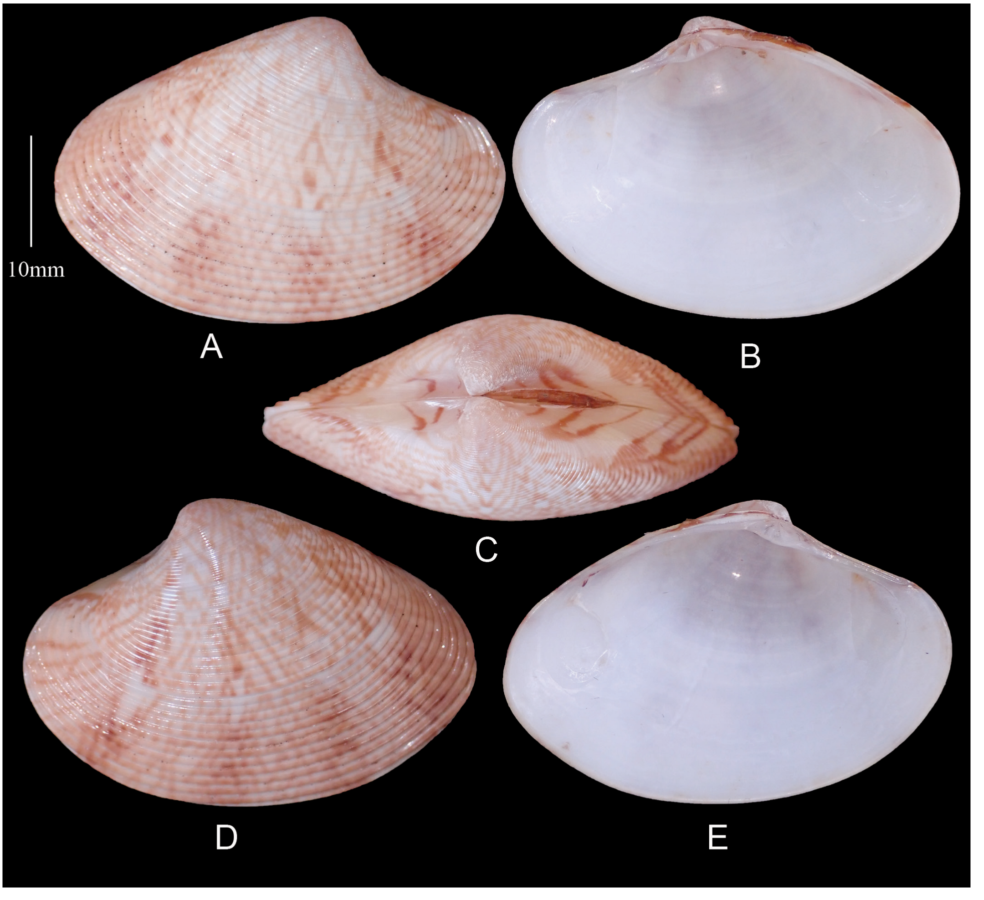

Figure 10. *Protapes gallus* Topotype **A** right valve dorsal **B** right valve ventral **C** dorsal margin **D** left valve dorsal **E** left valve ventral (DABFUK), Dharmadam, Kerala, South west coast of India.

Protapes ziczac (Linnaeus, 1758)
Figure 11

Original combination. *Venus ziczac* Linnaeus, 1758

Synonyms. (from MolluscaBase 2018d) *Venus sinuosa* Lamarck, 1818; *Tapes inflata* Römer, 1870

Type locality. Linnaeus (1758) gives the type locality as the Indian Ocean.

Material examined. Neendakara, Kollam, 5 live collected specimens + 18 empty articulated shells; Dharmadam, Kannur, 3 live collected specimens.

Description. Shells to 50 mm, solid, inflated, equivalve, inequilateral, beaks slightly in front of midline. Outline sub-ovate, lunule margin impressed, anterior margin pronounced, posterior ventral margin subtruncate, posterior area strongly sinuous. Lunule lanceolate, weakly ridged. Escutcheon narrow, smooth. Sculpture of raised concentric ridges separated by nearly equal-sized grooves. Pallial sinus narrow, apex

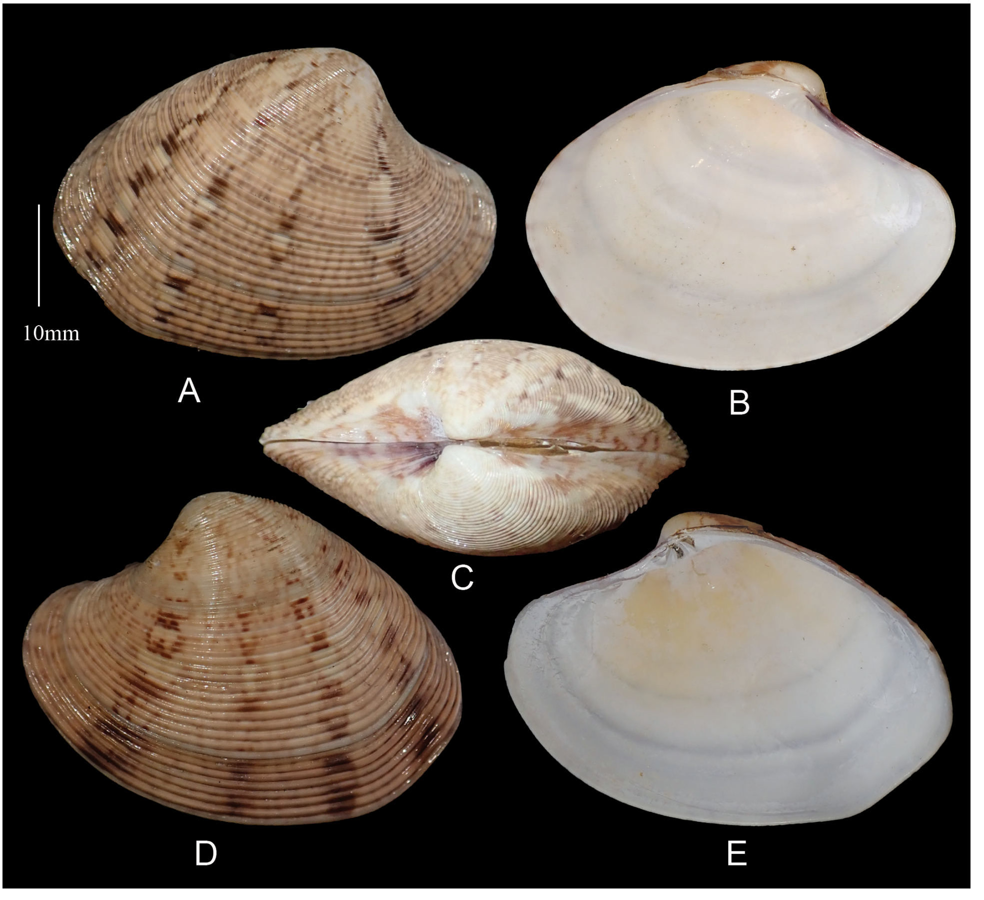

Figure 11. *Protapes ziczac* **A** right valve dorsal **B** right valve ventral **C** dorsal margin **D** left valve dorsal **E** left valve ventral (DABFUK), Kollam, Kerala, South west coast of India.

rounded, ascending steeply towards umbonal cavity. Shell external colour tan with bright zigzag streaks and four brown rays radiating from umbo to ventral margin. Shell interior colour white with yellowish tinge in umbonal cavity.

Distribution. The species has an Indian Ocean distribution with records from the Red Sea, Aden, East Africa, Somalia, Mozambique, Maputo, Inhambane, Nacala, Natal, Madagascar, Oman, and Persian Gulf (Huber 2010).

Remarks. *Protapes ziczac* (Linnaeus, 1758) has an inflated, heavy, and solid shell with the external sculpture the strongest of any species of *Protapes*.

The species was recorded as *Protapes sinuosa* (Lamarck 1819) by Oliver and Glover (1996) from the Arabian Sea, but has subsequently been shown to be *Protapes ziczac* (Huber, 2010). Huber (2010) gave *P. sinuosa* as a junior synonym and also synonymised *Tapes inflata* Römer, 1870 with *P. ziczac*, but Huber (2010) doubted the locality given as Sri Lanka. He regarded the Indo-Pacific shells identified as *P. sinuosa* as a new taxon, *P. swenneni* (Huber, 2010).

Discussion

It is evident from the results that the Ashtamudi Lake short-neck clam fishery is based primarily on *Marcia recens* and not *Paphia malabarica* (= *Protapes gallus*). It is surprising that two such different shells should have become so confused. The literature citations for *Paphia malabarica* in India are extensive (Ramakrishna and Dey 2010) but many of them are not accompanied by illustrations and therefore they do not allow identification. Where illustrations are presented as *Protapes* (Subba Rao et al. 1987: pl VII, fig. 12), Subba Rao et al. (1992: pl 26, fig. 1), and Ramakrishna and Dey (2010: pl XLIX, fig. 247), the generic identifications are correct. That, illustrated by Ramakrishna and Dey (2010: pl XLIX, fig. 247) seems to resemble *P. monstrosus* due to its more solid and inflated shell. Ramakrishna and Dey (2010: pl XLIX, fig. 247) and Subba Rao (2017: pl 77, fig. 352) have clearly illustrated the characteristic ascending pallial sinus of the genus *Protapes*. A similar historical background for *Marcia recens* also exists again exemplified by the references cited in Ramakrishna and Dey (2010). In this case no accompanying illustrations were present.

It would appear that a lack of illustrations in recent Indian literature have led to a misidentification and this has been carried into modern references referring to the Ashtamudi clam even where *Marcia* shells are illustrated: Appukuttan (1993: pl 1, fig. A, B, pl II), Joe (1993: 39, photo 2), CMFRI (2006: 78), Kripa et al. (2006: 9; fig. 1), Mohamed et al. (2013: 16, 20), Smita (2014: pl1.4 a, b, c, pl 1.5), Ampili (2014: 8, pl 1.1, fig. 1.1a; 161, pl, 7.1, fig. 7.2a), Ampili and Sreedhar (2015: 2, fig. 1), and CMFRI (2015, cover page). The taxonomic errors in identification in the initial publications were further exacerbated by subsequent publications, including those of the Central Marine Fisheries Research Institute in India. This has also resulted in the certification of fishery in the name of *Paphia malabarica* by the Marine Stewardship Council in 2014. The images shown in the websites of Central Marine Fisheries Research Institute in India, World Wide Fund for Nature India and Marine Stewardship Council related to certification of Ashtamudi Lake clam fishery also present images of *Marcia* spp. as *Paphia malabarica.*

No deleterious effects on the viability of the fishery have resulted from this error in identification but from a legislative context applying the incorrect name to the exploited species could undermine its certification and protection. On the basis of this study, the species involved in the Marine Stewardship Council certification would be better considered at the generic level of *Marcia* or at the species level for *Marcia recens*, the most dominant species in the Ashtamudi Lake clam fishery zone. We have limited this proposal to the Ashtamudi fishery as, at this time, we are unable to confirm the identity of clams from other fisheries, including those cited as exploiting *Marcia opima*. It is possible that the name "short-neck clam" is applied loosely to both *Marcia* species. Subba Rao gives the Tamil name "vazhukku matti" for *M. opima* but none for *M. recens*, perhaps indicating a lack of discrimination by fishermen. In this context it will be necessary to ascertain the relative abundance of the two *Marcia* species in any fishery and elucidate the ecology of these species especially their micro-habitat preferences.

Misidentification can undermine comparative biological studies. For example, Joy and Chakraborty (2017) describe anti-oxidant properties extracted from the Ashtamudi clams but wrongly identify them as *Paphia malabarica (= Protapes gallus)*. Any subsequent attempts to repeat such research using true *Protapes* may give entirely different results.

Marcia recens has now been confirmed from its type locality in Tuticorin and is conspecific with the Ashtamudi Lake population in Kerala. Similar shells are known from further north at Mumbai but its northern limit is not known nor where, or if, it overlaps with *Marcia cordata*, a widespread Arabian species. It would appear that *M. recens* extends throughout the Indo-Pacific although the molecular data from Chen et al. (2011) suggests that the systematics of *Marcia* may be more complex than currently estimated.

While this study has correctly identified the Ashtamudi clam, many unresolved issues surround this species and the genus as a whole. Molecular studies are necessary to resolve the population differences within *M. recens* and the relationship between it and *M. cordata* and *M. opima*. *Marcia recens* is in many ways similar to some species of *Tapes* and *Politapes* and here too a molecular resolution is needed. Morphologically other species of *Marcia* have been separated into *Hemitapes* (Huber 2010) and this too needs a molecular clarification.

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RESEARCH ARTICLE

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Taxonomy of myid bivalves from fragmented brackish-water habitats in India, with a description of a new genus *Indosphenia* (Myida, Myoidea, Myidae)

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Abstract

A group of small bivalves inhabiting Indian brackish-water estuaries and lagoons (known locally as backwaters), variously assigned to *Corbula*, *Cuspidaria*, and *Sphenia*, are reviewed and, based on shell characters, shown to be congeneric. Molecular (COI) and morphological data indicate that this group belongs to the family Myidae. Furthermore, the combined data suggest that these Indian myids are a sister taxon of the genus *Sphenia*. The Indian material studied herein exhibits a functional morphology typical of infaunal bivalves, whereas typical *Sphenia* are nestling and epibyssate. A new genus, *Indosphenia*, is thus erected for the Indian group and includes five species, one of which is named in this study.

Indosphenia kayalum Oliver, Hallan & Jayachandran, **gen. et sp. n.** is described from the Cochin Backwater on the western coast of India. *Cuneocorbula cochinensis* (Preston, 1916) is transferred to *Indosphenia*. Additionally, the west coast taxa *I. abbreviata* (Preston, 1907), *I. abbreviata chilkaensis* (Preston, 1911) and *I. sowerbyi* (EA Smith, 1893) are recognised herein. *Corbula alcocki* Preston, 1907, *Corbula gracilis* Preston, 1907, *Corbula calcaria* Preston, 1907 and *Corbula pfefferi* Preston, 1907 are placed in synonymy with *I. abbreviata*, and *Cuspidaria annandalei* Preston, 1915 is synonymised with *I. abbreviata chilkaensis*.

Keywords
Anatomy, Bivalvia, brackish waters, COI, India, morphology, taxonomy

Introduction

Extensive estuarine and lagoon systems are found around both the eastern and western coasts of India (Fig. 1). The malacofauna was extensively investigated in the early twentieth century and many new taxa were published by HB Preston (1907, 1911, 1915, 1916), see Table 1.Preston described rather similar morphotypes as separate species from the isolated and geographically separated brackish water environments such as the Gangetic Delta, Lake Chilka and Cochin Backwater. The taxonomy of many bivalve species described by Preston has been confusing, at least in part because Preston did not describe details of the hinge. Consequently, some species were described under *Cuspidaria* while others under *Corbula*, groups that are not closely related and only superficially similar with respect to their shell morphology. In some instances, the original generic placements remained unchallenged (Ramakrishna and Dey 2010) while others were changed (Oliver et al. 2016). Preston (1907) described five new species of *Corbula* from one single locality, but there was no indication of any habitat segregation or the degree of morphological variation. This led to an inconsistent situation in the subsequent literature as summarised below.

Ramakrishna and Dey (2010) synonymised *Corbula alcocki* and *C. pfefferi* under *C. abbreviata* while retaining *C. calcarea* and *C. gracilis* as valid species; additionally, they transferred *C. chilkaensis* to *Cuspidaria*. Huber (2010) argued that all of the above species described by Preston in 1907 should be considered a single species, proposing the name *Potamocorbula abbreviata* (Preston, 1907) be used. Subba Rao (2017) followed Huber (2010) and also placed *Cuspidaria annandalei* into synonymy with *Corbula chilkaensis* under *Potamocorbula chilkaensis*.

Bearing this taxonomic background in mind, in 2016, one of the present authors (Philomina Joseph) collected a sample of fragile, thin-shelled bivalves living among filamentous green algae, on a muddy substrate, in the upper brackish regions of the Cochin Backwater. This bivalve could not be identified from the available literature

Table 1. List of species considered in this paper recorded from the Indian subcontinent.

Original combination	Name currently used in MolluscaBase (2018)	Type locality
Sphenia perversa (Blanford, 1867)	*Sphenia perversa* (Blanford, 1867)	Pegu, Irawady Delta, Myanmar
Sphenia sowerbyi EA Smith, 1893	*Sphenia sowerbyi* EA Smith, 1893	Pondicherry
Corbula abbreviata Preston, 1907	*Potamocorbula abbreviata* (Preston, 1907)	Port Canning
Corbula alcocki Preston, 1907	*Potamocorbula alcocki* (Preston, 1907)	Port Canning
Corbula calcaria Preston, 1907	*Potamocorbula abbreviata* (Preston, 1907)	Port Canning
Corbula gracilis Preston, 1907	*Potamocorbula abbreviata* (Preston, 1907)	Port Canning
Corbula pfefferi Preston, 1907	*Potamocorbula abbreviata* (Preston, 1907)	Port Canning
Corbula chilkaensis Preston, 1911	*Potamocorbula chilkaensis* (Preston, 1911)	Lake Chilka
Cuspidaria annandalei Preston, 1915	*Cuspidaria annandalei* Preston, 1915	Lake Chilka
Cuspidaria cochinensis Preston, 1916	*Cuneocorbula cochinensis* (Preston, 1916)	Cochin Backwater

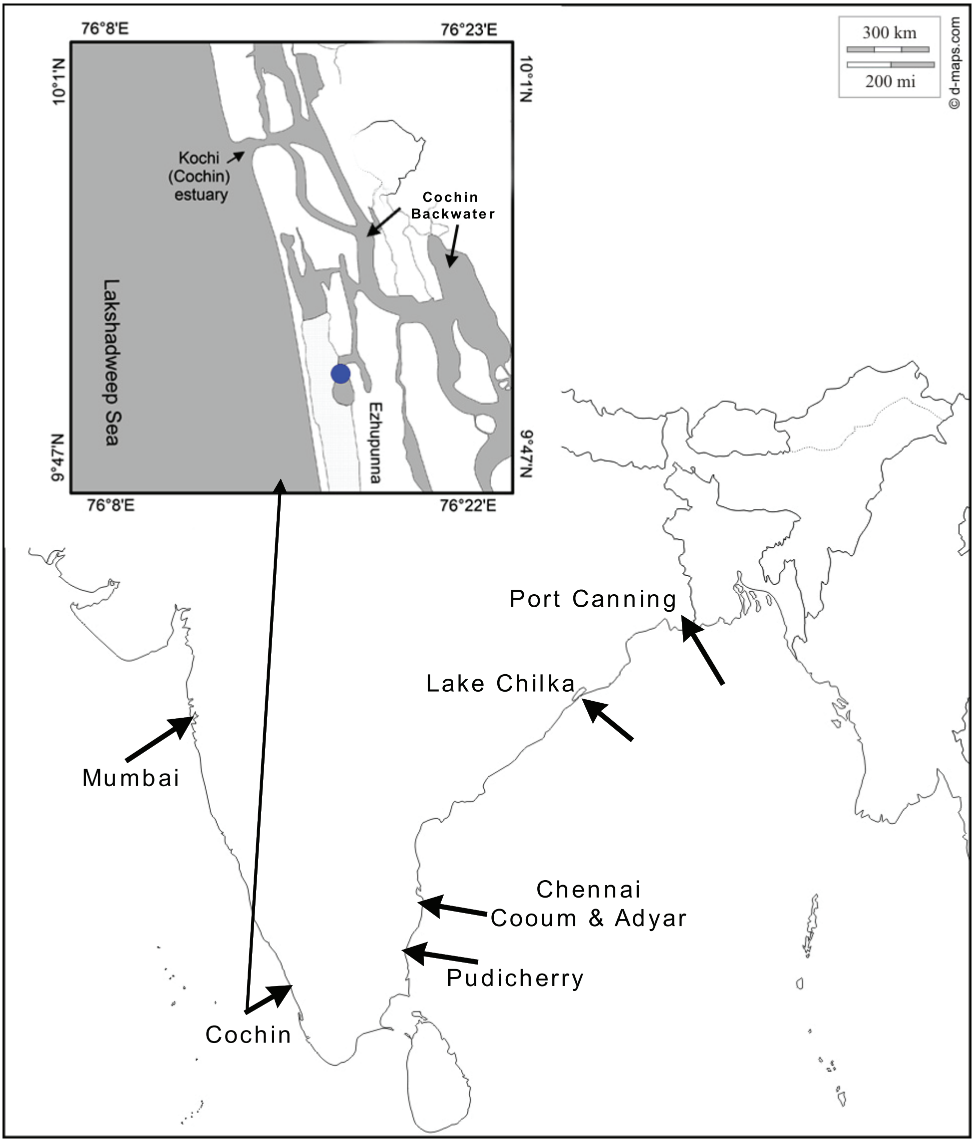

Figure 1. Map of India showing locations of sample sites. Insert showing detailed location of type locality of *Indosphenia kayalum* within the Cochin Backwater.

including the latest book on Indian bivalves by Subba Rao (2017). The aim of this research was primarily to identify this enigmatic bivalve, but as the authors undertook this work they realised that all the Indian brackish water taxa assigned to *Potamocorbula* are in fact members of the Myidae, and not the Corbulidae.

Two other species of Myidae have been recorded from Indian estuaries; *Sphenia perversa* was recorded from various localities on the coast of the Bay of Bengal by Subba Rao et al. (1992; 1995) and by Dey (2008). *Sphenia sowerbyi*, which was described from the Chennai (Madras) region, has not been recorded in Indian taxonomic literature cited above, but was cited in an ecological paper on tidal pools near Mumbai (Satam and Deshmukh 2013). The myid fauna of the Indian lagoons and estuaries is summarised in Table 1 and it is this set of taxa that are reviewed in this paper.

Materials and methods

Very little original material exists for those taxa described by Preston (1907, 1911, 1916), except for syntypes now held in the ZSI (Kolkata), NHMUK (London), and NMW (Cardiff). Access to these type specimens has been limited, and the co-joined valves of the few specimens made available have been deemed too fragile to separate and adequately examine. Fortunately, a relatively large number of shells from Port Canning (the type locality for Preston's (1907) species) are present in the NHMUK, as is an extensive series of *Sphenia sowerbyi* from Chennai. The only material available for molecular work was that recently collected from Cochin by P Joseph. Given that only one Indian species was available for DNA extraction the only aim of the molecular study was to support the family placement. The use of COI was adopted for this purpose and other genes were not analysed because this paper does not attempt a molecular phylogeny of the Myoida.

Molecular analysis

Specimens for molecular examination were preserved in 100% ethanol. The ethanol- preserved samples were re-hydrated in sterile distilled water for 10–12 hours at ambient room temperature prior to DNA extraction. Genomic DNA was extracted from macerated muscle tissue using the DNeasy Blood & Tissue Kit (Qiagen) following the spin column protocol. The polymerase chain reaction (PCR) mixture consisted of 25 μL Master Mix (Takara Clontech EmeraldAmp® GT PCR Master Mix), 1 μL forward primer, 1 μL reverse primer, 8 μL template DNA, and 15 μL distilled deionised water. The amplification primers were LCO-1490 F (5'- GGTCAACAAATCATAAAGATATTGG-3') and HCO-2198 R (5'-TAAACTTCAGGGTGACCAAAAAATCA-3'), used for amplifying mitochondrial cytochrome c oxidase subunit I (mtCOI) gene sequences (Folmer et al. 1994).

Amplification was carried out in an Agilent thermal cycler (Sure cycler 8800). The amplification protocol followed a sequence of denaturation at 94 °C for 1 min., annealing at 37 °C for 2 mins and extension at 72 °C for 3 mins; 40 cycles were performed. Amplified products exhibiting distinct bands after agarose gel (1.2%) electrophoresis were purified and sent to SciGenom Labs (SciGenom Labs Pvt, Ltd. Ernakulam, India) for sequencing.

For the analysis, only the forward primer sequences were used. Sequences with a product length of 614–625 base pairs were obtained without any gaps or stop codons. The sequences thus obtained were assembled using BioEdit 7.0.9 (Hall 1999) and the alignment was performed using ClustalX (Thompson et al. 1997).

BioEdit v7.0.9 (Hall 1999) was used to compile sequences, which were subsequently aligned with MEGA7 (Kumar et al. 2016). Missing nucleotides in the alignment were substituted by N's. A hierarchical likelihood test was performed in MEGA7 to identify the most suitable model for phylogenetic analysis.

MEGA7 was used also to conduct a Maximum Likelihood analysis with 1000 bootstrap repetitions. In all, six myid species plus three outgroup taxa (two corbulids plus the venerid *Circe scripta* [Linnaeus, 1758]) were chosen for the molecular analysis. GenBank accession vouchers for these outgroup taxa are shown in the phylogram. The phylogram was generated using MEGA7. Sequences have been submitted to GenBank and their identification codes are attached to the phylogram in Fig. 2.

Microscopy

Specimens were examined under a Leica MZ12 stereomicroscope and photographed with a Leica Z6 macroscope with Helicon Focus stacking software. Anatomical observations were made on formaldehyde-fixed specimens using the above microscopes; some specimens were stained in methylene blue to enhance contrasts, whereas some were fixed in Bouin's solution. For scanning electron microscopy, specimens were dried and gold-coated prior to observation with a Jeol Neoscope. The shells were measured with an eyepiece graticule. The statistical analyses were applied from JMP™ statistical software.

Specimens examined

Details of the specimens described in this study are given below for each taxon. Type material in the Zoological Survey of India was not studied directly because this institute will not lend material, and funds were not available to visit Kolkata. Syntypes of some species were available in British museums and original and subsequent illustrations were used. Attempts to borrow the material described as *Sphenia sowerbyi* by Satam and Deshmukh (2013) were unsuccessful.

Comparative material examined

Sphenia perversa 6 specimens, Kungkraben Bay, Thailand, Coll PG Oliver. 3 valves, Bombay, ex ME Deakin Coll., NHMUK1909.9.23.306-8.

Sphenia binghami 4 specimens, Pwlldu Bay, South Wales, coll. PG Oliver; many shells from Tenby and Weymouth.

Sphenia rueppelli 1 shell, Yemen, Red Sea, NMW.Z.1995.008.11.

Sphenia cf. *rueppelli* 12 shells, Karachi, NHMUK 20090386. *Mya arenaria* juvenile specimens from the British Isles, NMW.

Mya truncata juvenile specimens from the British Isles, NMW.

Institutional abbreviations:

NMW/NMWZ	National Museum of Wales, Cardiff
NHMUK	Natural History Museum, London
ZSI	Zoological Survey of India, Kolkata

Results

Molecular Analysis

The evolutionary history was inferred by using the Maximum Likelihood method based on the Hasegawa-Kishino-Yano model (Hasegawa et al. 1985). The tree with the highest log likelihood (-2576.44) is shown in this study (Fig. 2). A discrete Gamma distribution was used to model evolutionary rate differences among sites (5 categories (+*G*, parameter = 0.4468)). The analysis involved 12 nucleotide sequences. Codon positions included were 1st+2nd+3rd+Noncoding. All positions containing gaps and missing data were eliminated. There were 401 positions in the final dataset.

Although based solely on a single gene and with a limited dataset, our phylogenetic analysis strongly suggests that the new species belongs in the family Myidae, thus corroborating the morphological evidence. We note that the bootstrap support throughout the phylogram is not strong overall (only two branches are statistically significant, see Fig. 2); however, this may be resolved in future analyses where additional genes more suited for elucidating deeper branches are used. *Mya* is recovered as monophyletic in this analysis and is sister to *Sphenia binghami*. *Mya* and *Sphenia* are joined as sister to the brackish-water taxon described in this study, in which four identical haplotypes are recovered in the phylogram.

Morphology

The hinge morphology of the five species examined in this study (*Sphenia sowerbyi*, *Corbula alcocki*, *Corbula gracilis*, *Cuspidaria annandalei* and the Cochin Backwater sample) is consistent with that of the Myidae, notably with *Mya arenaria*, *M. truncata*, and *Sphenia binghami*. Huber's (2010) placement of these in *Potamocorbula* (family Corbulidae) can be dismissed through comparison of the hinge morphology (Fig. 3a–e). In *Potamocorbula* (Fig. 3e) and the similar *Lentidium*, there is a well-defined projecting cardinal tooth in the right valve. This tooth arises from below the hinge margin and fits into a deep socket in the right valve anterior to the chondrophore. In both corbulid genera, the chondrophore is heavy and relatively narrow. In the myids (Fig. 3a–d) there is a pseudo-tooth in the right valve, but this develops as a thickening of the hinge margin and is never as well-developed as the corresponding tooth in corbulids. The myid chondrophore, as seen in *Sphenia* (Fig. 3c, d) and juvenile *Mya*

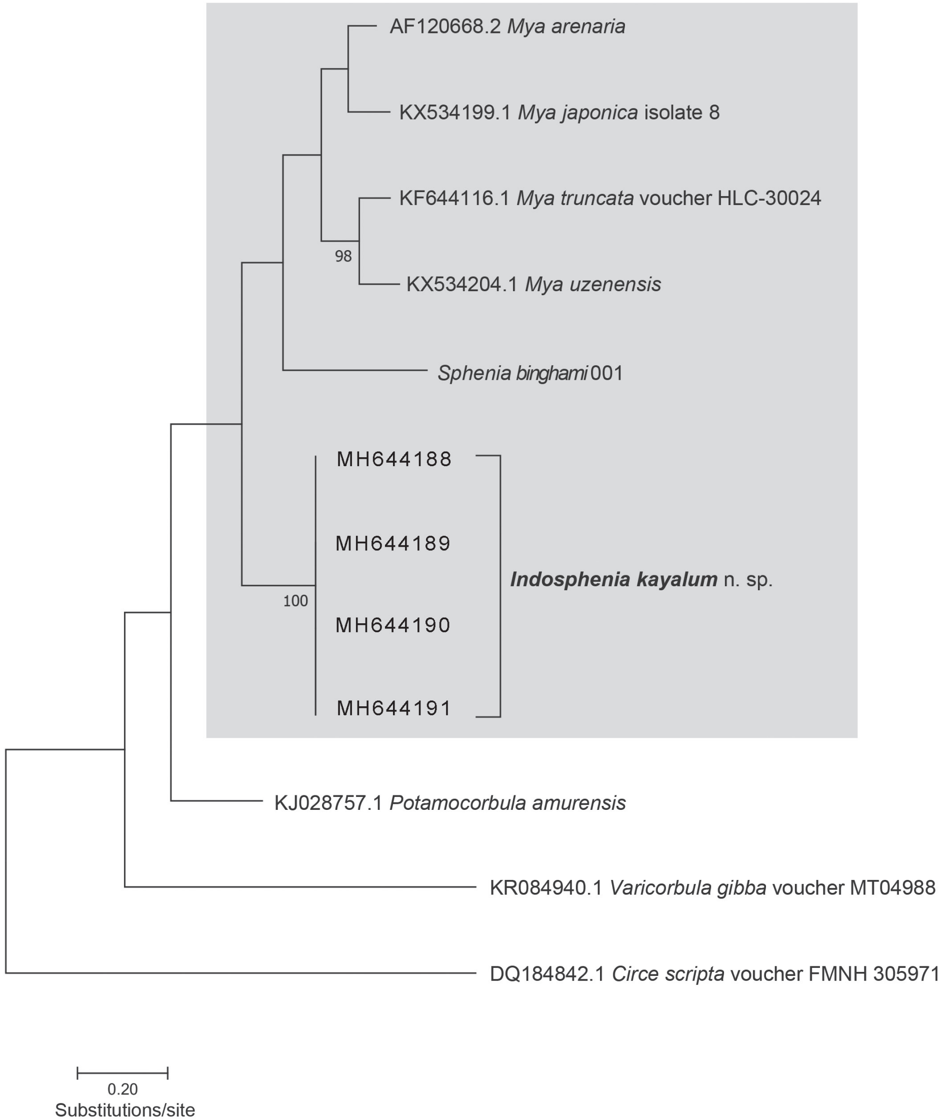

Figure 2. Phylogram showing Maximum Likelihood method based on the Hasegawa-Kishino-Yano model. The tree with the highest log likelihood (- 2576.44) is shown. The percentage of trees in which the associated taxa clustered together is shown next to the branches where such values exceed 95%. Initial tree(s) for the heuristic search were obtained automatically by applying Neighbor-Join and BioNJ algorithms to a matrix of pairwise distances estimated using the Maximum Composite Likelihood (MCL) approach, and then selecting the topology with superior log likelihood value. Grey area indicates Myidae.

(Fig. 3a, b), has a posterior flange extending behind the ligament area. This suggests that most, if not all, of the Indian brackish water taxa assigned to *Corbula*, *Cuspidaria*, and *Sphenia* share more affinities with the Myidae than the Corbulidae.

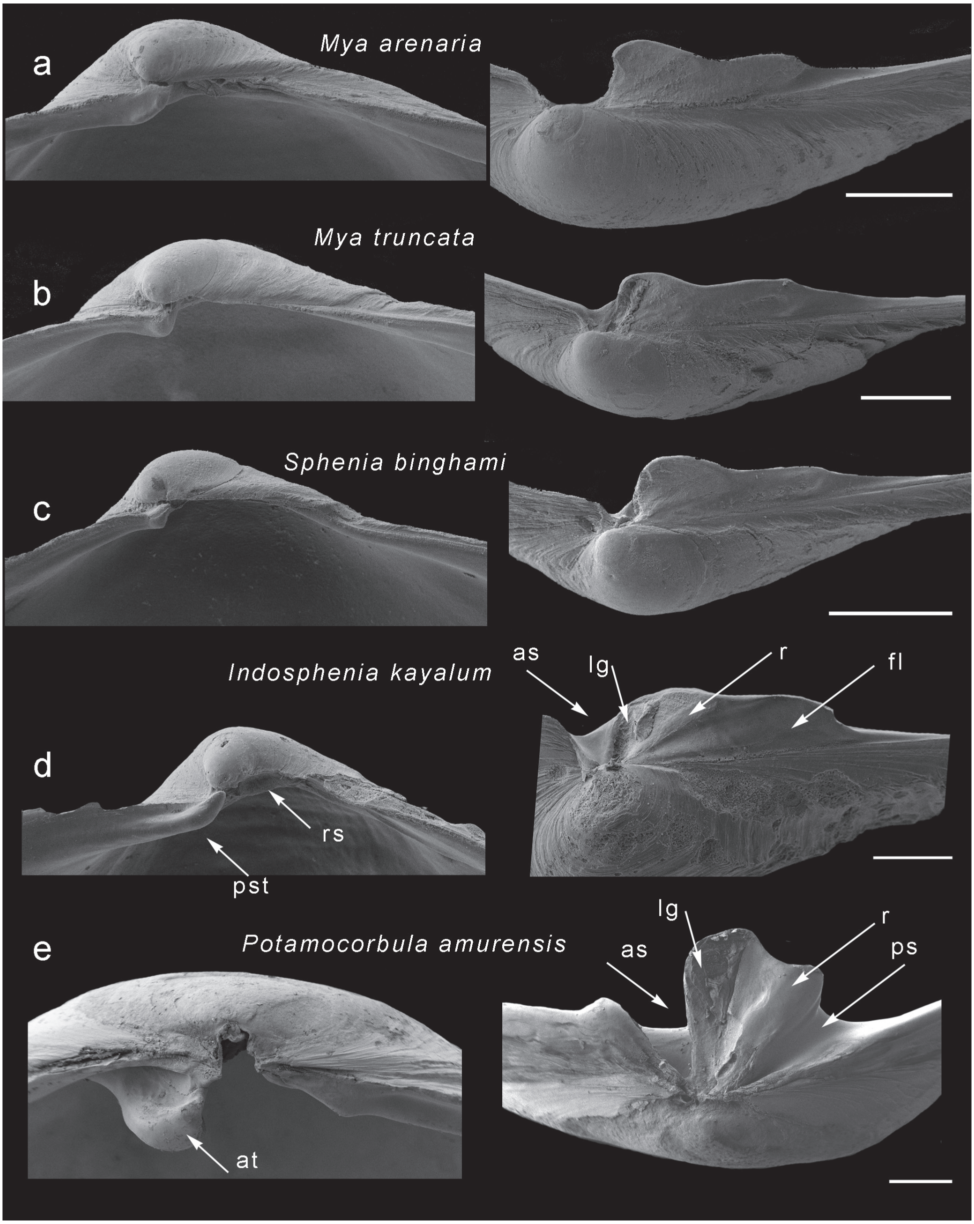

Figure 3. Scanning electron micrographs of hinges of myids and *Potamocorbula*. Left hand series are right valves, left hand series are left valves with the chondrophore viewed from above. **a** *Mya arenaria* **b** *Mya truncata* **c** *Sphenia binghami* **d** *Indosphenia kayalum* **e** *Potamocorbula amurensis*. Scale bar: 500 µm. Abbreviations: as, anterior socket. at, anterior tooth. fl, posterior flange. lg, ligament plate. ps, posterior socket. pst, pseudotooth. r, ridge. rs, resilifer.

Of available myid genera, *Sphenia* is the most similar, and indeed EA Smith (1893) placed his Indian species *sowerbyi* in that genus. However, from comparisons within the species assigned to *Sphenia*, there is evidence that two groups are present; those species that are epibyssate (Fig. 4) and nestle among hard substrates (*S. binghami*, *S. perversa*, and *S. rueppelli*), and those that are endobyssate in soft substrates (brackish water taxa).

Given that we have both morphological and molecular distinctions between *Sphenia* sensu stricto and the endobyssate taxon, we describe the latter as a new genus, *Indosphenia.*

Myoidea Lamarck, 1809
Myidae Lamarck, 1809

***Indosphenia* Oliver, Hallan & Jayachandran, gen. n.**
http://zoobank.org/16D87E93-91A4-41E6-97E9-91903543A6DE

Type species. (here designated) *Indosphenia kayalum* sp. n.

Nominal species included. *Sphenia sowerbyi* EA Smith, 1893; *Corbula alcocki* Preston, 1907; *Corbula gracilis* Preston, 1907; *Cuspidaria annandalei* Preston, 1915; *Cuspidaria cochinensis* Preston, 1916.

By inference from descriptions *Corbula abbreviata* Preston, 1907; *Corbula calcaria* Preston, 1907; *Corbula pfefferi* Preston, 1907; *Corbula chilkaensis* Preston, 1911.

Description. Slightly inequivalve, left valve smaller than right valve, almost equilateral to posteriorly extended, rather inflated. Outline subovate, anterior end broadly rounded; posterior narrowed, sub-rostrate. Sculpture of commarginal lines and very thin, weak lamellae; rostrum with a defined keel, at least in early growth stages. Pallial sinus very shallow, adductor muscle scars subequal, posterior scar subcircular, anterior scar elongate. Right valve with sub-umbonal, depressed resilifer accommodating chondrophore from left valve. Anteriorly, small projecting pseudo-tooth appears as extension of anterior margin (Fig. 3d). Left valve with projecting laminar chondrophore (Fig. 3d) plus shallow triangular depression anteriorly. Ligament attachment in narrow deep groove and extending over anterior part of chondrophore; ligament separated from posterior flange by weak ridge. Chondrophore extending posteriorly as narrow flange with median flexure in some individuals, its posterior end rounded and its outer face slightly sinuous in juveniles; in adults, posterior flange projects beyond ligamental portion and is rounded.

In larger specimens, anterior tooth on right valve can be eroded and scarcely visible, chondrophore can project further and flange can be reduced. Mantle edge fused except for pedal gape and short paired fused siphons. Mantle patterned with darkly pigmented radiating blotches. Gills with both demibranchs. Labial palps small. Byssus of very fine threads, but not observed in all species.

Etymology. *Indosphenia* - combining the taxon provenance (India) with the related genus *Sphenia*. Gender feminine.

Remarks. The molecular and morphological data strongly suggest that *Indosphenia* is a member of the Myidae. Huber (2010) postulated that all *Corbula* species described from Port Canning by Preston (1907) should be considered as a single species in the genus *Potamocorbula*. This conclusion was apparently reached on the basis of Preston's descriptions rather than examination of actual specimens. Given that Preston did not

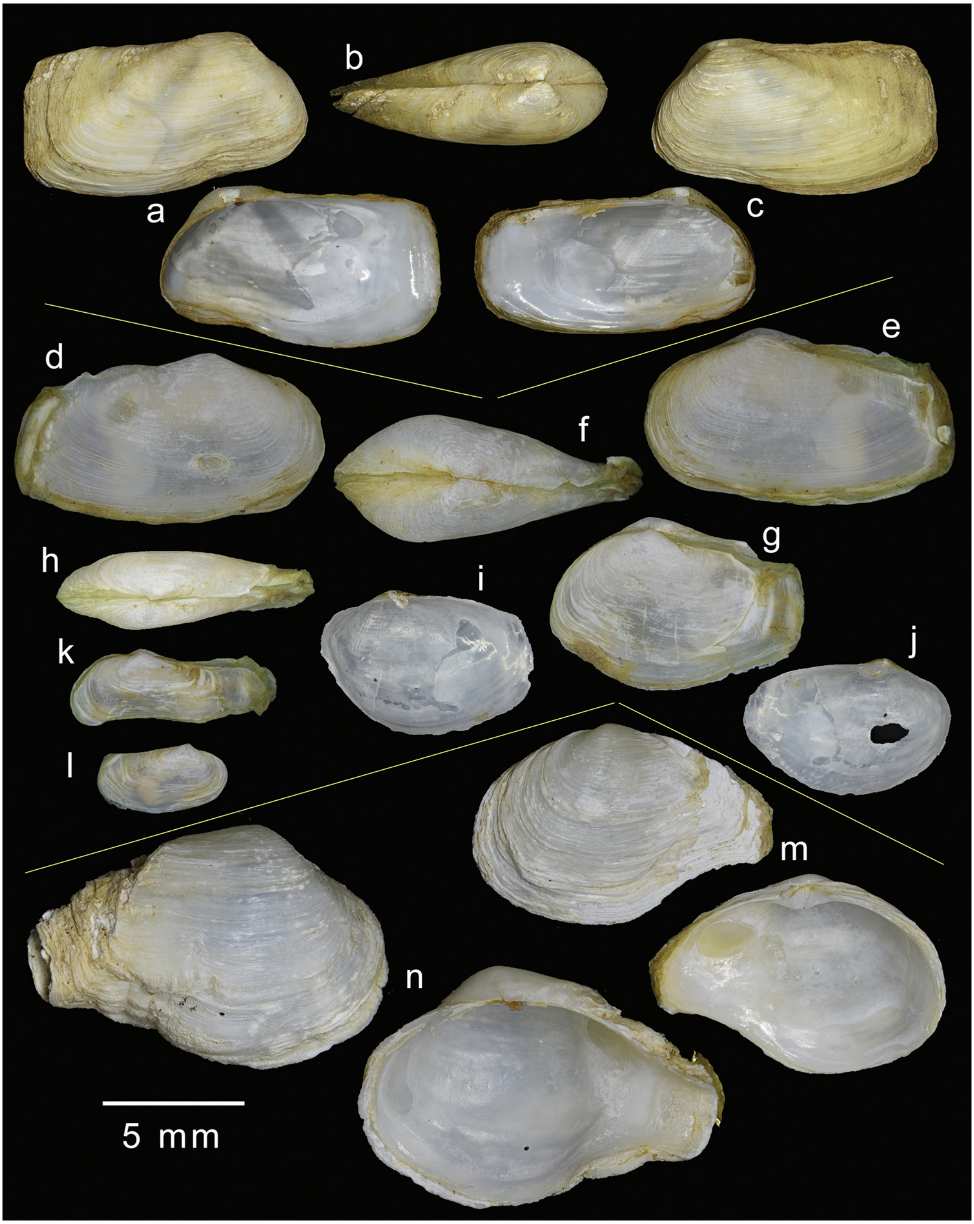

Figure 4. Comparison of shells of three species of epibyssate nestling species of *Sphenia*. **a–c** *Sphenia binghami*, British Isle. **d–j** *Sphenia perversa*, Kungkraben Bay, Thailand **m–n** *Sphenia ruepellii*, Yemen, Arabian Sea.

describe the hinge and seemingly confused the anterior and posterior ends, it is not surprising that their true relationship went unrecognised until now.

The structure of the hinge of *Indosphenia* is generally identical to that of *Sphenia* sensu stricto as represented by its type species *S. binghami*, and its Indian Ocean counterpart *S. perversa*. However, this structure is also very similar to that seen in the juveniles of both *Mya arenaria* and *Mya truncata.* Consequently, hinge structure would not appear to be a useful character at the generic level. Instead, it suggests that *Sphenia* represents a neotenous retention of the juvenile byssate characters of *Mya*.

Compared to the deep burrowing habits of *Mya*, *Sphenia* exhibits a byssate nestling habit, which is manifested in their differing characters; typical *Sphenia* (Fig. 4) is irregular, heteromyarian and strongly inequilateral with the anterior end reduced. The posterior end is subtruncate and the siphons are large with well-developed musculature (Fig. 11e) and a corresponding deep and broad pallial sinus inside the shell valves. The following species share the nestling habit with corresponding similarities in shell form and anatomy: *S. binghami*, (see Yonge 1951), *S. perversa* (see this paper), *S. antillensis* Dall & Simpson, 1901 (see Narchi and Domaneschi 1993), *S. fragilis* (H & A Adams, 1854), *S. hatcheri* Pilsbry, 1899 (see Pastorino and Bagur 2011), *S. coreanica* Habe 1951 (see Zhang et al. 2012) and *S. elongata* Zhang et al., 2012. A further four East Pacific species are described by Coan (1999) and these too would appear to be nestling taxa.

Indosphenia differs from *Sphenia* in being almost equilateral with a narrow, almost rostrate, posterior end and a very short pallial sinus. This reflects the infaunal lifestyle of *I. kayalum*. Some specimens of *I. sowerbyi* have the posterior end encrusted with epifauna while the anterior end is relatively clean, suggesting that this species lives in sediment with the anterior end at, or close to, the sediment surface.

***Indosphenia abbreviata* (Preston, 1907)**

Corbula abbreviata Preston, 1907: 215, fig. 1; Ramakrishna and Dey 2010: 269.
Corbula alcocki Preston, 1907: 215, fig. 2.
Corbula calcarea Preston, 1907: 216, fig. 3; Ramakrishna and Dey 2010, 269.
Corbula gracilis Preston, 1907: 216, fig. 4; Ramakrishna and Dey 2010: 270.
Corbula pfefferi Preston, 1907: 216, fig. 5.
Potamocorbula abbreviata (Preston): Huber 2010: 771; Subba Rao 2017: 431; MolluscaBase 2018b.

Type material examined. *Corbula alcocki*, Syntype, 1 shell, Port Canning, purchased from Preston, HMUK1909.8.18.33.

Corbula gracilis, Syntype, 1 shell, Port Canning, purchased from Preston, HMUK1909.8.18.32.

The type material of *C. abbreviata*, *C. calcarea*, and *C. pfefferi* was not available for study.

Other material examined. *Sphenia* sp. 20 shells and single valves, "Port Canning" [can be interpreted as the Matla River at Port Canning], SE of Kolkata, 22°18.7'N, 88°40.6'E, ex Godwin-Austin Coll, NHMUK 20170342.

Sphenia sp. 5 shells and 1 single valve, Pt. Canning, Matla River, ex Blandford Coll, HMUK 20170343.

Corbula intumescens manuscript name of Stoliczka. 4 shells. Canning, ex. Dr F. Day, HMUK91.9.19.20-3.

Corbula tumescens manuscript name of Day 4 shells. Port Canning, NHMUK 88.12.4.703-6.

Type localities. All species described by Preston (1907) are localised as "Port Canning, Lower Bengal; in brackish pools". Port Canning lies on the Matla River approximately 80 km upstream from the mouth of the estuary. Both the manuscript names of Stoliczka have the same locality of "Port Canning".

Description. Shell (Fig. 5a–d) small, reaching 10 mm in length, thin, fragile, inequivalve - left valve slightly smaller; slightly inequilateral, beaks slightly to the front of centre (PL/AL = 1.3); moderately inflated (L/T = 2.1). Beaks prosogyrate, directed anteriorly. Outline subovate-sub-rostrate, L/H = 1.6, anterior end broadly rounded, ventral margin curved, posterior end much narrower than anterior end, sub-rostrate. Posterior area demarcated by sharp carina running from beak to ventral margin of rostrate posterior end. Postero-dorsal margin concave. Posterior end rounded, but often eroded and obscured by periostracum extending beyond shell. Sculpture of weak commarginal lines and raised threads forming weak projections on posterior carina.

Prodissoconch (Fig. 9b) consisting of small P1 (65 µm) and much larger P2 (182 µm); P1 with punctate micro sculpture; P2 with commarginal ridges crossed by sparse radial threads. Hinge myid, with chondrophore in left valve. Chondrophore (Fig. 7a) with proportionately narrow ligament insertion plate and long posterior flange; ridge between ligament area and flange weak. Right valve with very weak pseudo cardinal tooth (Fig. 7g) commonly rising dorsally to obscure beak.

Intraspecific variation. Some shells in the unidentified samples from Port Canning are distorted with the rostrate posterior end upturned (Fig. 5e), while others are truncate posteriorly (Fig. 5f). While the overall outline is different, the hinge remains identical in structure (Fig. 7c). The syntype of *Corbula alcocki* (Fig. 5g, h) represents the posteriorly truncated form, whereas the syntype of *C. gracilis* (Fig. 5i, j) is closer to the typical shape. The samples labelled as *Sphenia tumescens* and the sample collected by Blandford, contain larger shells (up to 12 mm in length) (Fig. 6f). Of these, many are more elongate and narrower (Fig. 6a–d, g) and with a larger length to height ratio of 1.9, and where the posterior dorsal margin is less concave. Of the species described by Preston (1907), that of *calcarea* may be representative, but it is less than half the size of the shells described here. In one shell, from the *tumescens* sample, radial striations are present (Fig. 6e), most visible on the interior (Preston's *pfefferi* form). The prodissoconch (Fig. 9a) is identical to that of the typical form in having a radial sculpture.

Remarks. The shells from Port Canning are highly variable, with many showing distortions of some degree, although the overall form is broadly rounded with a deep anterior end and a sub-rostrate posterior end. Some samples contain a higher proportion of shells that are less deep and more elongate, and these have the manuscript names of *tumescens* Stolizcka and *intumescens* Day.

While the extremes of this form look very different, there are intergrades, and in all of these the prodissoconch has the same pattern of radial striations.

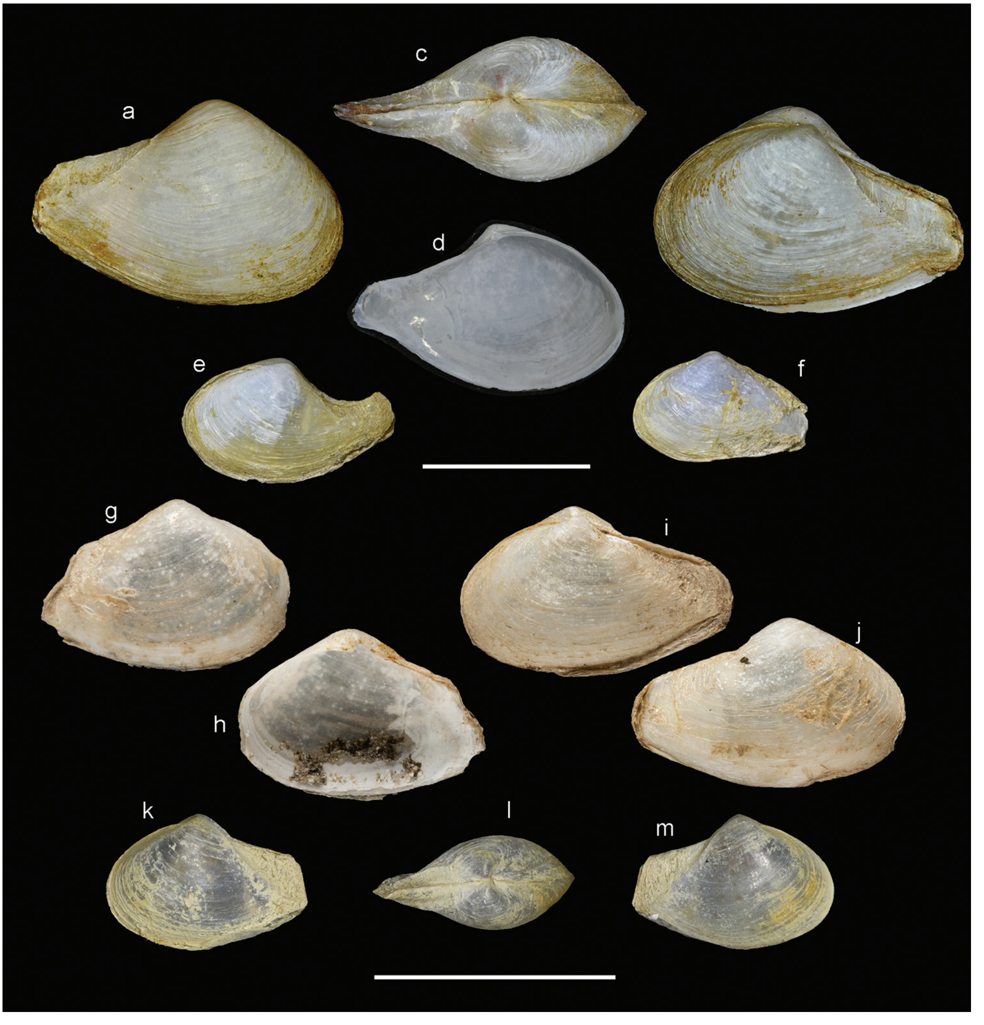

Figure 5. Shell variation in *Indosphenia abbreviata*. **a–d** typical form from Port Canning, NHMUK 20170342 **e, f** distorted varieties from Port Canning, NHMUK 20170342 **g, h** syntype of *Corbula alcocki* Port Canning, NHMUK 1909.8.18.33 **i, j** syntype of *Corbula gracilis* , Port Canning NHMUK 1909.8.18.32 **k–m** syntype of *Cuspidaria annandalei* NMW1955.158.18922. Scale bar: 5 mm.

While Port Canning is given as the locality, the precise habitat is not provided for these samples, although one does mention the Matla River. Preston (1907) stated that his species came from brackish pools, so it may be that this species inhabits a range of habitats within the Matla River estuary. Port Canning is some 80 km from the open sea of the Bay of Bengal and is undoubtedly subject to much variation in salinity, certainly between isolated pools and the main river channel. Without supporting molecular data, we regard these forms to be part of a single species. The earliest available name for this taxon is *abbreviata* Preston, 1907, which is based on individuals that in the context of the current sample set may not be typical, in having the posterior end shortened.

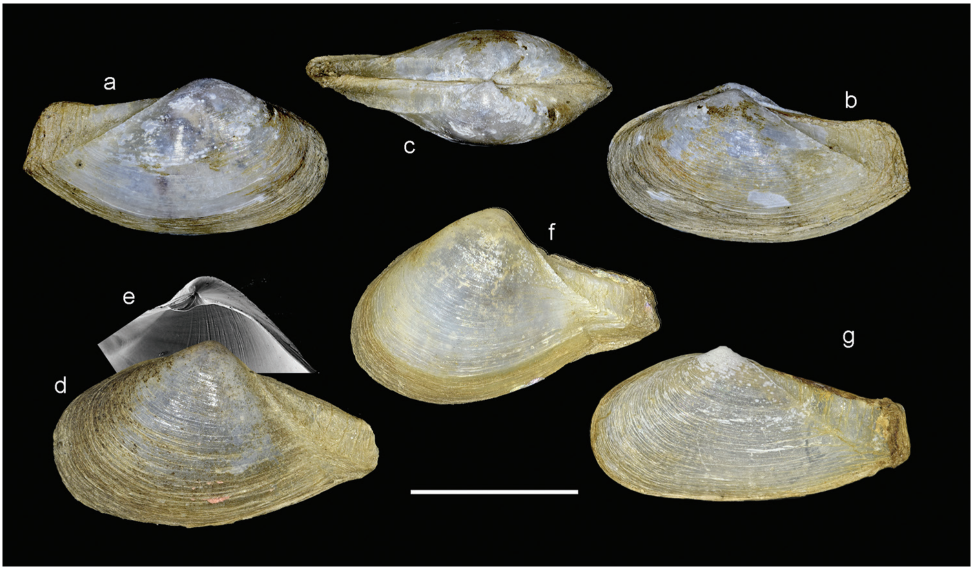

Figure 6. Variations of *Indosphenia abbreviata* all from Port Canning. **a, b** narrow form , NHMUK 20170343 **d–f** *tumescence* form NHMUK 88.12.4.703 **e** Scanning electron micrograph of interior of **d** showing radial ridges **g** *intumescence* form NHMUK 91.9.19.20. Scale bar: 5 mm.

However, we consider that Huber (2010) was the first reviser of this group of species and we therefore retain the earliest name and the one given priority by him. This is also the name adopted by Subba Rao (2017).

Indosphenia abbreviata chilkaensis (Preston, 1911)

Corbula chilkaensis Preston, 1911: 39, fig. 2; Subba Rao 2017: 432.

Cuspidaria annandalei Preston, 1915: 308, figs 23, 23a; Ramakrishna and Dey 2010: 303–4; MolluscaBase 2018d.

Type material examined. *Corbula chilkaensis*. Type material was not available for study.

Cuspidaria annandalei. Syntypes, 3 shells, Lake Chilka [this can be interpreted as 19°42.9'N, 85°18.6'E]. Ex Preston, NMW.1955.158.18922-18923.

Type localities. *Corbula chilkaensis*. "Rambha, S. end of Lake Chilka" [this can be interpreted as off Rambha approximately 19°31.2'N, 85°6.3'E].

Cuspidaria annandalei. "Lake Chilka, 4–9 miles E. by S.1/2 S. of Patsahanipur, 4–5 ft" [this can be interpreted as off Patasanipur approximately 19°42.9'N, 85°18.6'E].

Remarks. Examination of shells (Fig. 5k–m) of *Cuspidaria annandalei* shows these to be identical with small specimens of the typical Port Canning form, including the presence of radial striations on the prodissoconch. Lake Chilka, some 55 km in length, is situated in the northern part of the Bay of Bengal approximately 400 km south-west of Port Canning and is largely isolated from the Bay of Bengal by a long shore bar, only

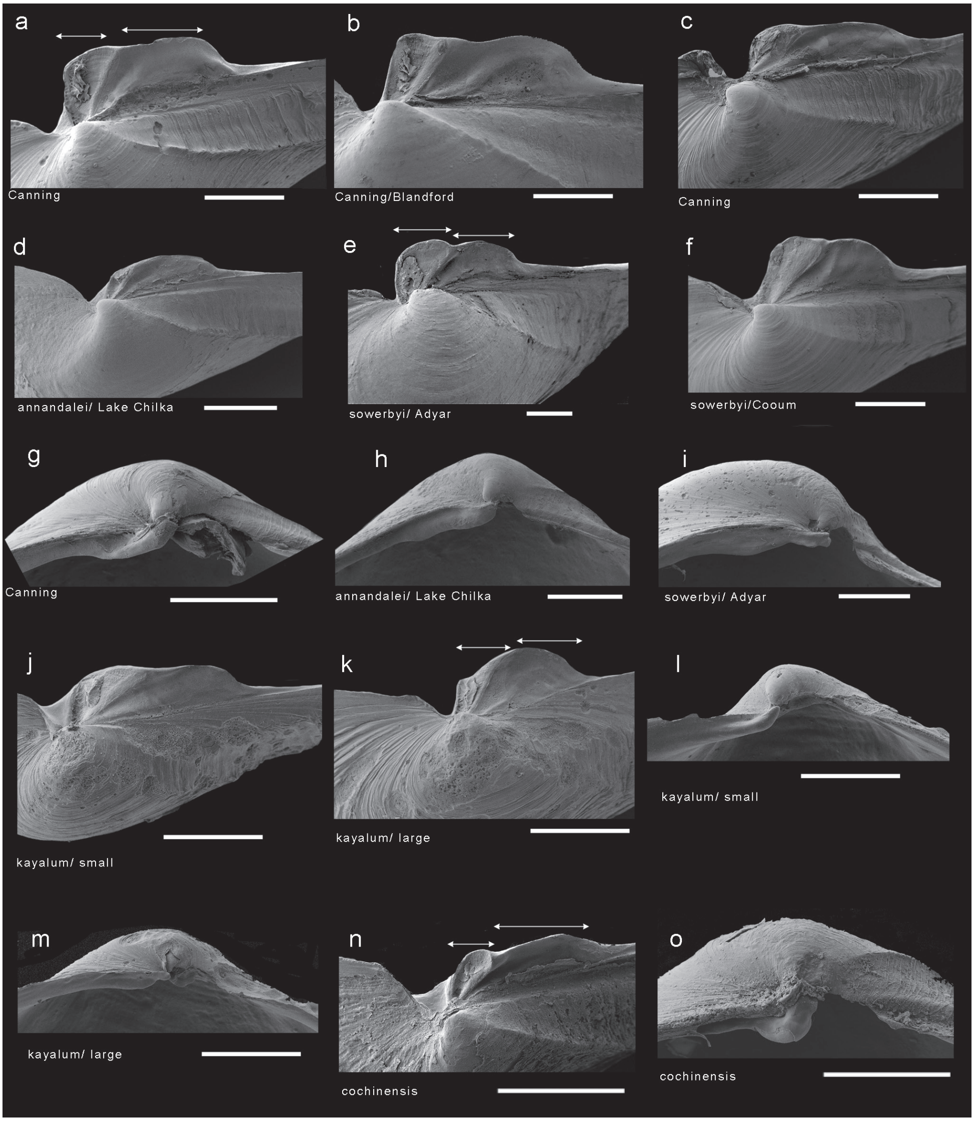

Figure 7. Scanning electron micrographs of the hinges of *Indosphenia* species. **a** chondrophore of *I. abbreviata* typical form from Port Canning **b** as **a** but from narrow form **c** as **a** but from distorted form **d** chondrophore of syntype of *Cuspidaria annandalei* **e** chondrophore of *I. sowerbyi* from Adyar **f** as *e* but from Cooum **g** right valve pseudo tooth in *I. abbreviata* **h** right valve pseudotooth in syntype of *Cuspidaria annandalei* **i** right valve pseudotooth in *I. sowerbyi* **j–k** chondrophores in small and large specimens of *I. kayalum* **l–m** right valve pseudo tooth small and large specimens of *I. kayalum* **n–o** chondrophore and right valve pseudo tooth of *I. cochinensis*. Scale bar: 5 mm.

connected by a channel less than 2 km wide. For the moment, and based on significant morphological similarities, we regard all of the taxa from the northern part of the Bay of Bengal to be a single species, taking the name of *Indosphenia abbreviata* (Preston, 1907), with the Lake Chilka population herein deemed a subspecies. However, we note that future molecular study may suggest genetic divergence not readily apparent based on shell morphology.

Indosphenia sowerbyi (EA Smith, 1893)

Sphenia sowerbyi EA Smith, 1893: 280, pl. 15, fig. 8.

Type material examined. Syntypes, 5 shells, Ariancoupar near Pondicherry [this can be interpreted as the Chunnambar River mouth, Ariyankuppam, Pudicherry, 11°52.8'N, 79°48.5'E]. NHMUK 1893.3.16.6-10.

Other material examined. 4 shells, NMW 1955.158 15753 and 50+ shells, NHMUK 1953.1.7, all from Adyar, Madras [this can be interpreted as the Adyar River Mouth, Adyar, S of Chennai], 13°0.8'N, 80°15.4'E, all Winckworth Collection, March 1931 to June 1936.

50+ shells, Cooum River, Madras [this can be interpreted as the Cooum River mouth, Chennai, 13°4.3'N, 80°16.1'E]. Winckworth Collection, September 1931.

Type locality. Ariancoupan, Pondicherry [this can be interpreted as the Chunnambar River Mouth, Ariyankuppam, Pudicherry, 11°52.8'N, 79°48.5'E].

Description. The sample from Adyar most closely matches the form of the syntypes (Fig. 8l–o) from Ariyankuppam, and is described here as typical. Shell (Fig. 8a–e) to over 12 mm in length, inequivalve, left valve slightly smaller; slightly inequilateral, beaks slightly to the posterior (PL/AL = 0.83–0.97); moderately inflated (L/T = 1.9–2.2). Beaks prosogyrate, directed anteriorly. Outline subovate-sub-rostrate, anterior end broadly rounded, ventral margin curved, L/H = 1.6–1.8; posterior end much narrower than anterior end, sub-rostrate, demarcated initially by sharp carina running from beak to ventral margin of posterior end, but this carina rapidly becoming obsolete; posterior dorsal margin concave; posterior end rounded, often eroded and obscured by periostracum extending beyond shell. Sculpture of weak commarginal lines and dense, thin raised lamellae - these more prominent on angle of rostrum. Exterior of shell with persistent, thin, straw-coloured periostracum. Prodissoconch (Fig. 9c) small P1 (75 µm) much larger P2 (189 µm); P1 with punctate micro sculpture, P2 with commarginal ridges. Hinge myid, with chondrophore in left valve. Chondrophore (Fig. 7e) with proportionately wide ligament insertion plate and short posterior flange with rounded margin; ridge between ligament area and flange prominent. Right valve with very weak pseudo cardinal tooth (Fig. 7i) commonly rising dorsally to obscure beak. Muscle scars poorly defined. Anterior adductor muscle scar elongate and placed medially on anterior face. Posterior adductor muscle scar subcircular, placed close to dorsal margin. Pallial sinus a shallow depression, more sinusoidal than U-shaped (Fig. 8d).

Intraspecific variation. Comparisons of shells from the Adyar and Cooum rivers show some significant difference in shape, despite the rivers being only 6 km apart. The shells from the Cooum River (Fig. 8g–i, k) are shorter posteriorly, thus the beaks are closer to the posterior end, and the height and tumidity are proportionately greater. The

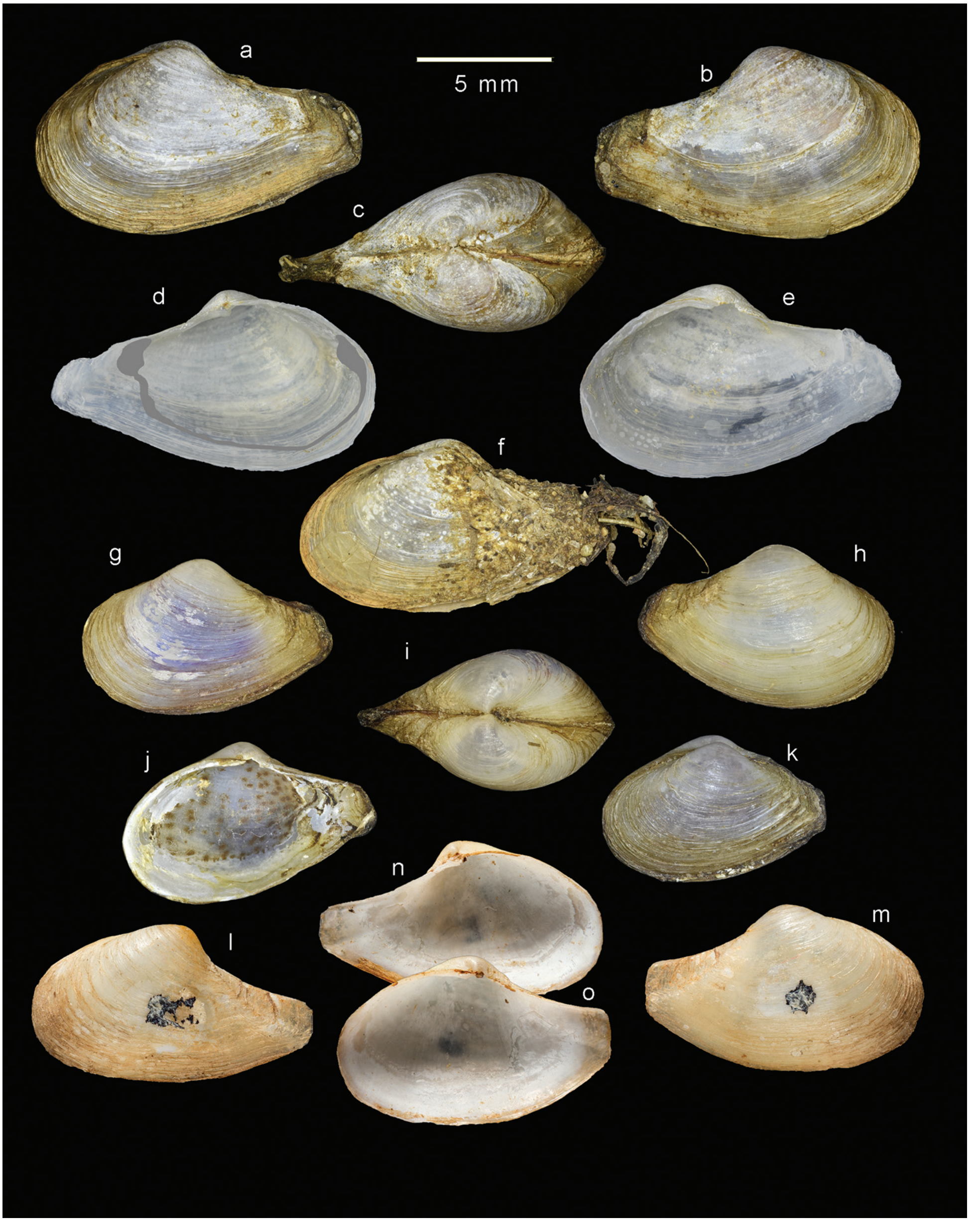

Figure 8. Variations of *Indosphenia sowerbyi.* **a–c** typical form from Adyar river **d–e** internal views of cleaned valves from Adyar river, pallial line false colour added **d**. **f** specimen with epifauna attached to posterior end, from Adyar river **g–h** specimen from Cooum river **j** internal showing blotched pattern on dry mantle tissue **k** posterior sculptured variety from Cooum river **l–n** Syntype of *Sphenia sowerbyi* from Ariancoupan, Pudicherry NHMUK 1893.3.16.6-7. Scale bar: 5 mm.

shells from the Cooum River are more robust and about 20% are tinged with pale purple (Fig. 8g). Although the tissues are dry, the blotched pattern (Fig. 8j) on the mantle has been preserved and it matches that present in both *I. abbreviata* and *I. kayalum*.

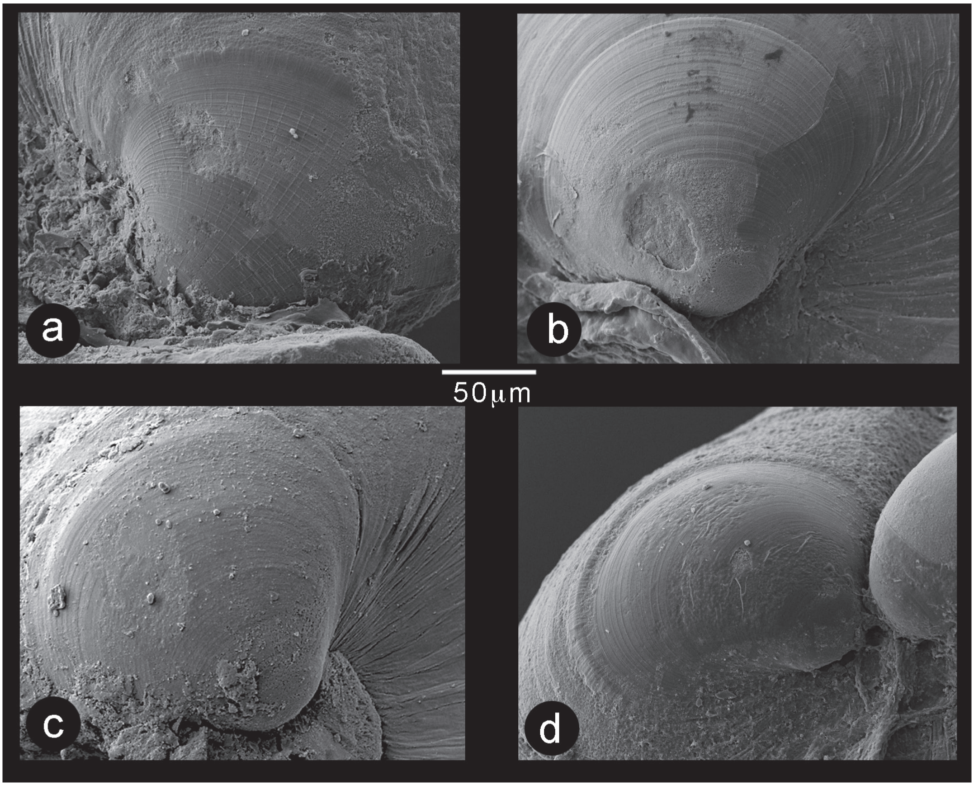

Figure 9. Scanning electron micrographs of the prodissoconchs of *Indosphenia* species. **a** *I. abbreviata* elongate form **b** *I. abbreviata* typical form **c** *I. sowerbyi* **d** *I. kayalum*.

Remarks. *Indosphenia sowerbyi* has a thicker shell than either *I. abbreviata* or *I. kayalum* and possesses a much more prominent sculpture. The beaks lie closer to the posterior end, which is the opposite of both *I. abbreviata* and *I. kayalum*. Furthermore, the posterior carina is not developed, whereas in *I. abbreviata* it is finely developed. Additionally, prodissoconch 2 shows no radial sculpture, as is present in *I. abbreviata,* making it more similar to *I. kayalum* in this character.

Indosphenia kayalum Oliver, Hallan & Jayachandran, gen. n. et sp. n.
http://zoobank.org/1AA6C5B9-A1B4-4671-A138-84AE3A7A181B

Type material. Holotype (Fig. 10a–c), 1 specimen in 70% ethanol, Length = 7.6 mm. Anterior length = 3.4 mm, Height = 5.4 mm, Tumidity = 3.6 mm. Ezhupunna region of Cochin Backwater, Vembanad Lake 9°50'43.9"N, 76°17'17.2"E. Coll. Philomina Joseph, 3 March 2016. ZSI M-31827/8. **Paratypes** 20 specimens, as holotype, ZSI M-31828/8. Voucher specimens associated with GenBank sequences MH644188-644191, as holotype, ZSI M-31829/8 to M-31833/8

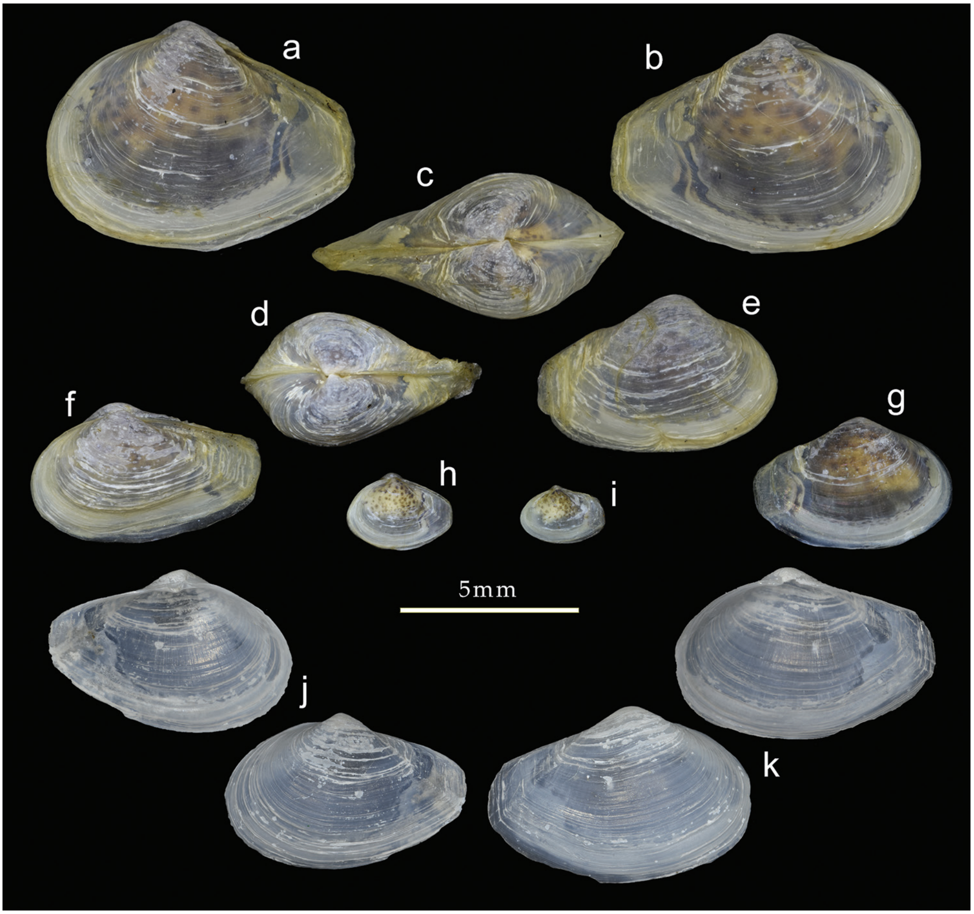

Figure 10. Specimens of *Indosphenia kayalum*. **a–c** holotype **d–i** paratypes showing size series and variations **j, k** interior and exterior of cleaned shells.

Type Locality. Ezhupunna region of Cochin Backwater, Vembanad Lake 9°50'43.9"N, 76°17'17.2"E.

Description. *Shell* (Fig. 10a–k) small, to 8.2 mm in length, thin, translucent, fragile, slightly inequivalve - left valve slightly smaller and overlapped by right valve, tumid across umbonal region (length/tumidity ratio = 2.26 but variable, some specimens more tumid, some much less, range from 1.8 to 2.6. Outline inequilateral, beaks slightly in front of midline with average ratio of posterior length/anterior length = 1.25, but variable due to degree of posterior extension, more equilateral in small shells; overall subovate, broadly rounded anteriorly, narrowed posteriorly, sub-rostrate. Poorly defined weak ridge demarcates narrow posterior dorsal area, best seen in juveniles. Sculpture of commarginal growth lines and weak (but raised) threads. Prodissoconch (Fig. 9d) small P1 (55 μm) much larger P2 (145 μm); P1 with punctate micro sculpture, P2 with commarginal ridges. Hinge myid with chondrophore in left valve.

Chondrophore projecting, laminar (Figs 3d, 7j–k), with shallow triangular depression in front; ligament attachment in narrow, deep groove, extending over anterior part of chondrophore; ligament separated from posterior flange by weak ridge. Chondrophore extending posteriorly as narrow flange, with median flexure; posterior rounded and outer face slightly sinuous in juveniles (Fig, 7j), rounded in adults (Fig. 7k). Right valve (Fig. 3d, 7l–m) with resilifer, depressed subumbonally accommodating left valve chondrophore. Anteriorly small projecting pseudo- tooth appears as extension of anterior margin. Muscle scars poorly defined; anterior adductor scar elongate, placed medially on anterior face; posterior adductor scar subcircular, close to dorsal margin. Pallial sinus (Fig. 10j, k) shallow depression, more sinusoidal than U- shaped.

Anatomy (Fig. 11a–d). Adductor muscles proportionately not large; posterior rounded in section, with posterior pedal retractor inserted immediately to its dorsal; anterior adductor muscle elongate, with anterior pedal retractor inserted at its dorsal edge. Mantle thin, distinctly patterned with brown radiating spots (Fig. 11a) visible through thin shell. Margins of mantle mostly fused, small anterior-ventral pedal gape present. Siphons (Fig. 11c, d) fused, rather short, with outer ring of 12–14 tentacles surrounding both inhalant and exhalant apertures; exhalent aperture with simple retractile tube, while inhalant aperture has inner ring of ten tentacles, the anterior-most larger and dull orange in colour. Foot small, distinct heel producing fine, multi-threaded byssus. Gills (Fig. 11b) large, inner and outer demibranchs present, fully reflexed; those of outer demibranch reflected dorsally. Labial palps very small with few sorting ridges. Only detail of alimentary canal readily observable is large style sac penetrating deep into posterior of foot.

Etymology. The specific name *kayalum* is from “kayal” the Malayalam (South Indian language) name for the backwaters of Kerala state in which this species lives. The name is intended as a noun in apposition.

Habitat. The specimens were found attached to the filamentous alga *Microspora* sp. that was growing on wooden poles in the shallow (1 m) channel in the backwater. The bottom substrate consisted of silty-sand and the measured salinity was 5‰ (oligohaline). Occurring with *I. kayalum* were the bivalves *Mytilopsis sallei* and *Arcuatula* along with a large number of amphipods and polychaetes.

Remarks. In overall shell shape, *Indosphenia kayalum* is most similar to the typical form of *I. abbreviata*, but it differs in being less tumid and with a less well-defined rostrate posterior end on which the carina is weak to obsolete. Prodissococh 2 in *I. abbreviata* has radial lines, whereas in *I. kayalum* P2 has only commarginal lines. In size, the prodissoconchs are similar, as is also the punctate sculpture of P1. *Indosphenia sowerbyi* is much larger, and more robust, such that the sculpture is of commarginal raised ridges, especially over the posterior area. In outline, *I. sowerbyi* is more tumid, less deep and the beaks are behind the midline. The sculpture of the larval shells is the same. *Indosphenia cochinensis* has a heavier shell that is rather narrow, it has very prominent ridges, and is distinctly rostrate posteriorly.

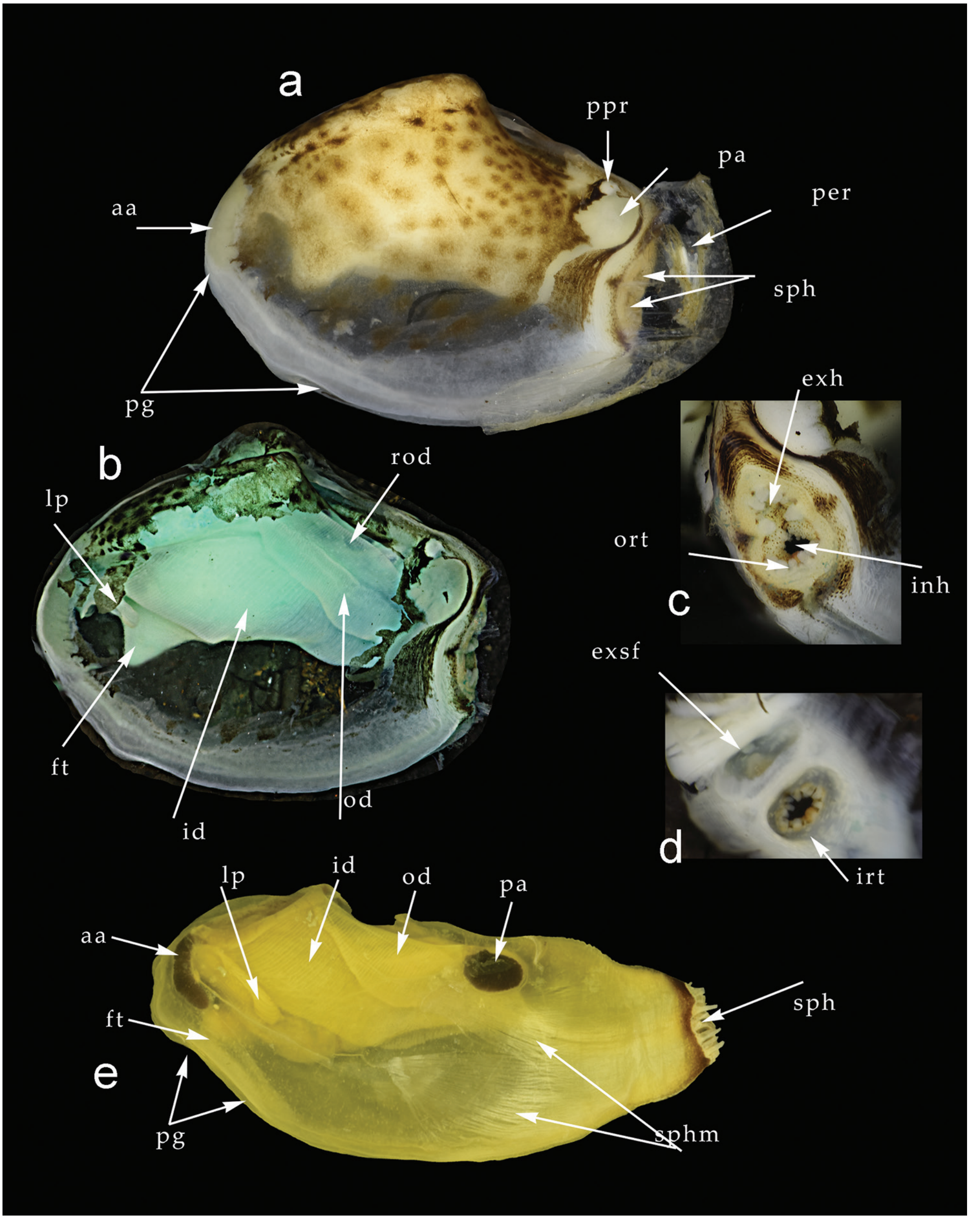

Figure 11. a–d Gross anatomy of *Indosphenia kayalum* **a** left side after removal of the shell **b** left side after removal of shell and mantle **c** exterior view of the siphonal apertures **d** interior view of the siphonal apertures **e** Gross anatomy of *Sphenia binghami* from the left side after removal of the shell and anterior mantle. Abbreviations: aa, anterior adductor muscle. exh, exhalant siphon. ft, foot. id, inner demibranch. inh, inhalant siphon. irt, inner ring of tentacles. lp, labial palps. od, outer demibranch. ort, outer ring of tentacles. pa, posterior adductor muscle. per, periostracum. pg, pedal gape. ppr, posterior pedal retractor muscle. rod, reflected portion of outer demibranch. sph, siphons. sphm, siphonal muscles.

Indosphenia cochinensis (Preston, 1916)

Cuspidaria cochinensis Preston, 1916: 39, figs 17, 17a.
Cuneocorbula cochinensis (Preston, 1916): Oliver et al. 2017: 1224–5, fig. 2.

N.B. *Cuspidaria cochinensis* (Fig. 12a–c) was transferred from the Cuspidariidae into the corbulid genus *Cuneocorbula* by Oliver et al. (2016). Besides its extremely corbulid-like shell, the hinge is reminiscent of that of corbulids in which there is a relatively prominent tooth in the right valve. However, following this review, this tooth is no longer regarded as equivalent to the large anterior tooth possessed by *Potamocorbula* and *Lentidium*. The tooth in *C. cochinensis* (Fig. 7o) is a thickening of the hinge margin and thus structurally identical to the pseudo tooth seen in *Mya* and *Sphenia*. The chondrophore of *C. cochinensis* (Fig. 7n) has a posterior flange and this too is identical to the form seen in *Sphenia*. Consequently, we transfer *Cuneocorbula cochinensis* to *Indosphenia* in the Myidae.

Discussion. The form of the hinge in *Indosphenia* is more similar to that of juvenile *Mya* and *Sphenia* supporting the placement of *Indosphenia* in the Myidae rather than the Corbulidae. The molecular phylogenetic analysis conducted herein, using COI places *Indosphenia kayalum* in the Myidae, although with no significant bootstrap support. However, in combination with the morphological data, we consider this molecular result as adding further confidence to this family placement.

The variability in shell form across the species herein assigned to *Indosphenia* can be seen both visually in the shells figured and in the graphical display of morphometric parameters (Fig. 13). The morphometric parameters show considerable variation within, and overlap between, most populations. Of the samples measured, that of *I. sowerbyi* from the Cooum River appears to be the most distinctive, even from the Adyar population of the same species only six kilometres distant. Using only dried shells from historical collections we cannot employ molecular techniques to distinguish any effects of geographical distance from habitat. In the Cochin Backwater, there are two quite distinct ecological forms that are separated ecologically. *Indosphenia cochinensis* is infaunal, living in sand and found close to the entrance of the Kodungallur-Azhikode Estuary, where average salinity is 15.6 ‰. This contrasts with *I. kayalum* that lives byssally attached among algae and below in muddy sediment in an isolated embayment of Lake Vembanad, with a very low salinity of 5 ‰. These locations are approximately 40 km apart, but they are poorly connected, having separate channels into the Indian Ocean.

The environment may be more important than geographical separation in directing the form of the shell in *Indosphenia*, so although we have aggregated all of the Port Canning forms under *I. abbreviata,* it is possible that the two primary forms represent different species. The length/height and length/tumidity ratios (Fig. 13a, c) are significantly different but we have very poor locality and habitat details, only the general location of Port Canning, to make any inferences. Within the estuary of the Matla River there is likely to be a gradient of salinity and a variety of habi-

Figure 12. a–c Shell of *Indosphenia cochinensis* from Kodungallur- Azhikode estuary. NMW.Z.2015.020.1.

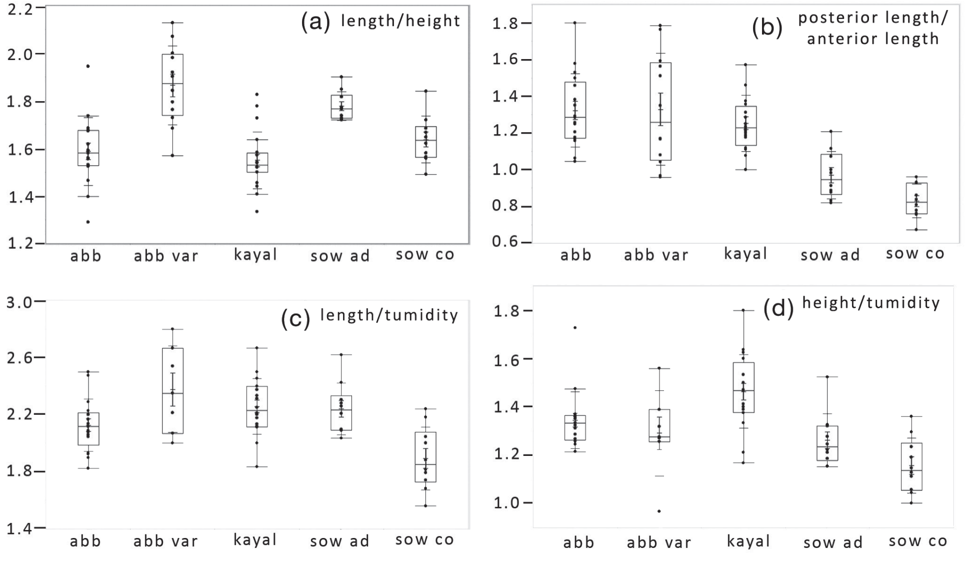

Figure 13. Box plots of the ratios of four parameters for shell shape in five populations of *Indosphenia*. **a** length to height **b** posterior length to anterior length **c** length to tumidity **d** height to tumidity. Abbreviations: abb, typical *I. abbreviata* in lot NHMUK 20170342. abb var, *I. abbreviata* variations in lots NHMUK20170343, NHMUK 91.9.19.20.& NHMUK 88.12.4.703. kayal, *I. kayalum*. sow ad, *I. sowerbyi* from Adyar. sow co, *I. sowerbyi* from Cooum.

tats. Taxonomic problems with brackish water faunas were raised by Muus (1967) and genetic divergence was reviewed by Cognetti and Maltagliati (2000) but studies do not reveal consistent results. The European brackish water cockle *Cerastoderma glaucum* (Bruguière, 1798) is morphologically variable, having received 44 species, subspecies, or varietal names (MolluscaBase 2018a). The variation was considered to be ecophenotypic, but a recent molecular investigation has shown that many populations are sufficiently genetically distinct to warrant some nomenclatural recognition (Tarnowska et al. 2010). A similar result was found for the bivalve *Mytilaster minimus* (Poli, 1795) (Camilli et al. 2001).

González-Wangüemert and Vergara-Chen (2014) studying *Pomatoschistus marmoratus* (Risso, 1810) found significant diversity within Mar Menor lagoon, but Cavraro et al. (2017) did not find genetic diversity within the Venice lagoon for *Aphanius fasciatus* (Valenciennes, 1821). Both studies found significant diversity between lagoon and marine populations of the same species. We cannot be certain if there is genetic diversity within the Port Canning samples, but it cannot be excluded.

The morphological complexity of *Indosphenia* suggests that the brackish waters of India may well represent fragmented habitats and as such would make excellent sites for the study of genetic isolation and divergence.

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RESEARCH ARTICLE

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The spider mites of the genus *Eutetranychus* Banks (Acari, Trombidiformes, Tetranychidae) from Saudi Arabia: two new species, a re-description, and a key to the world species

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Abstract

Two new species of the genus *Eutetranychus* Banks are described and illustrated based on adult females and males, *E. spinosus* **sp. n.** from *Indigofera spinosa* Forssk (Leguminosae), *E. neotransversus* **sp. n.** from *Juniperus procera* Hochst. ex Endl. (Cupressaceae), and *E. palmatus* Attiah, 1967 is redescribed from *Washingtonia robusta* H. Wendl. (Arecaceae). Additionally, the intraspecific morphological variations within *E. orientalis* populations, collected from 28 various host plants and 80 different localities from six regions of Saudi Arabia from 2009 to 2017, are discussed and presented. The genus *Eutetranychus* is divided into two species groups based on the presence of one seta (*orientalis* group) or two setae (*banksi* group) on coxa II. In addition, seven *Eutetranychus* species are suggested as synonyms of *E. orientalis* (Klein, 1936) and *E. papayensis* Iqbal & Ali, 2008 is considered as species inquirenda. A key to all known species of the genus *Eutetranychus* is provided.

Keywords

Key, morphological variations, new species, *palmatus*, phytophagous mites

Introduction

The spider mites belonging to the genus *Eutetranychus* (Acari: Tetranychidae) mostly feed on shrub and tree leaves (Jeppson et al. 1975, Bolland et al. 1998) and make little webs on plant leaves (Saito 2010, Vacante 2010). Among *Eutetranychus* species, the Oriental red spider mite, *E. orientalis* (Klein) and African red spider mite, *E. banksi* (McGregor) have been recorded as major pests of citrus in many tropical and subtropical countries (Vacante 2010). Recently, *E. palmatus* Attiah was considered as a pest of date palms in Israel (Palevsky et al. 2010). Previously it has been reported from different palms (Arecaceae) from Egypt, Israel, Jordan, and Iran (Attiah 1967, Gerson et al. 1983, Kamali 1990, Ben-David et al. 2013).

The genus *Eutetryanchus* belongs to the tribe of Eurytetranychini Reck of the subfamily Tetranychinae. Banks (1917) considered *Eutetranychus* as subgenus of the *Neotetranychus* Trägårdh. Later, McGregor (1950) proposed *Eutetranychus* as valid and separated genus with type species *Tetranychus banksi*. Baker and Pritchard (1960) provided a key to the world with eight species of *Eutetranychus*. Later, only two regional keys of *Eutetranychus* species have been constructed from India and Africa including nine and 16 species, respectively (Nassar and Ghai 1981, Meyer 1987). To date, *Eutetranychus* includes 34 nominal species, mostly reported from Africa and Asia (Migeon and Dorkeld 2006–2017). Prior to this study, no diagnostic key to those world *Eutetranychus* species is available. Only four *Eutetranychus* species viz. *E. africanus* (Tucker), *E. banksi*, *E. orientalis* and *E. palmatus* have been reported from Saudi Arabia (SA) so far (Martin 1972, Alatawi 2011).

The two species *E. orientalis* and *E. banksi* are widely distributed over the world and have been reported from approximately 223 and 84 various host plants, respectively (Bolland et al. 1998, Migeon and Dorkeld 2006–2017, Mattos and Feres 2009, Vacante 2010). Morphological variations in shape and length of dorsal setae, striation pattern between setae *d1* and *e1* and legs chaetotaxy have been reported in these two species (Baker and Pritchard 1960, Chaudhri et al. 1974, Meyer 1974, Meyer 1987, Khanjani et al. 2017). Because of such variations, some *Eutetryanchus* species have been synonymized with *E. orientalis* (Baker and Pritchard 1960, Meyer 1987) and others with *E. banksi* (Pritchard and Baker 1955, Bolland et al. 1998).

The aims of the present study were to explore *Eutetranychus* species from Saudi Arabia, to develop a key to the world species of this genus and to discuss the morphological intraspecific variations in *E. orientalis* populations collected from different hosts and localities from Saudi Arabia. In this study, two new species of *Eutetranychus*; *E. spinosus* sp. n. and *E. neotransversus* sp. n. are described and illustrated based on adult females and males (Figs 1–30). Also, *E. palmatus* is redescribed and illustrated based on adult female and male (Figs 31–46) because its original description was brief and incomplete from date palm trees in Egypt (Attiah 1967). Two previous recorded species, *E. africanus* and *E. banksi,* from SA were not found in this comprehensive collection. The intraspecific morphological variations within *E. orientalis* populations collected from 28 various host plants and 80 different localities in six regions of SA during 2009 to 2017, are discussed and presented (Figs 47A–H, 48, 49).

Materials and methods

Eutetranychus spider mites were collected from diverse host plants from different localities in six regions (Al–Ula, Madina, Nijran, Riyadh, Tabuk, and Taif) of SA during 2009–2017. The mite specimens were collected by shaking the aerial parts of plants over a white piece of paper. The mites moving on paper were picked with camel hair brush and preserved in small vials containing 70% alcohol, then mounted in Hoyer's medium under a stereomicroscope (SZX10, Olympus, Tokyo, Japan). The specimens were examined and identified under a phase contrast microscope (BX51, Olympus®, Japan) using keys and available literature. Different mite body parts were pictured by using an auto-montage software system (Syncroscopy, Cambridge, UK) and then drawn with Adobe Illustrator (Adobe SystemInc., San Jose, CA, USA). All measurements are given in micrometers. The lengths of the legs were measured from the base of the trochanter to the tip of tarsus. The measurements are presented for the holotype followed by the range of paratypes in parenthesis. The morphological terminology used in this study follows that of Lindquist (1985). All collected specimens including type specimens of the new species have been deposited at King Saud University Museum of Arthropods (**KSMA**, Acarology section), Department of Plant Protection, College of Food and Agriculture Sciences, King Saud University, Riyadh, SA.

Family TETYRANYCHIDAE Donnadieu
Subfamily Tetranychinae Berlese
Tribe Eurytetranychini Reck

Genus *Eutetranychus* Banks

Neotetranychus (*Eutetranychus*) Banks, 1917: 197.
Anychus McGregor, 1919: 644.
Eutetranychus Banks, McGregor 1950: 267.

Type species. *Tetranychus banksi* McGregor, 1914.

Diagnosis. Based on Meyer 1987. The genus *Eutetranychus* can be recognized by the combination of following characters: Propodosomal setae three pairs (*v2*, *sc1* and *sc2*); opisthosomal setae 10 pairs (*c1–3, d1–2, e1–2, f1–2, h1*); setae *f1* either normally or widely spaced; anal setae (ps_{1-2}) and para anal setae (h_{2-3}) each two pairs; empodium absent or reduced to small rounded tiny knob; true claws pad-like; tarsi I with two or three solenidia (two solenidia closely associated with fastigial setae *ft*), tarsi II with one or two solenidia; coxa II with either one or two setae.

Species group *banksi*

Diagnosis. Coxa II with two setae.

***Eutetranychus spinosus* sp. n.**
http://zoobank.org/DA81A602-25EC-458E-86B9-C029405EDEC4
Figures 1–15

Diagnosis. (Based on female). Dorsal body setae long, slender, serrate, all set on small tubercles except *v2* and *sc1*, dorsocentral setae *c1*, *e1* and *f1* longer than the distance between their base and the bases of next consecutive setae; setae *c1* and *f1* shorter than distances between *c1–c1* and *f1–f1* respectively, setae *e1* almost as long as distance *e1–e1*; dorsum with simple striae except area anterior to setae *sc1* with lobed striae, striae between setae *d1* “V” shaped, genua and tibiae I–IV 5–5–3–3; 9(1)–7–8–8, respectively.

Description. Female (n = 12) (Figures 1–7).

Body oval, color in life greenish yellow. Length of body (excluding gnathosoma) 315 (312–325), (including gnathosoma) 396 (390–405), maximum width 221 (218–231).

Dorsum (Figure 1). Propodosoma medially with longitudinal striae; hysterosoma medially with transverse striae except area between setae *d1* and *e1* forming a V-shaped pattern; dorsal striae simple except anterior of setae *sc1* with small lobes; all dorsal setae slender, serrated and sub-equal in length, setae *sc2* and hysterosomal setae set on small tubercles; setae *v2* almost reaching 2/3 to the distance *v2–v2*; dorsocentral setae *c1*, and *f1* reaching to past bases of next consecutive setae; setae *e1* almost as long as distance *e1–f1*; setae *f1* slightly more widely spaced than *e1*. Length of dorsal setae: *v2* 44 (41–45), *sc1* 56 (53–58), *sc2* 44 (42–46), *c1* 50 (47–52), *c2* 44 (42–45), *c3* 46 (45–48), *d1* 53 (51–55), *d2* 47 (45–49), *e1* 47 (46–48), *e2* 44 (42–45), *f1* 48 (47–50), *f2* 42 (40–44), *h1* 42 (40–44); distance between dorsal setae: *v2–v2* 66 (63–68), *sc1–sc1* 95 (91–97), *sc2–sc2* 165 (162–170), *c1–c1* 63 (60–67), *c2–c2* 147 (142–150), *c3–c3* 200 (195–210), *d1–d1* 95 (92–97), *d2–d2* 189 (186–191), *e1–e1* 53 (50–55), *e2–e2* 158 (155–160), *f1–f1* 58 (55–64), *f2–f2* 79 (77–82), *h1–h1* 34 (33–36), *v2–sc1* 42 (40–44), *sc1–sc2* 50 (48–53), *sc2–c3* 45 (44–47), *sc2–c2* 53 (52–55), *sc2–c1* 95 (93–98), *c1–c2* 44 (42–46), *c2–c3* 33 (32–36), *c1–d1* 37 (36–39), *c2–d2* 68 (66–70), *d1–e1* 51 (49–52), *d2–e2* 59 (57–60), *e1–f1* 42 (40–44), *e2–f2* 48 (46–50), *f1–h1* 39 (36–41), *f2–h1* 25 (22–27).

Venter (Figure 2). Ventral cuticle medially with transverse striae from setae *1a* to setae *g1*, length of ventral setae: *1a* 50 (48–53), *3a* 42 (41–44), *4a* 44 (43–46), *1b* 42 (40–45), *1c* 45 (41–46), *2b* 42 (40–43), *2c* 39 (37–41), *3b* 47 (45–49), *4b* 42 (41–43); distance between intercoxal and coxae setae: *1a–1a* 37 (35–38), *1b–1c* 17 (17–18), *3a–3a* 79 (77–80), *4a–4a* 75 (73–78); aggenital setae: *ag* 37 (37–38), *ag–ag* 54 (49–57); genital setae: *g1* 31 (30–33), *g2* 32 (31–34), *g1–g1* 26 (23–28), *g2–g2* 60 (57–61); anal setae two pairs: *ps1* 12 (12–13), *ps2* 12 (11–13), *ps1–ps2* 8 (8–9), *ps1–ps1* 21 (20–23), *ps2–ps2* 17 (17–18); para-anal setae two pairs *h2* 21 (19–22), *h3* 19 (18–19), *h2–h2* 25 (23–26), *h3–h3* 45 (40–45). All ventral setae simple except *h2* and *h3* barbed. Spermatheca elongated and sacculus terminally rounded (Figure 2C).

Gnathosoma (Figure 3). Subcapitular setae *m* 41 (39–43), *m–m* 31 (29–32) (Figure 2). Palp femur and genu each with one setae *d* 51 (49–55), *l”* 43 (40–45); palp tibia with three setae *d* 34 (31–34), *l”* 21 (20–22), *l’* 13 (13–14) and a palp tibial claw; palp tarsus 17(17–18) long, 13 wide, with 3 simple setae *a* 13 (12–13), *b* 9 (9–10), *c* 13

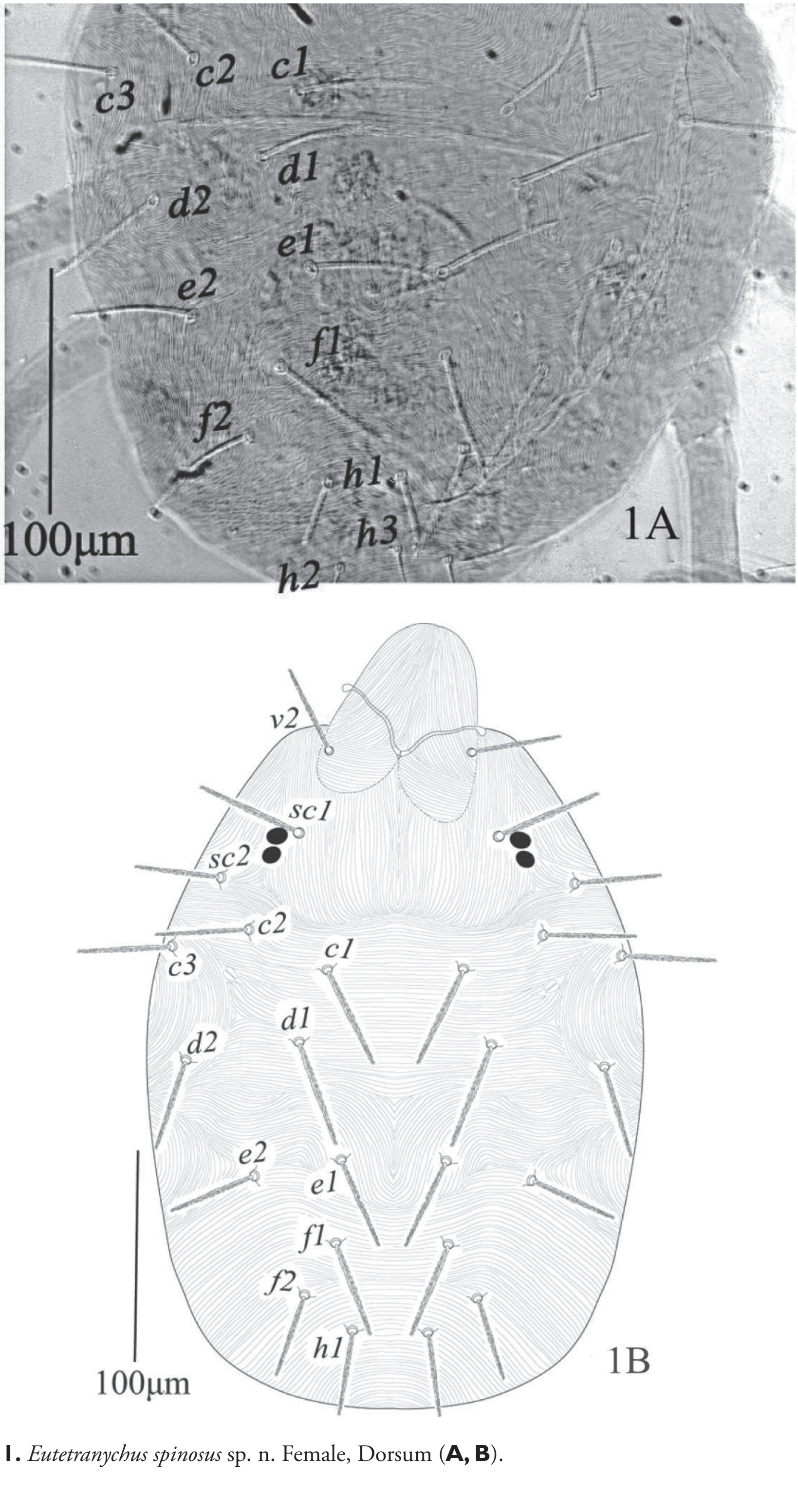


Figure 1. *Eutetranychus spinosus* sp. n. Female, Dorsum (**A, B**).

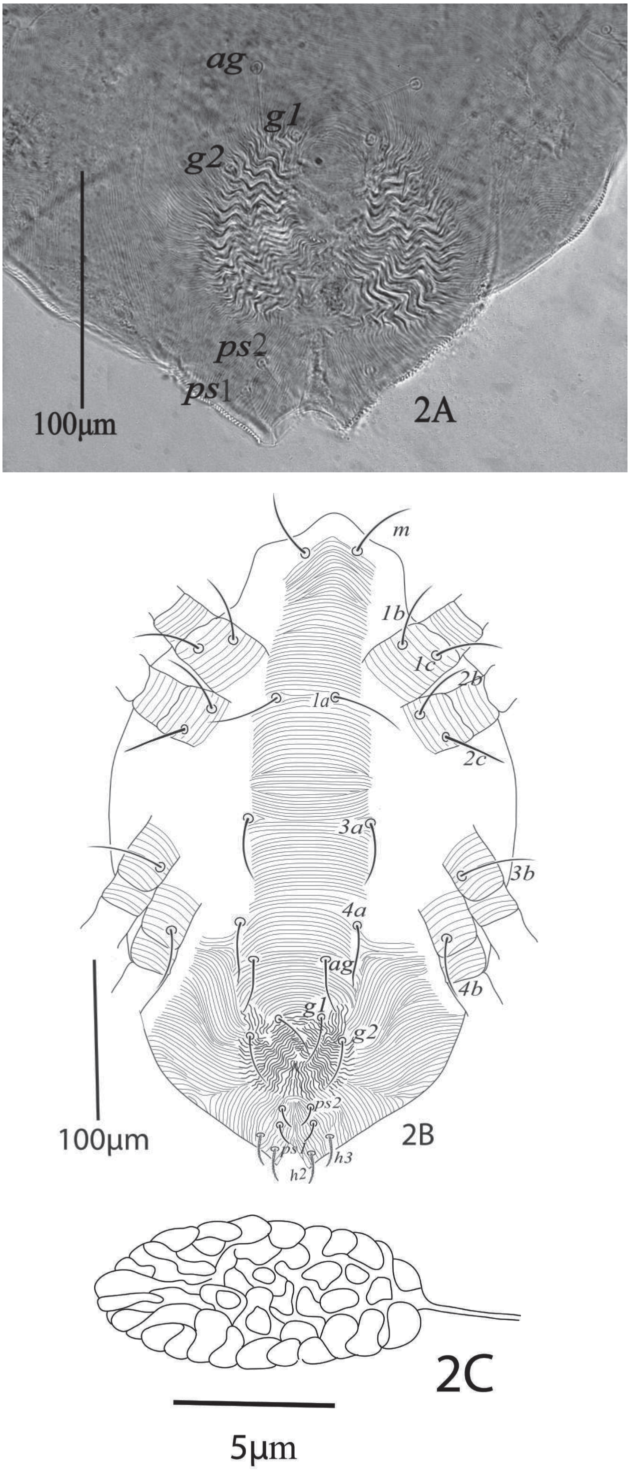


Figure 2. *Eutetranychus spinosus* sp. n. Female **A** genito-anal region **B** Venter **C** Spermatheca.

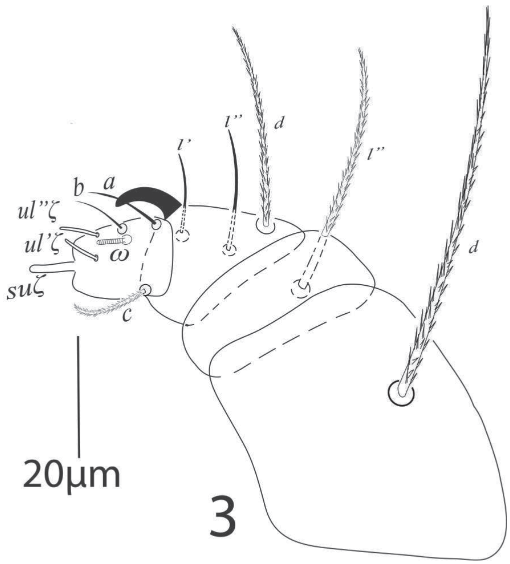


Figure 3. *Eutetranychus spinosus* sp. n. Female, Palp.

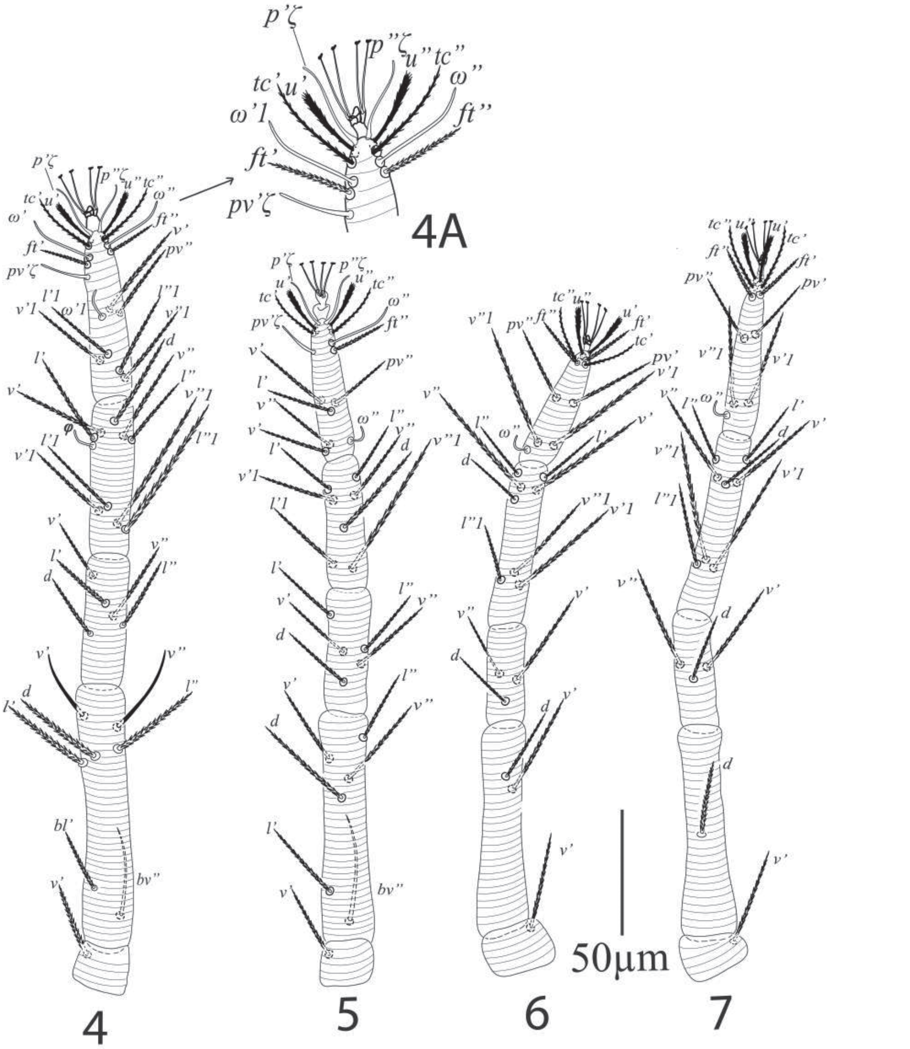
(13–14), 3 eupathidia *suζ* 7.5 (7.5–8), width 1.3 (1–1.5), *ul"ζ* = *ul'ζ* 6.5 (6.5–7) width 1.2 (1–1.3), a solenidion ω 5 long width 2 (1.8–2.3) (Figure 3). Stylophore anteriorly rounded; peritremes ending with simple bulb (Figure 1).

Legs (Figures 4–7). Length of legs I–IV (trochanter to pretarsus): 320 (313–323), 263 (255–270), 294 (288–300), 336 (325–340) respectively; leg I: trochanter 21 (19–21), femur 105 (100–109), genu 53 (51–55), tibia 63 (60–68), tarsus 79 (74–82); leg II: trochanter 16 (15–17), femur 95 (91–99), genu 42 (41–44), tibia 53 (51–55), tarsus 58 (54–60); leg III: trochanter 17 (17–18), femur 86 (84–90), genu 44 (42–47), tibia 71 (68–75), tarsus 76 (74–79); leg IV: trochanter 19 (18–20), femur 105 (102–108), genu 47 (45–50), tibia 79 (76–83), tarsus 86 (83–90); legs chaetotaxy I–IV (eupathidia and solenidia in parenthesis): coxae 2–2–1–1; trochanters 1–1–1–1; femora 7–6–2–1; genua 5–5–3–3; tibiae 9(1)–7–8–8; tarsi 12(3ζ, 3ω)–10(3ζ, 2ω)–10(1ω)–10(1ω).

Male (n = 3) (Figures 8–15).

Length of *body* (excluding gnathosoma) 300–310, (including gnathosoma) 350–361, maximum width 237–246.

Dorsum (Figure 8). Propodosoma medially with longitudinal striae; hysterosoma medially with transverse to irregular striae and forming a V-shaped pattern in between setae *d1* and *e1*; all dorsal body setae slender, serrated and sub-equal in length, hysterosomal setae set on small tubercles. Length of dorsal setae: *v2* 34–38, *sc1* 35–40, *sc2* 32–37, *c1* 31–35, *c2* 36–39, *c3* 32–35, *d1* 29–32, *d2* 33–35, *e1* 33–38, *e2* 32–35, *f1* 28–33, *f2* 33–37, *h1* 23–26, *h2* 15–19, *h3* 13–16; distance between dorsal setae: *v2–v2* 45–50, *sc1–sc1* 73–80, *sc2–sc2* 162–173, *c1–c1* 44–47, *c2–c2* 112–120, *c3–c3* 150–162, *d1–d1* 65–70, *d2–d2* 136–151, *e1–e1* 37–41, *e2–e2* 90–100, *f1–f1* 35–40, *f2–f2* 55–60, *h1–h1* 14–17, *h2–h2* 10–13, *h3–h3* 32–36, *v2–sc1* 28–32, *sc1–sc2* 32–33, *sc2–c3* 55–60, *sc2–*



Figures 4–7. *Eutetranychus spinosus* sp. n. Female, **4** Leg 1 **4A** Leg 1 tarsus **5** Leg 2 **6** Legs 3 **7** Leg 4.

c2 45–50, *sc2–c1* 55–60, *c1–c2* 30–34, *c2–c3* 22–26, *c1–d1* 39–43, *c2–d2* 50–56, *d1–e1* 42–46, *d2–e2* 35–40, *e1–f1* 20–24, *e2–f2* 35–40, *f1–h1* 36–41, *f2–h1* 25–30.

Venter (Figure 9). Area between setae *1a* to *ag* with transverse striae; length of ventral setae: *1a* 30–33, *3a* 31–35, *4a* 32–37, *1b* 40–45, *1c* 40–45, *2b* 30–33, *2c* 37–41, *3b* 36–39, *4b* 36–41; distance between setae: *1a–1a* 30–36, *1b–1c* 17–18, *3a–3a* 62–68, *4a–4a* 51–58; aggenital setae: *ag* 15–18, *ag–ag* 49–54; genital setae: *g1* 9–13, *g2* 8–10, *g1–g1* 14–17, *g2–g2* 15–18; anal setae two pairs: *ps1* 10–12, *ps2* 11–13, *ps1–ps2* 3–4, *ps1–ps1* 24–28, *ps2–ps2* 22–26.

Gnathosoma (Figure 10). Subcapitular setae *m* 30–34, *m–m* 27–31 (Figure 9); palp femur and genu each with one setae *d* 35–41, *l"* 31–35; palp tibia with three setae *d*

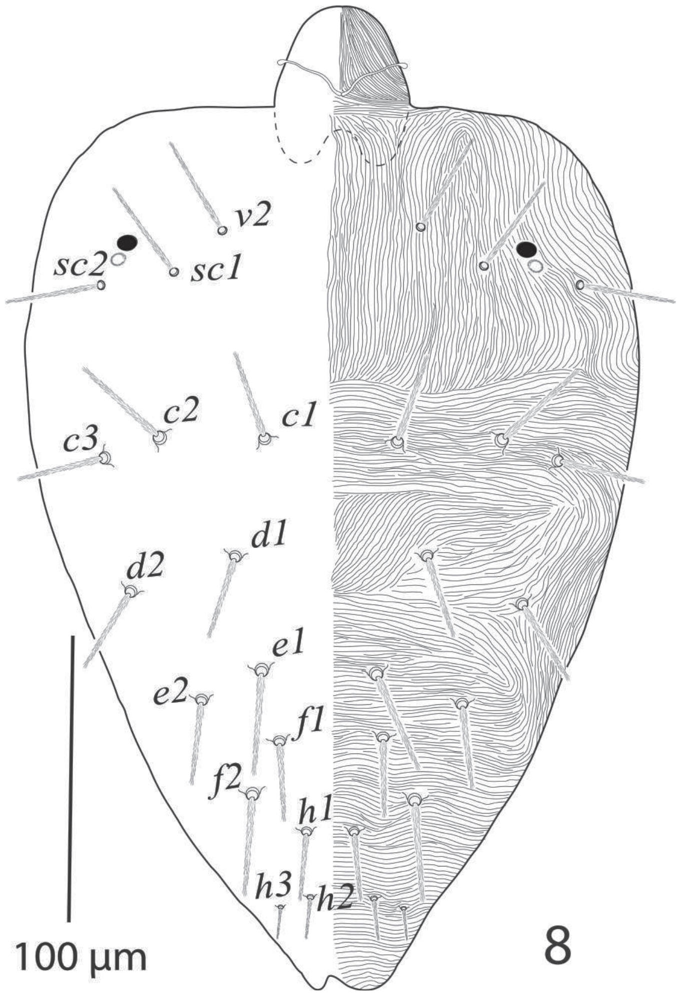


Figure 8. *Eutetranychus spinosus* sp. n. Male, Dorsum.

18–22, *l"* 21–25, *l'* 13–14 and a palp tibial claw; palp tarsus 11–14 long, 10 wide, with 3 simple setae *a* 9–11, *b* 7–10, *c* 8–10, 3 eupathidia *su*ζ 6.5–7, width 0.9 (0.8–1), *ul*ζ = *ul'*ζ 6–7, width 0.8 (0.7–1) a solenidion ω 4 long width 1 (0.9–1.2) (Figure 10). Stylophore anteriorly rounded; peritremes ending with simple bulb (Figure 8).

Aedeagus (Figure 11) Aedeagus bends dorsad at an angle of 90°; the bent portion narrowly rounded toward tip and blunt distally, shaft 18 long, 7 wide, bent portion 3 long.

Legs (Figures 12–15). Length of legs I–IV (trochanter to pretarsus): 313–328, 235–250, 263–280, 278–295 respectively; legs I–IV chaetotaxy (eupathidia and solenidia in parenthesis): coxae 2–2–1–1; trochanters 1–1–1–1; femora 8–7–4–3; genua 5–5–4–4; tibiae 8(4)–7(3)–8–8; tarsi 11(3ζ, 2ω)–11(3ζ, 2ω)–10(1ω)–10(1ω).

Immature stages. unknown.

Etymology. The species name is derived from name of the host plant species, *Indigofera spinosa*, of which type specimens were collected.

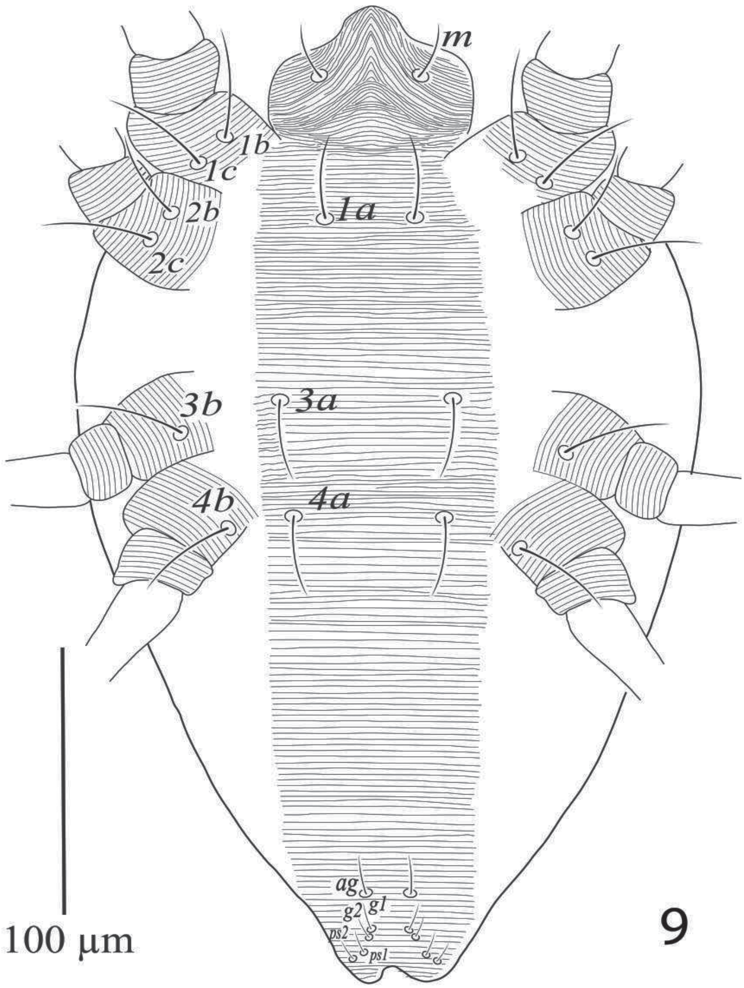


Figure 9. *Eutetranychus spinosus* sp. n. Male, Venter.

Type material. Holotype female and four paratype females, *Indigofera spinosa* (Leguminosae), Al- Shifa road, Taif, 21°05.824'N, 040°19.111'E, elevation 2102 m, 11 Oct 2016, leg. M Kamran and M Rehman; five paratype females, *Indigofera spinosa* (Leguminosae), As Sayl Saghir, Taif, 21°30.521'N, 040°28.202'E, elevation 1516 m, 10 Sept 2017, leg. Eid M Khan and M Rehman; two paratype females, *Indigofera spinose* (Leguminosae), Al Sayl Kabeer, Taif, 21°37.371'N, 040°24.212'E, elevation 1240 m, 15 Sept 2017, leg. Eid M Khan and M Rehman.

Remarks. *Eutetranychus spinosus* sp. n. belongs to the *banksi* species group. It closely resembles *E. namibianus* Meyer 1987 because both have same legs chaetotaxy (Table 1) and dorsal striae pattern. However, the new species differs from *E. namibianus* by all dorsal setae slender, much longer, mostly longer than the distance between their base

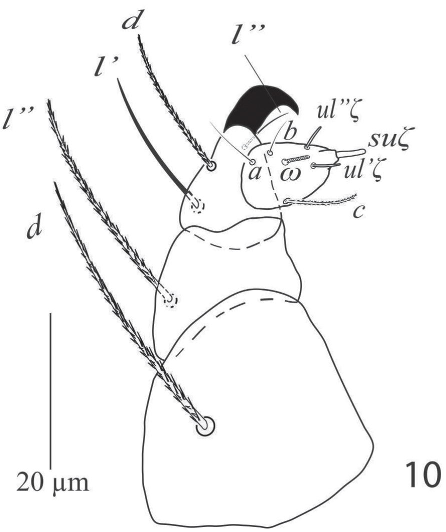


Figure 10. *Eutetranychus spinosus* sp. n. Male, Palp.

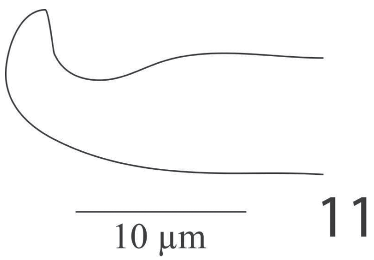
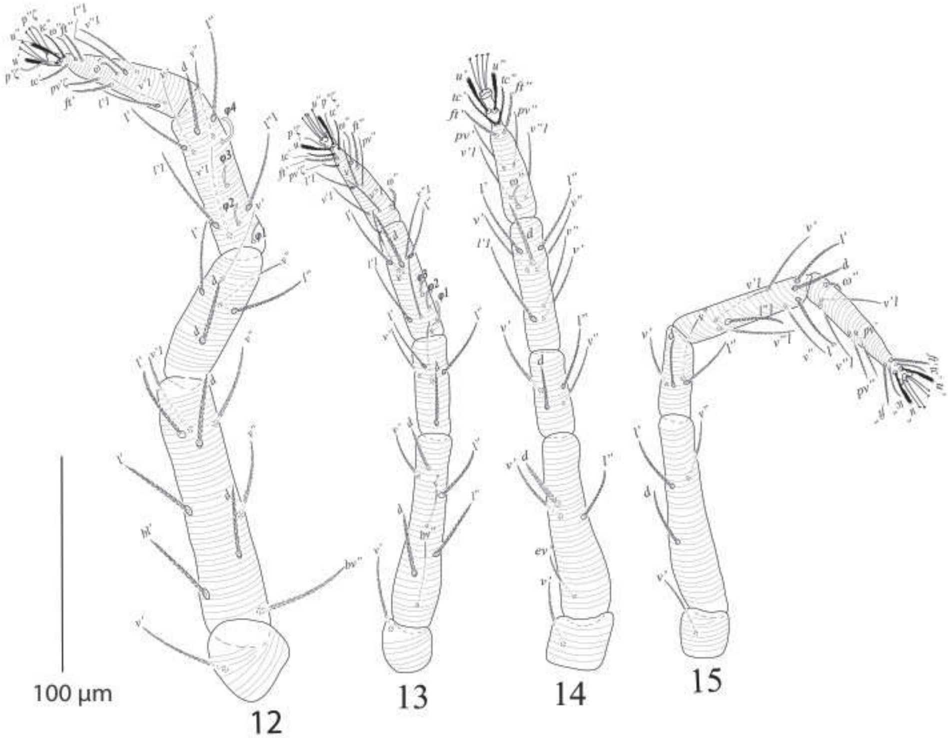


Figure 11. *Eutetranychus spinosus* sp. n. Male, Aedeagus.

and the bases of next consecutive setae vs. all dorsal setae sub-spatulate, small, far behind the bases of next consecutive setae, setae *c1* and *e1* crossing the bases of next consecutive setae vs. reaching less than half distance to the bases of setae next in line and all hysterosomal setae set on strong tubercles vs. only some setae on opisthosoma set on tubercles in *E. namibianus.* The new species also resembles *E. acaciae* Miller 1966 because both have all dorsal setae slender, much longer, and mostly longer than the distance between their base and the bases of next consecutive setae. The new species can be separated from *E. acaciae* by setae *f1* slightly more widely spaced as setae *e1* vs. *f1* two time more widely spaced as compare to *e1*, differences in legs chaetotaxy, genua I–IV with 5–5–4/3–3 vs. 3–3–1–1 and femora II & III with 6 & 2 vs. 4 & 3, respectively in *E. acaciae*.

Species group *orientalis*

Diagnosis. Coxa II with one seta.



Figures 12–15. *Eutetranychus spinosus* sp. n. Male, **12** Leg 1 **13** Leg 2 **14** Leg 3 **15** Leg 4.

***Eutetranychus neotranversus* sp. n.**
http://zoobank.org/50D5AC16-EE8D-4508-8A29-103B8FA68D34
Figures 16–30

Diagnosis (Female). Dorsal body setae slender and serrate, all set on small tubercles; hysterosoma medially with transverse striae; propodosoma with lobed striae, hysterosomal striae simple (without lobes); stylophore slightly notched anteriorly; leg I shorter than body length; femora, genua, tibiae and tarsi I–IV: 5–4–2–1; 4–4–1–2; 6 (1)–5–4–4; 12(3ζ, 2ω)–11(3ζ, 1ω)–10(1ω)–10(1ω), respectively.

Description. Female (n = 8) (Figures 16–22). *Body* oval; length of body (excluding gnathosoma) 347 (340–355), (including gnathosoma) 425 (415–430) and maximum width 263 (255–270).

Dorsum (Figure 16). Propodosoma medially with longitudinal striae, propodosoma with lobed striae, hysterososma medially with transverse striae, hysterosoma with simple striae; dorsal body setae slender and serrate, all dorsal setae with small tubercles, setae *v2* reaching about two third to the distance *v2–v2*, reaching to the base of setae *sc1*; most hysterosomal setae distinctly shorter than distances of setae next row distance *f1–f1* almost as long as *d1–d1* but more widely spaced than *c1–c1* and *e1–e1*. Length of dorsal setae: *v2* 34 (32–36), *sc1* 37 (36–38), *sc2* 32 (32–33), *c1* 24 (24–25), *c2* 36 (35–36), *c3* 23

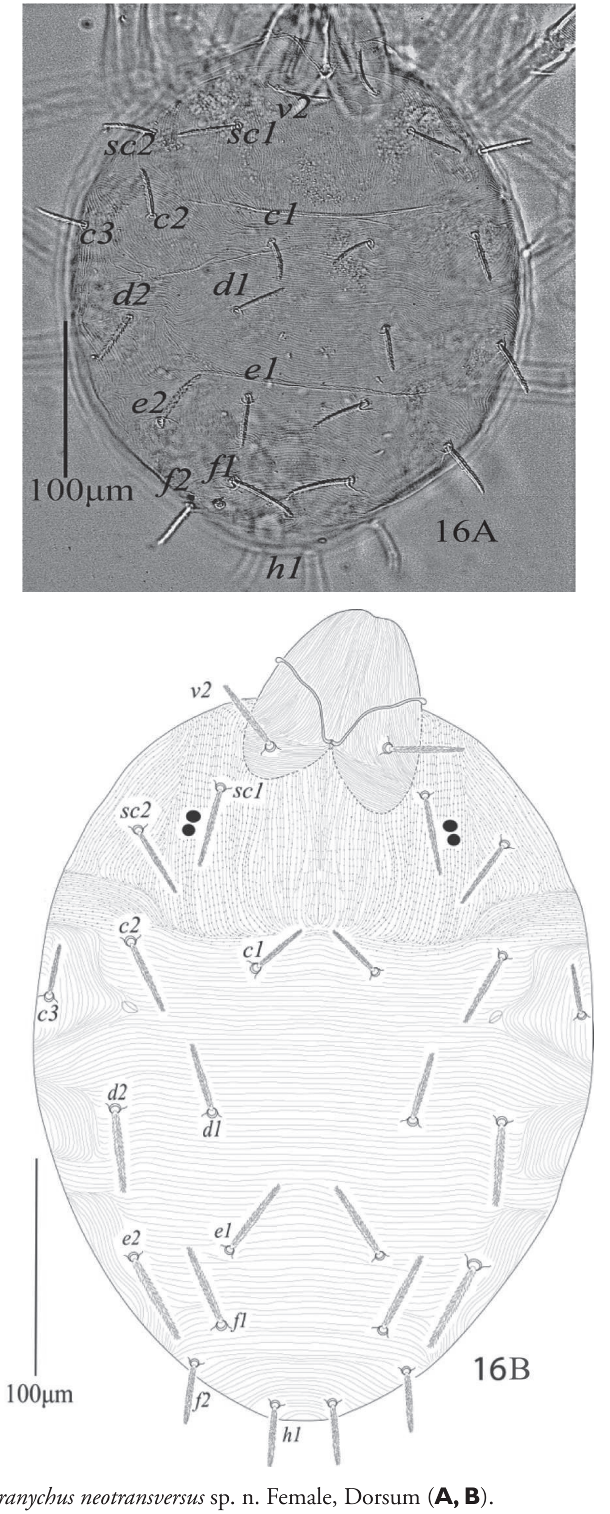


Figure 16. *Eutetranychus neotransversus* sp. n. Female, Dorsum (**A, B**).

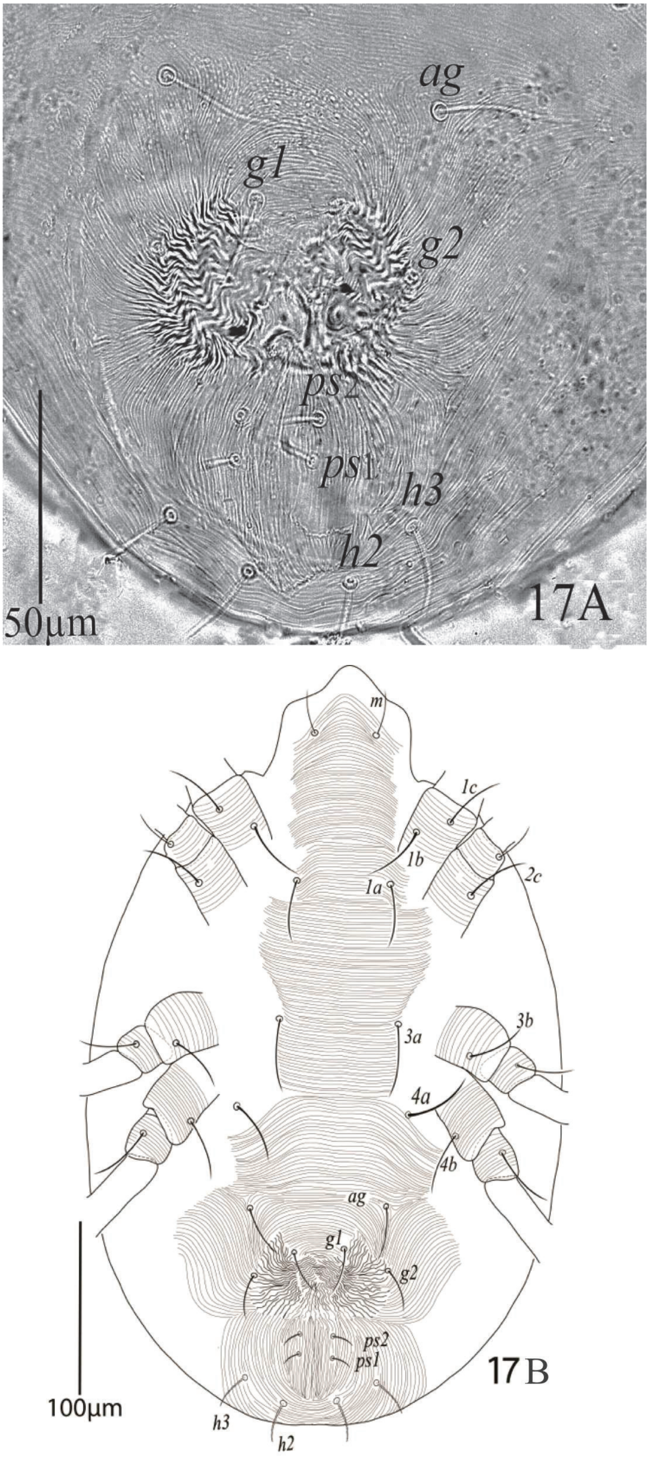


Figure 17. *Eutetranychus neotransversus* sp. n. Female, **A** Genito-anal region **B** Venter.

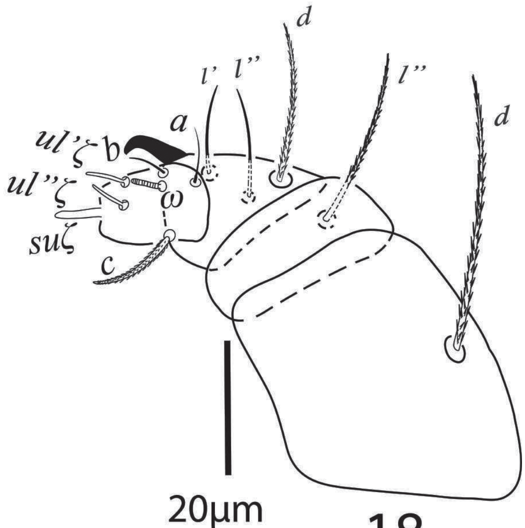


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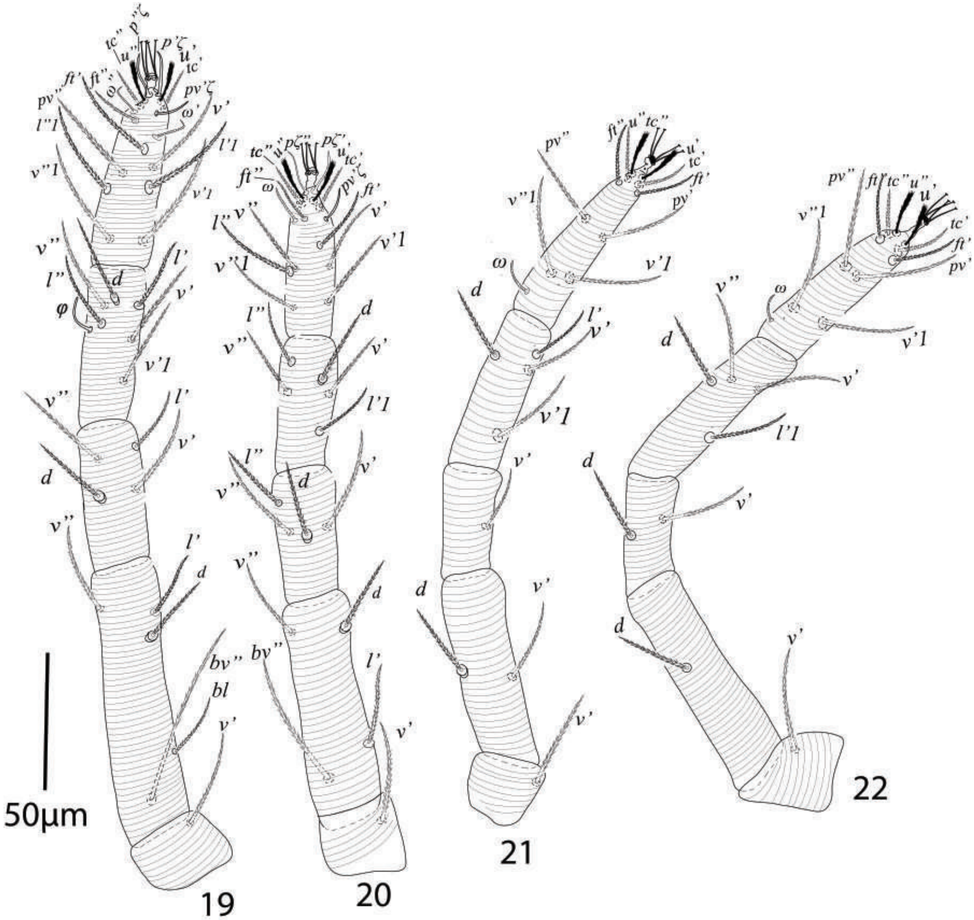
Figure 18. *Eutetranychus neotransversus* sp. n. Female, Palp.

(22–23), *d1* 33 (33–35), *d2* 38 (36–38), *e1* 37 (36–38), *e2* 42 (40–44), *f1* 39 (36–41), *f2* 26 (24–27), *h1* 28 (27–29); distances between dorsal setae: *v2–v2* 53 (51–55), *sc1–sc1* 95 (93–96), *sc2–sc2* 163 (160–165), *c1–c1* 58 (55–59), *c2–c2* 168 (160–170), *c3–c3* 263 (260–268), *d1–d1* 95(93–97), *d2–d2* 179 (174–185), *e1–e1* 63 (61–66), *e2–e2* 168 (163–170), *f1–f1* 73 (70–75), *f2–f2* 100 (97–102), *h1–h1* 26 (25–28), *v2–sc1* 27 (26–29), *sc1–sc2* 43 (42–45), *sc2–c3* 89 (87–90), *sc2–c2* 58 (57–59), *sc2–c1* 86 (85–87), *c1–c2* 53 (52–55), *c2–c3* 50 (50–52), *d1–d2* 48 (47–49), *e1–e2* 47 (46–48), *f1–f2* 21 (20–22), *c1–d1* 63 (60–64), *c2–d2* 74 (73–75), *d1–e1* 68 (66–69), *d2–e2* 74 (73–75), *e1–f1* 42 (41–43), *e2–f2* 53 (52–54), *f1–h1* 40 (39–41), *f2–h1* 37 (36–38).

Venter (Figure 17). Area between setae *1a–g1* with transverse striae. Length of ventral setae: *1a* 37 (34–38), *3a* 39 (39–40), *4a* 40 (41–42), *1b* 44 (41–44), *1c* 43 (42–44), *2c* 37 (35–38), *3b* 36 (35–38), *4b* 36 (33–37); distances between intercoxal and coxae setae: *1a–1a* 53 (51–54), *3a–3a* 68 (66–70), *4a–4a* 95 (92–97); agential setae *ag* 42 (37–43), *ag–ag* 85 (83–86); genital setae: *g1* 33 (30–33), *g2* 32 (30–32), *g1–g1* 25 (24–26), *g2–g2* 81 (76–85); anal setae two pairs: *ps1= ps2* 14 (13–15), *ps1–ps1* 23 (21–23), *ps2–ps2* 23 (22–23); para–anal setae two pairs: *h2* 28 (27–28), *h3* 26 (26–28), *h2–h2* 31 (29–34), *h3–h3* 75 (72–77); all ventral setae simple except *h2* and *h3* slightly barbed. Spermatheca not clear.

Gnathosoma (Figure 18). Subcapitular setae *m* 23 (22–25), *m–m* 42 (39–44) (Figure 17). Palp femur and genu each with one setae, *d* 40 (39–44), *l"* 42 (40–43); palp tibia with three setae *d* 16 (14–17), *l"* 23 (21–25), *l'* 23 (21–25) and a palp tibial claw; palp tarsus 16 (16–17) long, 11 (11–12) wide at base, with three setae *a* 7 (7–8), *b* 7 (6–7) both simple, *c* 13 (12–13) slightly barbed, three eupathidia *suζ"* 7 (6.5–7) long,



Figures 19–22. *Eutetranychus neotransversus* sp. n. Female, **19** Leg 1 **20** Leg 2 **21** Leg 3 **22** Leg 4.

1.60 wide, *ul*”ζ 6, *ul*’ζ 6 and one solenidion ω 5 width 1.7 (1.5–2) (Figure 18). Stylophore anteriorly slightly notched; peritreme ending with a simple bulb (Figure 16).

Legs (Figures 19–22). Length of legs I–IV (trochanter to pretarsus): 257 (250–265), 221 (216–225), 215 (210–225), 242 (235–250) respectively; leg I: trochanter 24 (23–25), femur 105 (102–107), genu 58 (54–63), tibia 57 (54–59), tarsus 68 (66–70); leg II: trochanter 30 (29–33), femur 95 (92–98), genu 53 (50–55), tibia 48 (46–50), tarsus 63 (61–65); leg III: trochanter 32 (30–34), femur 74 (71–75), genu 40 (39–41), tibia 68 (66–70), tarsus 68 (66–70); leg IV: trochanter 32 (30–35), femur 95 (91–98), genu 42 (40–45), tibia 74 (71–76), tarsus 70 (69–73); chaetotaxy of legs I–IV (eupathidia and solenidia in parenthesis): coxae 2–1–1–1, trochanters 1–1–1–1, femora 5–4–2–1, genua 4–4–1–2, tibiae 6(1)–5–4–4, tarsi 12(3ζ, 2ω)–11(3ζ, 1ω)–10(1ω)–10(1ω).

Male (n = 2) (Figures 23–30).

Body oval; Length of body (excluding gnathosoma) 236–246, (including gnathosoma) 335–353, maximum width 154–165.

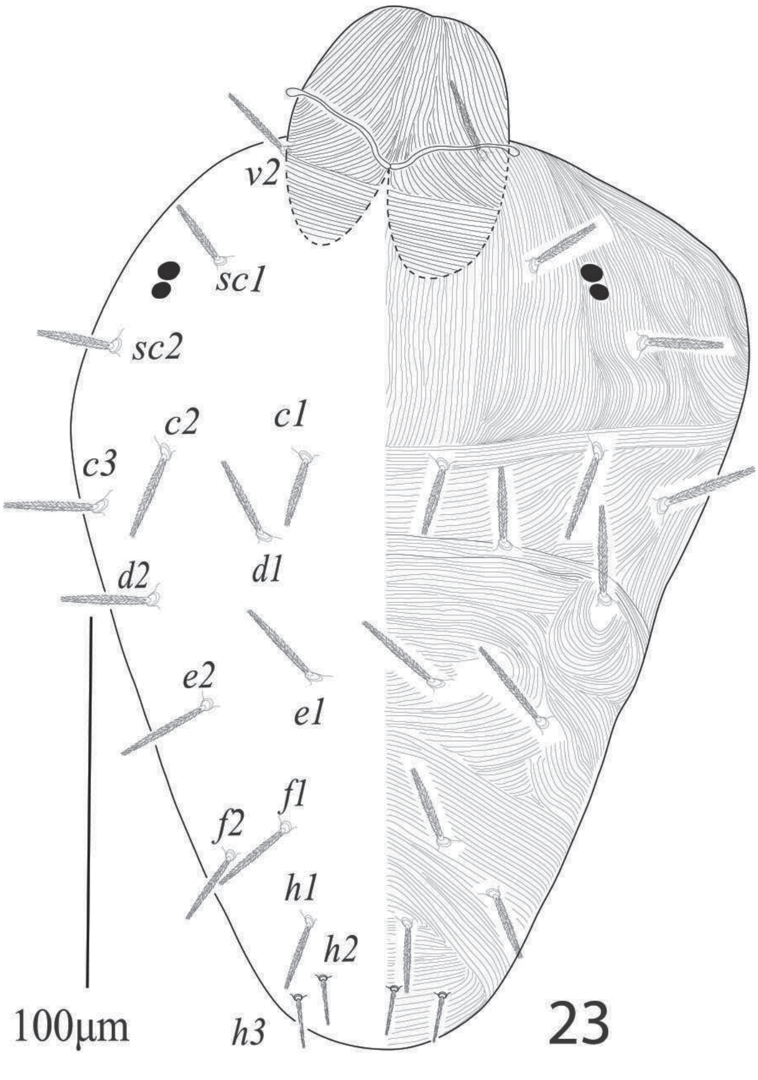


Figure 23. *Eutetranychus neotransversus* sp. n. Male, Dorsum.

Dorsum (Figure 23). Propodosoma medially with longitudinal striae; hysterosoma medially with transverse striae; all dorsal body setae slender, serrate and sub-equal in length, setae *sc2* and hysterosomal setae with small tubercles. Length of dorsal setae: *v2* 19–21, *sc1* 18–20, *sc2* 20–24, *c1* 19–22, *c2* 24–28, *c3* 21–24, *d1* 20–23, *d2* 25–27, *e1* 24–26, *e2* 20–24, *f1* 28–33, *f2* 20–23, *h1* 19–21, *h2* 9–11, *h3* 12–13; distance between dorsal setae: *v2–v2* 48–54, *sc1–sc1* 80–85, *sc2–sc2* 143–148, *c1–c1* 35–37, *c2–c2* 115–120, *c3–c3* 160–164, *d1–d1* 63–65, *d2–d2* 120–125, *e1–e1* 32–36, *e2–e2* 86–90, *f1–f1* 42–43, *f2–f2* 68–70, *h1–h1* 25–27, *h2–h2* 17–19, *h3–h3* 38–40, *v2–sc1* 32–33, *sc1–sc2* 36–38, *sc2–c3* 43–45, *sc2–c2* 32–34, *sc2–c1* 60–63, *c1–c2* 37–38,

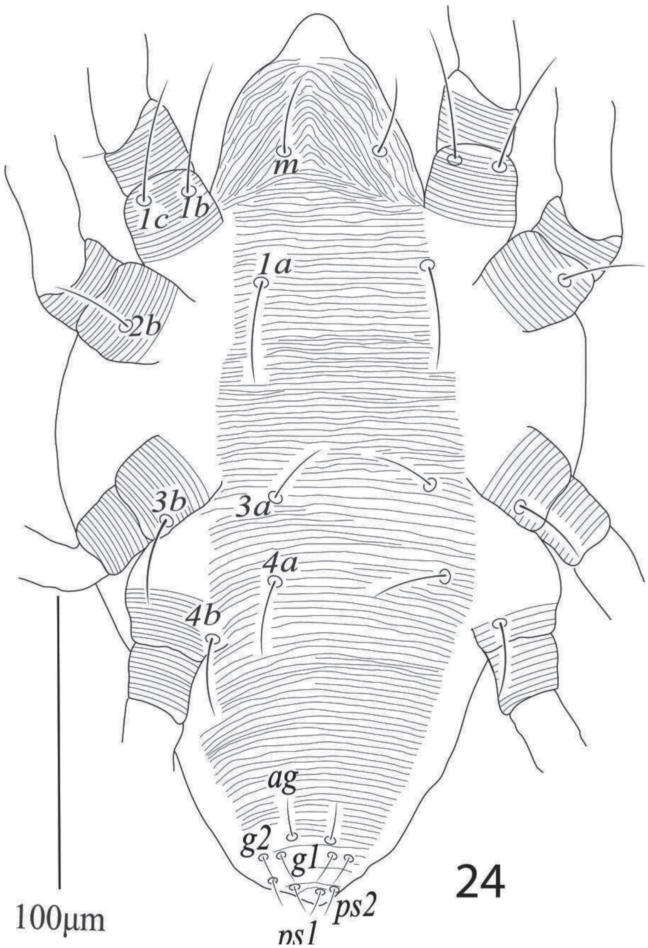


Figure 24. *Eutetranychus neotransversus* sp. n. Male, Venter.

c2–c3 26–28, *c1–d1* 24–26, *c2–d2* 37–38, *d1–e1* 42–45, *d2–e2* 32–34, *e1–f1* 43–45, *e2–f2* 38–40, *f1–h1* 22–22, *f2–h1* 28–30.

Venter (Figure 24). Idiosoma ventrally with transverse striae from setae *1a–ag*. Length of ventral setae; *1a* 35–38, *3a* 22–24, *4a* 26–28, *1b* 45–48, *1c* 42–47, *2b* 26–30, *3b* 30–33, *4b* 27–28; distance between setae: *1a–1a* 55–58, *1b–1c* 13–16, *3a–3a* 44–47, *4a–4a* 62–65; aggenital setae: *ag* 14–16, *ag–ag* 10–11; genital setae: *g1* 10–11, *g2* 11–12, *g1–g1* 16–17, *g2–g2* 24–26; anal setae two pairs: *ps1* 8–9, *ps2* 12–13, *ps1–ps1* 8–9, *ps1–ps2* 6–7.

Gnathosoma (Figure 25). Subcapitular setae *m* 24–28, *m–m* 30–31 (Figure 24); palp femur and genu each with one setae *d* 20–22, *l"* 26; palp tibia with three setae *d* 12–13, *l"* 17–19, *l'* 8 and a palp tibial claw; palp tarsus 11 long, 8 wide, with 3 simple setae *a* 7–8, *b* 6, *c* 10–11, 3 eupathidia *ul"*ζ = *ul'*ζ 6–7, width 0.7 (0.6–0.9) *su*ζ 4, 0.6 (0.5–0.7) a solenidion ω 3.5 long, width 1 (0.9–1.2) (Figure 25). Stylophore slightly notched; peritremes with simple bulb terminaly (Figure 23).

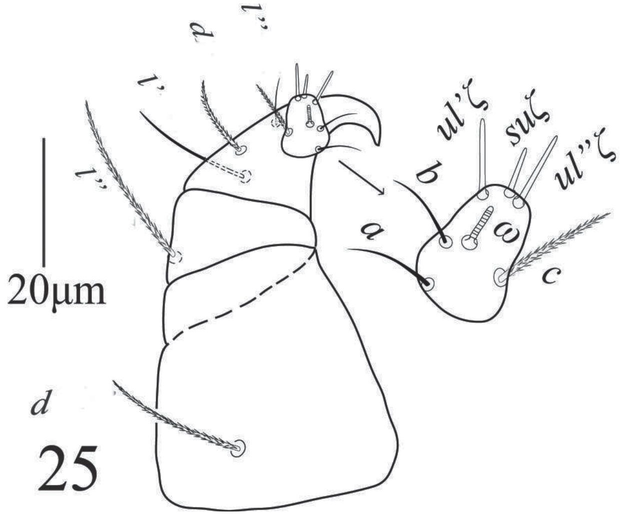


Figure 25. *Eutetranychus neotransversus* sp. n. Male, Palp.

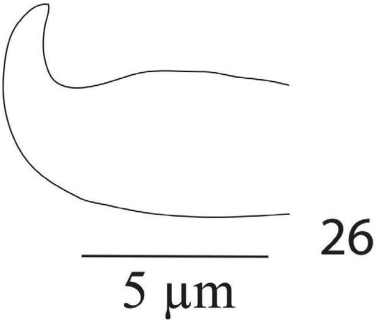


Figure 26. *Eutetranychus neotransversus* sp. n. Male, Aedeagus.

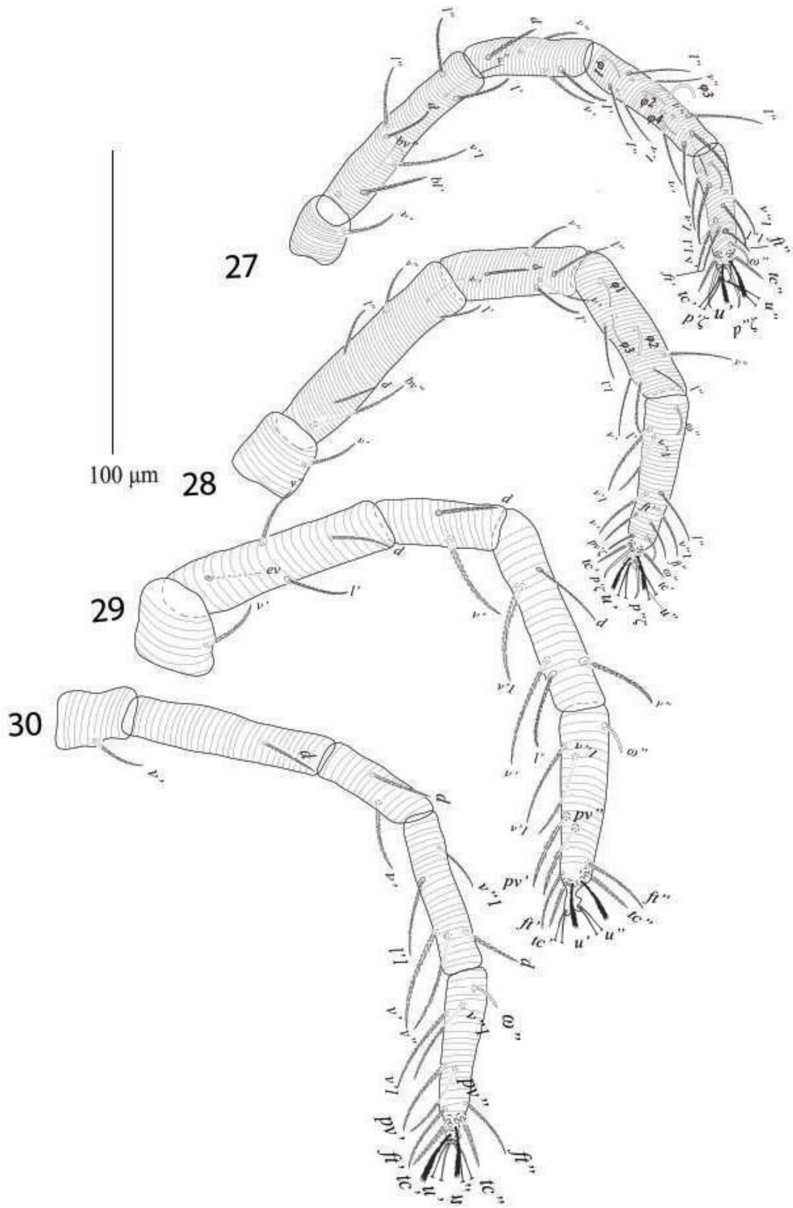
Aedeagus (Figure 26) bends dorsad at an angle of 90°; the bent portion blunt distally, shaft 8 long, 4 wide, bent portion 2.5 long.

Legs (Figures 27–30). Length of legs I–IV (trochanter to pretarsus): 315–325, 269–275, 265–271, 268–275 respectively; chaetotaxy of legs I–IV (eupathidia and solenidia in parenthesis): coxae 2–1–1–1, trochanters 1–1–1–1, femora 8–6–4–1, genua 5–5–2–2, tibiae 9(4)–5(3)–5–4, tarsi 11(2ζ, 2ω)–11(3ζ, 2ω)–10(1ω)–10(1ω).

Immature stages. Unknown.

Etymology. The species name is derived from the transverse striations on dorsal hysterosoma.

Type material. Holotype female and four paratype females, *Juniperus procera* Hochst. Ex Endl. (Cupressaceae), Al-Shifa road, Taif, 21°04.690'N, 040°18.928'E, elevation 2244 m, 11 Oct 2016, leg. M Kamran and M Rehman; three paratype females, *J. procera* , Ash Shifa road, Taif, 21°06.481'N, 040°20.526'E, elevation 2133 m, 12 Sept 2017, leg. Eid M Khan and M Rehman.



Figures 27–30. *Eutetranychus neotransversus* sp. n. Male, **27** Leg 1 **28** Leg 2 **29** Leg 3 **30** Leg 4.

Remarks. *Eutetranychus neotransversus* sp. n. belongs to *orientalis* species group. It closely resembles *E. transverstriatus* Smiley & Baker, 1995 because the entire hysterosoma dorsomedially in both bear transverse striations. The new species is different from *E. transverstriatus* by stylophore anteriorly slightly notched vs. rounded; hysterosomal striae without lobes vs. with distinct lobed striae; number of setae on femora I–IV 5–4–2–1 vs. 7–7–4–3; genu III 1 vs. 2 and tibiae I–IV 6(1)–5–4–4 vs. 10–6–6–6 in *E. transverstriatus* (Table 1).

***Eutetranychus palmatus* Attiah, 1967**
Figures 31–46

Eutetranychus palmatus Attiah, 1967: 12–13, Meyer 1974: 137, Meyer 1987: 78, Palevsky et al. 2010: 43–51, Ben-David et al. 2013: 129.

Material examined. Eight females, *Washingtonia* sp. (Arecaceae), Taif, 21°17.220'N, 040°21.963'E, elevation 1736 m, 11 Oct 2016, leg. M Kamran and M Rehman; seven females, *Washingtonia* sp., Tabuk, 28°23.754'N, 036°32.81'E.

Known Hosts. Date palm, *Phoenix dactylifera* L. (Attiah 1967, Palevsky et al. 2010); the desert fan palm, *Washingtonia filifera* Lindley, Wendland; doum palm, *Hyphaene thebaica* L. Martius; Canary Island palm, *Phoenix canariensis* Chabaud; mountain date palm, *Phoenix loureiroi* (Ben-David et al. 2007). Alatawi (2011) misidentified specimens of *E. orientalis* as *E. palmatus* collected from *Cucurbita moschata* Duchesne ex. Poiret (Cucurbitaceae).

Distribution. Egypt, Iran, Israel, and Saudi Arabia.

Redescription of female (n = 15) (Figures 31–38)

Body oval, color in life greenish yellow. Length of body (excluding gnathosoma) 414–425, (including gnathosoma) 435–455 and maximum width 325–345.

Dorsum (Figure 31). Dorsum with lobed striae, propodosoma medially with longitudinal striae, hysterosoma medially with transverse striae except area between setae *d1* and *e1* longitudinal or "V" shaped pattern; dorsal setae serrate, slightly lanceolate, setae *c1*, *d1, e1* reaching less than half to the distance of next consecutive setae; all dorsal setae without tubercles, propodosomal setae *v2* reaching about two third to the distance *v2–v2* and reaching to the bases of setae *sc1*, setae *c3*, *d2*, *e2*, *f2*, *h1* and all propodosomal setae relatively longer than dorsocentral setae *c1*, *d1*, *e1*. Length of dorsal setae: *v2* 47–52, *sc1* 30–33, *sc2* 30–34, *c1* 17–19, *c2* 20–22, *c3* 25–29, *d1* 20–23, *d2* 28–31, *e1* 21–25, *e2* 27–32, *f1* 25–30, *f2* 32–37, *h1* 32–37; distance between dorsal setae: *v2–v2* 63–70, *sc1–sc1* 125–133, *sc2–sc2* 234–245, *c1–c1* 67–73, *c2–c2* 184–195, *c3–c3* 280–296, *d1–d1* 123–140, *d2–d2* 245–255, *e1–e1* 55–62, *e2–e2* 172–181, *f1–f1* 44–47, *f2–f2* 116–130, *h1–h1* 48–52, *v2–sc1* 40–43, *sc1–sc2* 46–50, *sc2–c3* 79–84, *sc2–c2* 72–78, *sc2–c1* 116–127, *c1–c2* 57–60, *c2–c3* 53–57, *c1–d1* 59–63, *c2–d2* 93–97, *d1–e1* 66–74, *d2–e2* 88–94, *e1–f1* 47–50, *e2–f2* 62–66, *f1–h1* 62–67, *f2–h1* 42–45.

Venter (Figures 32, 34). Ventral integument with transverse striae between setae *1a* to *g1*. Length of ventral setae; *1a* 39–43, *3a* 30–34, *4a* 41–44, *1b* 35–39, *1c* 42–47, *2c* 36–40, *3b* 29–33, *4b* 42–46; distance between intercoxal and coxae setae: *1a–1a* 40–43, *1b–1c* 10–11), *3a–3a* 63–66, *4a–4a* 82–88; aggenital setae: *ag* 29–32, *ag–ag* 51–55; genital setae: *g1* 30–34, *g2* 26–31, *g1–g1* 28–32, *g2–g2* 61–66; anal setae two pairs: *ps1* 11–13, *ps2* 10–11, *ps1–ps1* 16–18, *ps1–ps2* 22–26; para anal setae two pairs: *h2* 18–20, *h3* 23–27, *h2–h2* 16–17, *h3–h3* 46–50, para-anal setae *h2* and *h3* finely serrated. Spermatheca oval, elongated and sacculus terminally rounded or slightly pointed as shown in figure 34.

Gnathosoma (Figure 31). Subcapitular setae *m* 30–34, *m–m* 37–42 (Figure 32). Palp femur and genu each with one setae *d* 45–49, *l"* 32–37; palp tibia with three setae *d*

Table 1. Legs chaetotaxy of world species of the genus *Eutetranychus* (including new species).

Species	Femora I–IV	Genua I–IV	Tibiae I–IV	Tarsi I–IV	Reference
Species group *orientalis*					
neotransversus sp. n.	5-4-2-1	4-4-1-2	6(1)-5-4-4	15(2)-14(1)-10(1)-10(1)	Present study
bilobatus	8-5-4-1	5-5-2-2	9(1)-6-6-7	15(2)-13(2)-10-10	Nassar and Ghai 1981
caricae	7-6-2-1	5-4-1-1	8-5-5-5	15(2)-12 (1)-10(2)-10(1)	Nassar and Ghai 1981
citri	–	–	9(1)-5	–	Attiah 1967
maximae	8-6-3-1	5-5-2-2	9(1)-6-5-7	15(2)-13(2)-10(1)-9(1)	Nassar and Ghai 1981
mirpuriensis	8-6-3-2	5-5-2-2	10-6-6-7	14-12-11-11	Chaudhri et al. 1974
nagai	8-5-3-1	5-5-2-2	9(1)-6-6-7	15(2)-13(1)- 9(2)-10 (1)	Nassar and Ghai 1981
orientalis	8-6-3/4 -1/2	5-5-2-2	9(1-4)-6(0-2)-6(0-1)-7	15(3)-13(1-2)-10(1)-10(1)	Meyer 1974
	8-6-4-2	5-5-2-2	9-7-6-7	15-13-11-11	Chaudhri et al. 1974
	8-7/6-3/4-1/2	5-5-2-2	9(1)-6-6-7	15(3)-13(1)-10(1)-10(1)	Khanjani et al. 2017
	8/7-7/6/5-4/3-1/2	5-5-2-2	9/8(1)-7/6-6/5-7/6	15(3)-13(1)-10(1)-10(1)	Present study
palmatus	–	–	9(1)	–	Attiah 1967
	8-6-2-1	5-5-2-2	9(2)-6(2)-6-7	15(3)-13(2)-10(1)-10(1)	Meyer 1987
	8-7-4-1	5-5-2-2	9(1)-6-6-7	15(3)-13(1)-10(1)-10(1)	Present study
pantopus	–	–	9(1)-5	–	Meyer 1974
pyri	–	–	9(1)-5	–	Attiah 1967
transverstriatus	7-7-4-3	4-4-2-2	10-6-6-6	10-10/9-10(1)-10(1)	Smiley and Baker 1995
**fici*	8-6-3-2	5-5/6-2-2	9(1)-6-6-7	15(1-3)-13(1)-10(1)-10(1)	Meyer 1987
**phaseoli*	8-7-3-1	5-5-2-2	9(1)-6-6-7	15(3)-13(2)-10(1)-10	Nassar and Ghai 1981
* *pruni*	8-7-3-1	5-5-2-2	9(1)-6-6-7	12(3)-11(1)-8(1)-8(1)	Smiley and Baker 1995
**ricinus*	8-7-4/3-2	5-5-2-2	9/8(1)-6-6-7	15(1)-10(1)-10(1)-10(1)	Smiley and Baker 1995
**sanaae*	8-7-4/3-1	5-5-2-2	9(1)-7/6-6-7	11(1)-11(2)-10(1)-10(1)	Smiley and Baker 1995
**guangdongensis*	Mentioned in original description same as *E. orientalis*				Ma and Yaun 1982
**xianensis*					Ma and Yaun 1982
Species group *banksi*					
spinosus sp. n.	8/7-6-2-1	5-5-4/3-3	9(1)-7-8-8	15(2)-13(2)-10(1)-10(1)	Present study
acaciae	6/7-4-3-1	3-3-1-1	8(1)-4/5-3-5	13(4)- 12(3)-10(1)-10(1)	Based on pictures send by Dr. Owen D. Seeman
africanus	8-6-3-1	5-5-2-2	9(1)-6-6-7	15(2/3)-13(1)-10(1)-10(1)	Meyer 1987
anitae	9-6-4-3	5-5-3-2	9(4)-7(2)-6/7-7	13(3)-12(2)-11(1)-10(1)	By personal communication with Dr. Elizeu Castro
banksi	6/7-4/6-2-1	4-4-2-2	9(1)-6-4/5-5/6	14(2)-12(2)-10(1)-10(1)	Mattos and Feres 2009
bredini	8-7-4-1	5-5-2-2	9(1)-5-5	–	Baker and Pritchard 1960
carinae	8-6-2-1	5-5-2-2	9(1)-6-5-6	15(2)-13(1)-10(1)-10(1)	Meyer 1987
clastus	8-6-3-1	5-5-2-2	9(1)-5-5-6	15(3)-13(1)-10(1)-10(1)	Meyer 1987
concertativus	7-6-2-2	5-5-5-3	9(1)-7-8-8	15(2)-13(2)-10(1)-10(1)	Meyer 1987
cratis	8-6-3-2	3-3-2-2	6(1)-5-4-5	14(3)-13(1)-10-10(1)	Meyer 1987
eliei	8-6-2-1	5-5-2-2	9(1)-6-5-6	15(1)-13(1)-10(1)-10(1)	Meyer 1987
enodes	8-6-3-1	5-5-2-2	9(1)-6-5-7	15(2)-13(2)-10(1)-10(1)	Meyer 1987
namibianus	7-6-2-1	5-5-3-3	9(1)-7-8-8	15(2)-13(1)-10(1)-10(1)	Meyer 1987
nomurai	6-6-2-1	5-5-2-2	9(1)-8/7-8/7-8/7/9	12/13/14(3)-12/13(1/2)-12/13(1/2)-10(1)	Flechtmann 1997
rhusi	7-6-2-1	5-5-3-3	9(1)-7-7-8/7	15(2)-13(1)-10(1)-10(1)	Meyer and Ueckermann 1988
swazilandicus	8-6-2-2	5-5-3-3	9(1)-7-8-8	15(3)-13(2) - 10(1) - 10(1)	Meyer 1987

* Suggested synonyms of *E. orientalis*

All missing characters/values in the table were not described or illustrated in the original descriptions/re-descriptions.

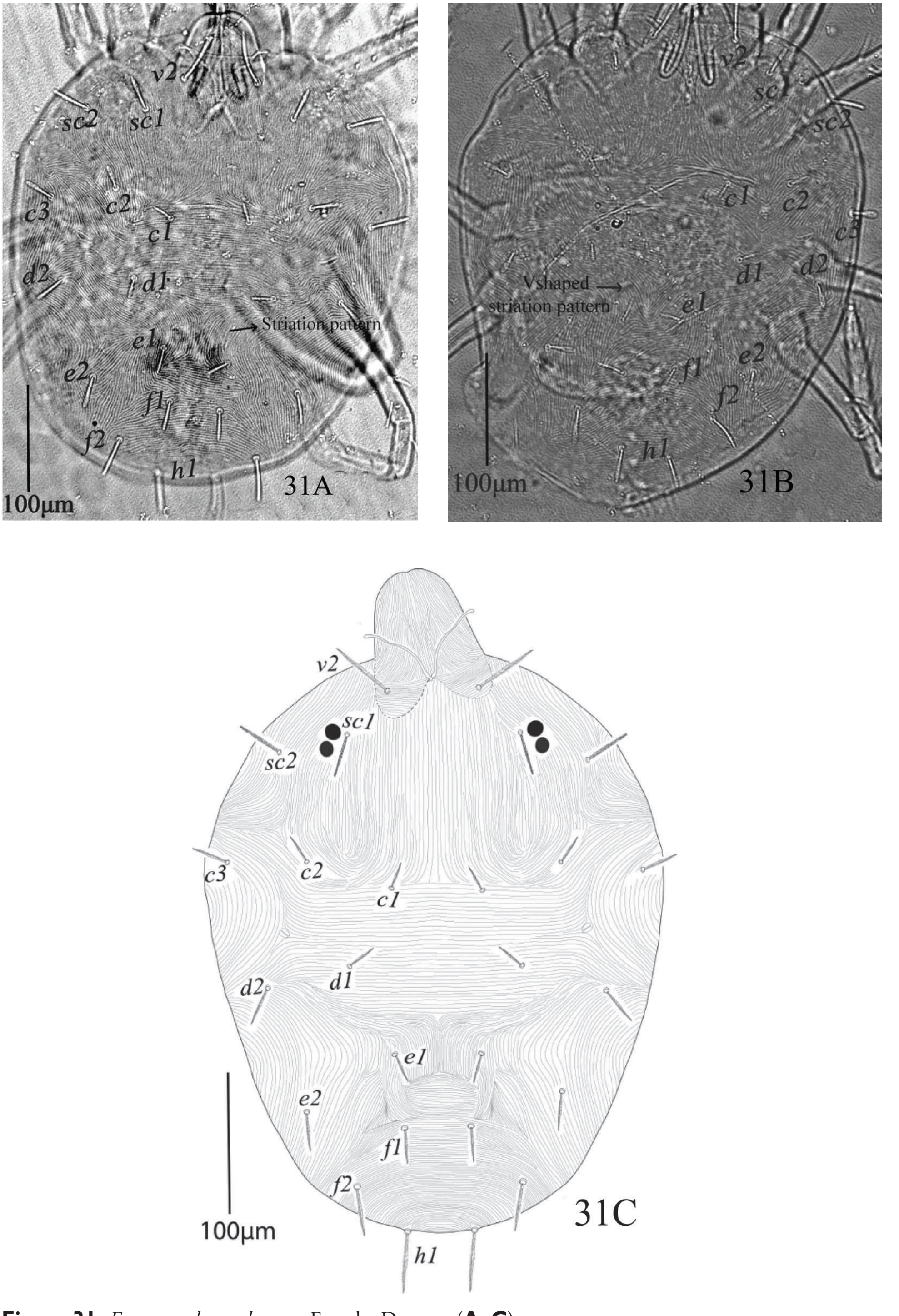


Figure 31. *Eutetranychus palmatus*, Female, Dorsum (**A–C**).

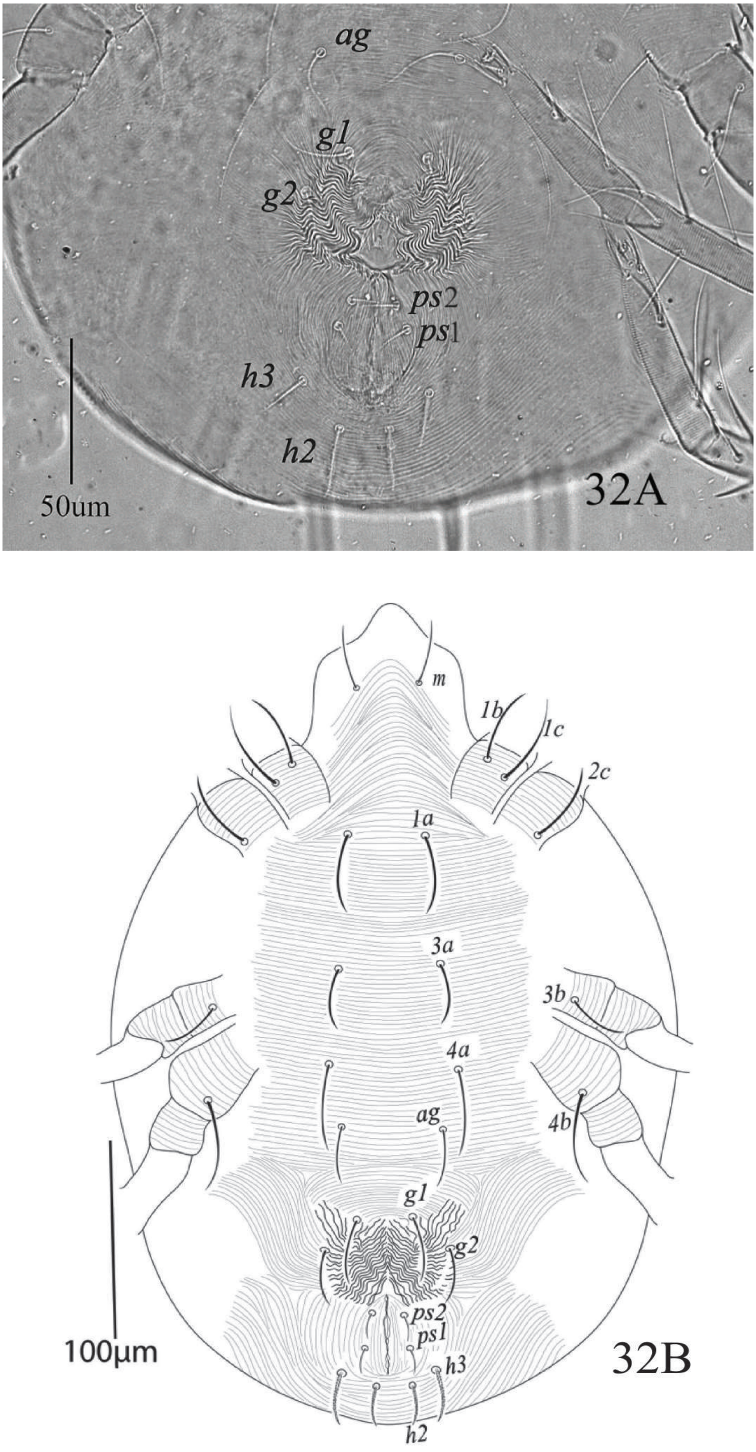


Figure 32. *Eutetranychus palmatus*, Female, **A** Genito-anal region **B** Venter.

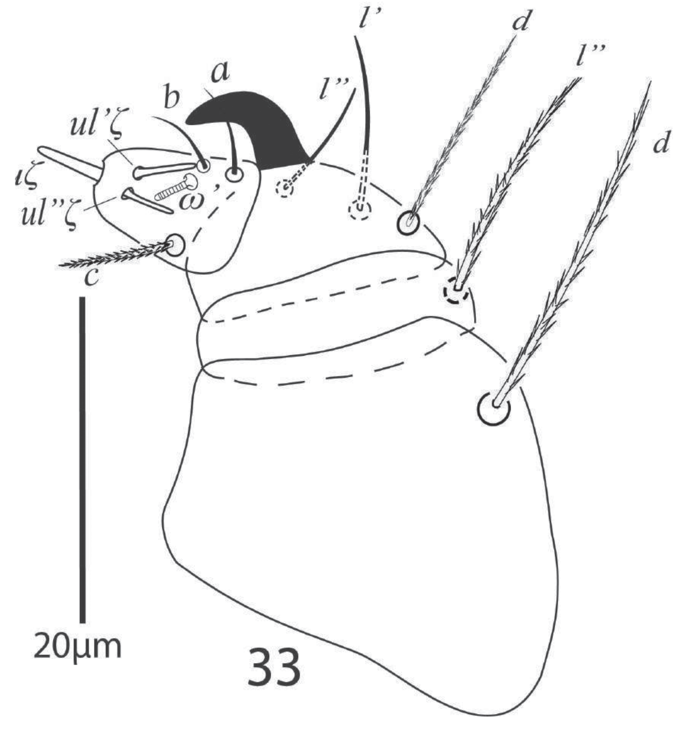


Figure 33. *Eutetranychus palmatus*, Female, Palp.

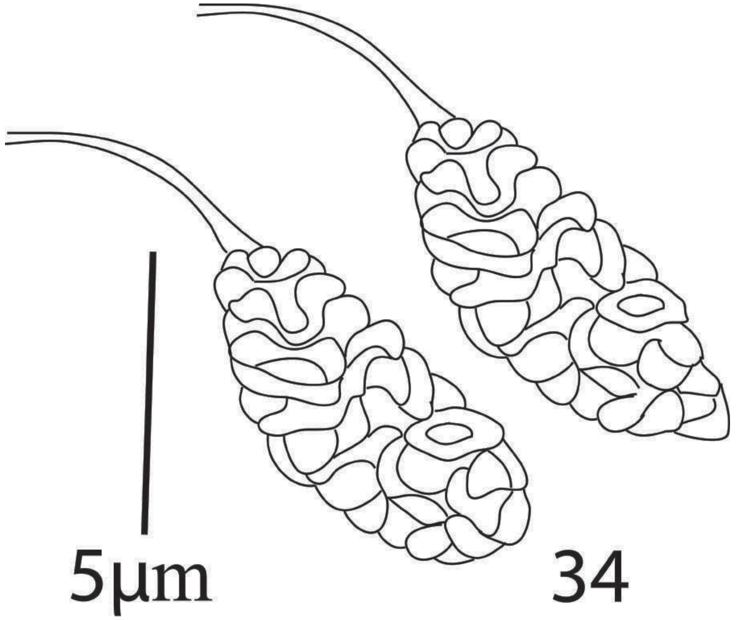
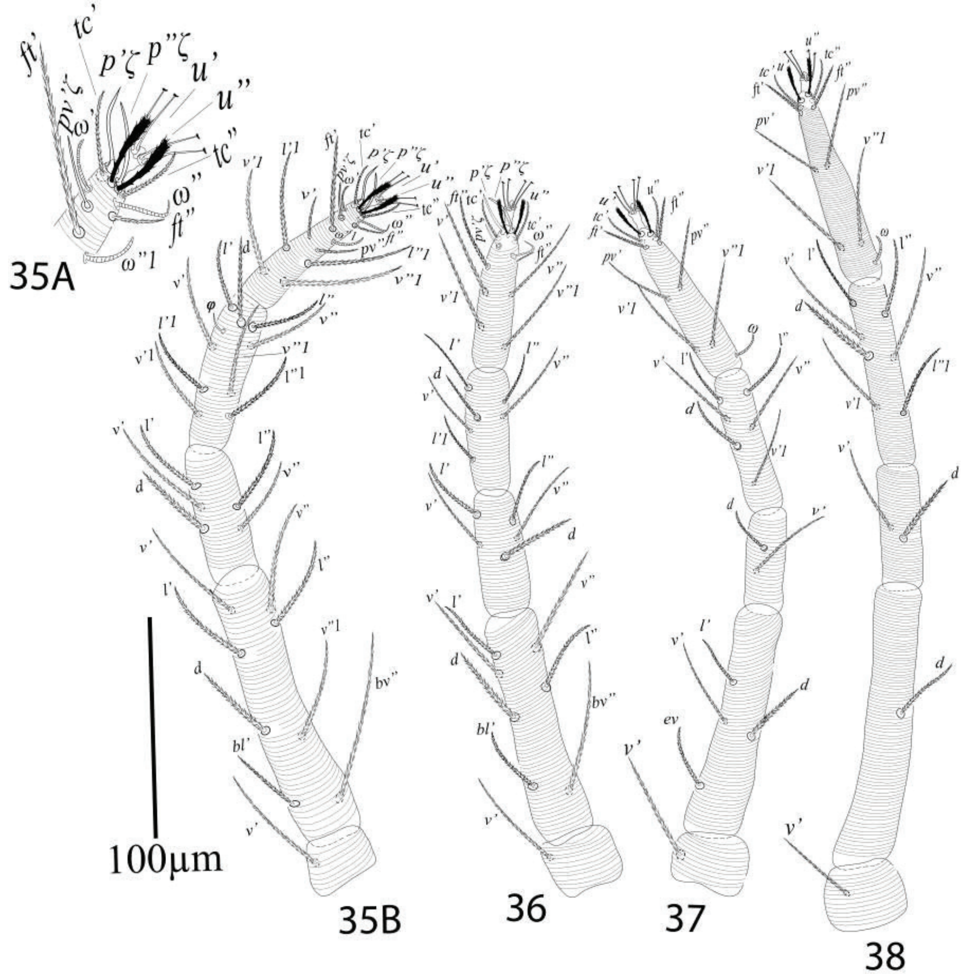


Figure 34. *Eutetranychus palmatus*, Female, Spermatheca.



Figures 35–38. *Eutetranychus palmatus*, Female, **35A** leg1 tarsus **35B** Leg 1 **36** Leg 2 **37** Leg 3 **38** Leg 4.

24–27, *l"* 21–24, *l'* 15–16 and a palp tibial claw; palp tarsus 19 long, 14 wide, with 3 simple setae *a* 10–11, *b* 9–10, *c* 13–14, 3 eupathidia *su*ζ 9, width 1.35–1.7, *ul"*ζ = *ul'*ζ 7–8, width 1.3–1.6 a solenidion ω 5 long, width 1.9–2.2 (Figure 33). Stylophore anteriorly slightly notched; peritremes ending with simple bulb (Figure 31).

Legs (Figures 35–38). Length of legs I–IV (trochanter to pretarsus): 320–340, 285–300, 280–295, 335–350 respectively; leg I 320–340: trochanter 30–33, femur 112–125, genu 61–68, tibia 63–72, tarsus 61–67; leg II 285–300: trochanter 30–33, femur 88–93, genu 50–55, tibia 46–50, tarsus 67–72; leg III 280–295: trochanter 25–30, femur 95 93–99, genu 30–33, tibia 58–63, tarsus 76–80; leg IV 335—350: trochanter 25–29, femur 110–117, genu 48–55, tibia 73–79, tarsi 77–82; legs chaetotaxy I–IV (solenidia in parenthesis): coxae 2–1–1–1, trochanters 1–1–1–1; femora 8–7–4–1; genua 5–5–2–2; tibiae 9(1) –6–6–7; tarsi 12 (3ζ, 3ω) –10(3ζ, 1ω) –10(1ω) –10(1ω).

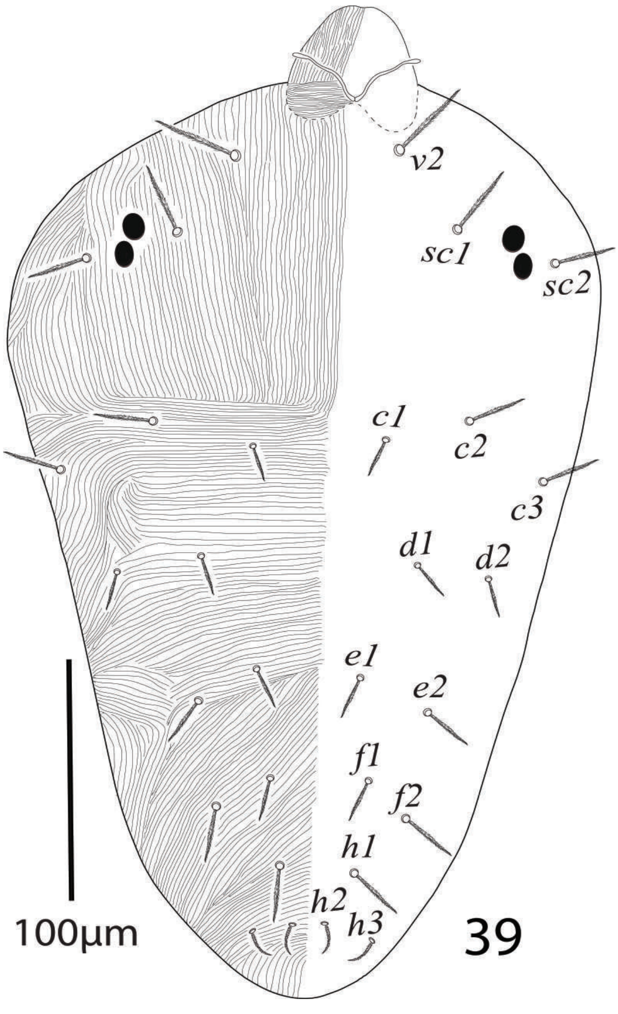


Figure 39. *Eutetranychus palmatus,* Male, Dorsum.

Male (n= 4) (Figures 39–46)

Body oval, length of body (excluding gnathosoma) 340–355, (including gnathosoma) 405–425 and maximum width 206–220.

Dorsum (Figure 39). Propodosoma medially with longitudinal striae, area between setae *c1–d1* with transverse striae and *e1–h1* with oblique striae; all dorsal setae short and slightly lanceolate, and without tubercles; length of dorsal setae: *v2* 30–32, *sc1* 28–33, *sc2* 21–24, *c1* 15–17, *c2* 19–22, *c3* 20–24, *d1* 14–16, *d2* 14–17, *e1* 16–19, *e2* 19–22, *f1* 16–18, *f2* 19–22, *h1* 25–28, *h2* 9–12, *h3* 11–13; distance between dorsal setae: *v2–v2* 60–68, *sc1–sc1* 90–103, *sc2–sc2* 180–195, *c1–c1* 45–52, *c2–c2* 115–125, *c3–c3* 180–196, *d1–d1* 80–89, *d2–d2* 130–142, *e1–e1* 38–44, *e2–e2* 80–89, *f1–f1* 35–40, *f2–f2* 65–70, *h1–h1* 25–30, *h2–h2* 11–13, *h3–h3* 41–48, *v2–sc1* 36–42, *sc1–sc2* 30–34, *sc2–c3* 75–84, *sc2–c2* 64–70, *sc2–c1* 86–96, *c1–c2* 38–42, *c2–c3* 33–37,

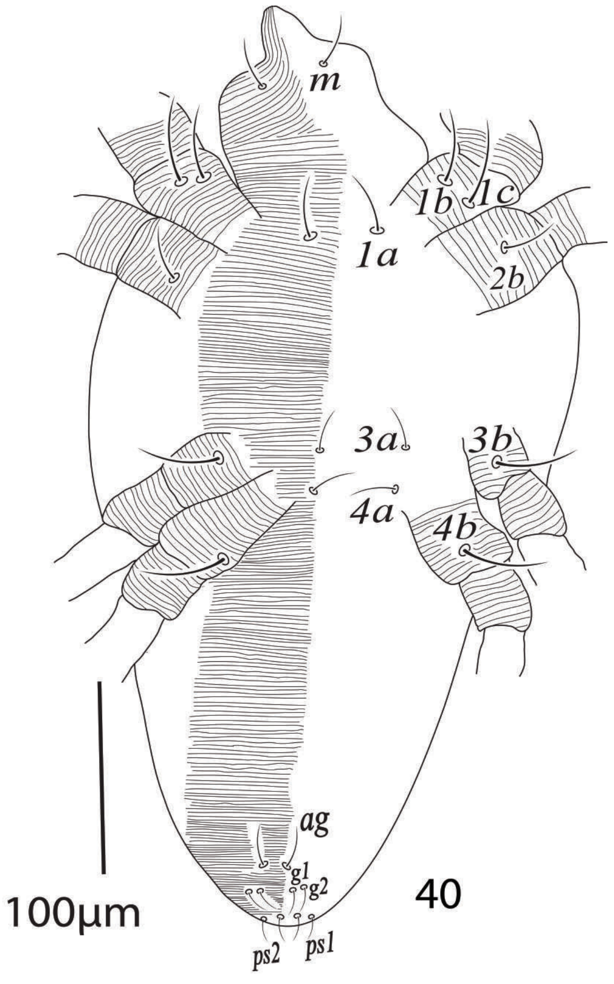


Figure 40. *Eutetranychus palmatus,* Male, Venter.

c1–d1 45–50, *c2–d2* 55–61, *d1–e1* 46–54, *d2–e2* 55–60, *e1–f1* 39–45, *e2–f2* 38–43, *f1–h1* 32–35, *f2–h1* 25–31.

Venter (Figure 40). Idiosoma ventrally with transverse striae; length of ventral setae; *1a* 30–32, *3a* 20–24, *4a* 24–28, *1b* 35–39, *1c* 42–47, *2b* 28–30, *3b* 39–43, *4b* 42–46, distance between setae: *1a–1a* 34–38, *1b–1c* 10–11, *3a–3a* 38–45, *4a–4a* 38–42; aggenital setae: *ag* 20–22, *ag–ag* 6–7; genital setae: *g1* 9–11, *g2* 10–11, *g1–g1* 16–17, *g2–g2* 25–28; anal setae two pairs: *ps1* 9–11, *ps2* 11–12, *ps1–ps1* 19–21, *ps1–ps2* 7.

Gnathosoma (Figure 41). Subcapitular setae *m* 27–29, *m–m* 30–33 (Figure 40); palp femur and genu each with one setae *de* 38–41, *l”* 21–25; palp tibia with three setae *d* 16–20, *l”* 21–25, *l’* 13–14 and a palp tibial claw; palp tarsus 9–10 long, 12 wide, with 3 simple setae *a* 7 –8, *b* 8, *c* 9–10, 3 eupathidia *ul”*ζ = *ul’*ζ 6.5–7, width 1 (0.9–1)

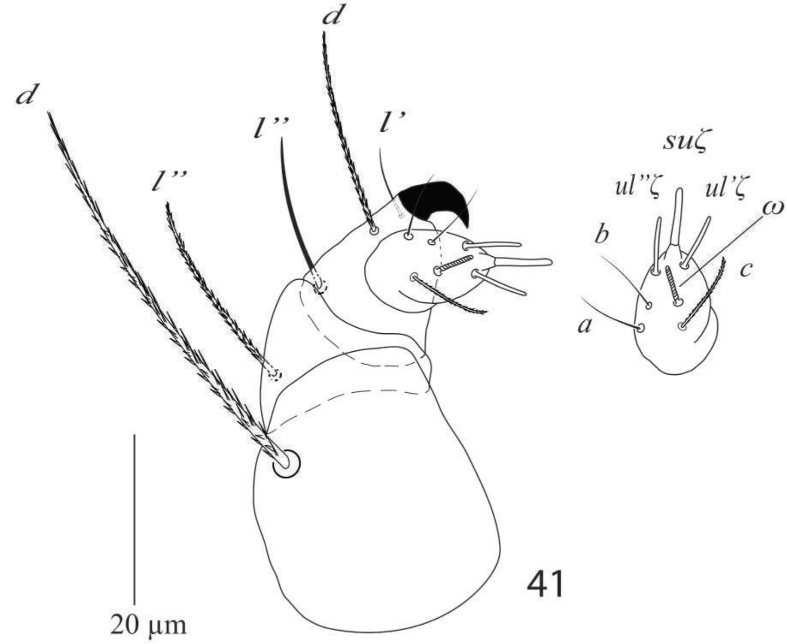


Figure 41. *Eutetranychus palmatus*, Male, Palp.

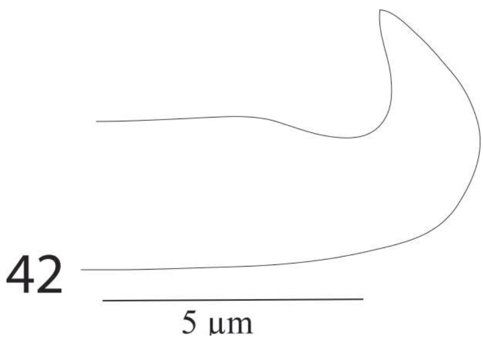
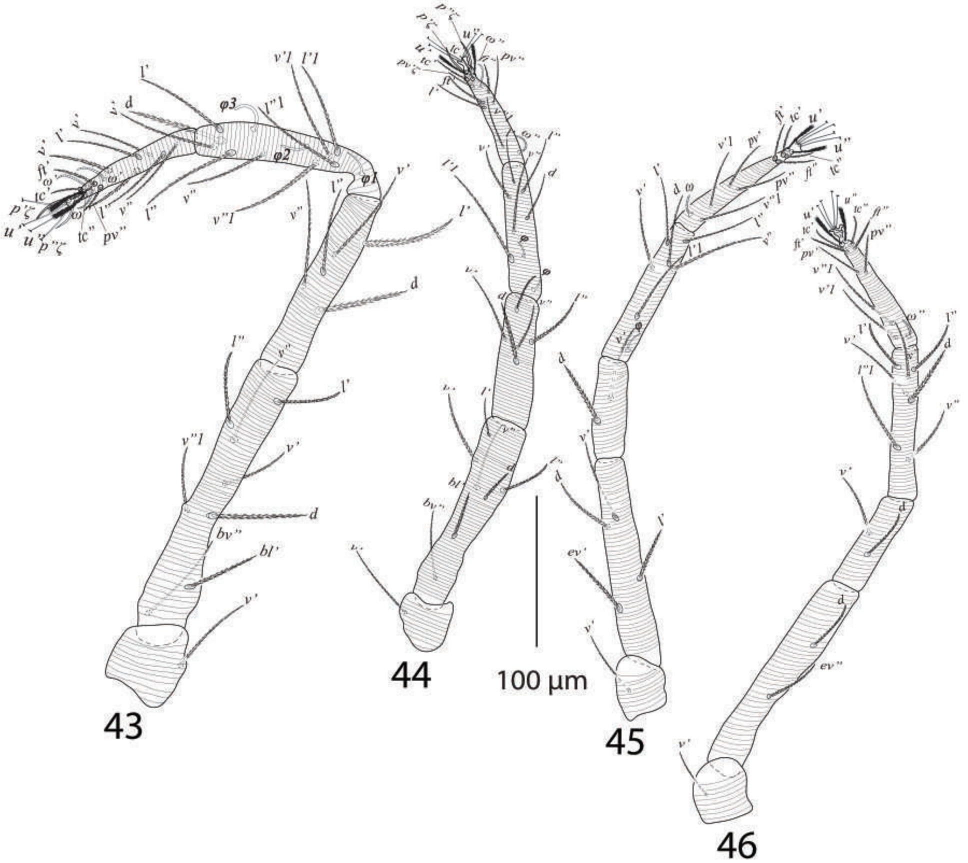


Figure 42. *Eutetranychus palmatus*, Male, Aedeagus.

suζ 4, width 0.7–0.9 a solenidion ω 3 long, width 1.2–1.7 (Figure 41). Stylophore notched; peritremes ending with simple bulb (Figure 39).

Aedeagus (Figure 42) bends dorsad at an angle of 70°; aedeagal knob pointed distally, shaft 10 long, 3.4 wide, bent portion 2.8 long.

Legs (Figures 43–46). Length of legs I–IV (trochanter to pretarsus): 470–485, 385–400, 402–425, 399–420 respectively; legs I–IV chaetotaxy (solenidia in parenthesis): coxae 2–1–1–1, trochanters 1–1–1–1; femora 8–7–4–1/2; genua 5–5–2–2; tibiae 9(3) –6(2)–6(1)–7; tarsi 12 (2ζ, 3ω)–10(3ζ, 2ω) –10(1ω)–10(1ω).



Figures 43–46. *Eutetranychus palmatus*, Male, **43** Leg 1 **44** Leg 2 **45** Leg 3 **46** Leg 4.

Remarks. *Eutetranychus palmatus* Attiah, 1967 is different from all other species of the genus *Eutetranychus* by having all dorsal body setae without tubercles. It was described and illustrated from date palm trees in Egypt (Attiah 1967), but its original description was briefly and incomplete i.e. leg chaetotaxy, length and distance of dorsal setae were not provided. Meyer (1987) identified some specimens as *E. palmatus* from date palms from Israel and provided legs chaetotaxy without illustrations. Chaetotaxy of *E. palmatus* specimens collected from *Washingtonia* sp. from Saudi Arabia is same as mentioned by Meyer (1987) except differences on femora II and III 7–4 vs. 6–2 in the specimens from Israel. However, femur III with three setae was illustrated in original illustrations (Attiah 1967). Moreover, Attiah (1967) and Meyer (1987) observed striations of prodorsum longitudinal and undulating in this species. Undulation in prodorsal striations usually happened during mounting is not important diagnostic character to differentiate the species of the genus *Eutetranychus*. Also, in this species striae between setae *d1* and *e1* were either longitudinal (Figure 31A) or "V" shaped (Figure 31B).

***Eutetranychus orientalis* (Klein)**
Figures 47, 48, 49

Anychus latus Klein, 1936: 3.
Eutetranychus orientalis (Klein): Baker and Pritchard 1960: 464–467.
Eutetranychus monodi Andre, 1954: 859.
Eutetranychus anneckei Meyer, 1974: 148–149.
Eutetranychus sudanicus Elbadry, 1970: 301–305.

Previous records from Saudi Arabia. Martin 1972, Alatawi 2011.

Material examined. Twenty seven females, *Citrus* sp., Education Farm, King Saud University, Riyadh, 24°44.253'N, 46°37.225'E, 01 Feb 02 Apr 2009, 26 Oct 01 Nov 2010, 14, 24 Apr 2011, leg. J Basahih, and T Martibi; one female, *Citrus* sp., Dariyah, Riyadh, 24°44.866'N, 46°34.624'E, 02 Feb 2009, leg. J Basahih; seven females, *Vitis vinifera* and *Citrus* sp., Ammaria, Riyadh, 24°49.194'N, 46°28.163'E, 12 Apr 2009, 10 Mar 2011, leg. W Negm; five females, Hayer, Riyadh, 24°23.611'N, 46°49.464'E, 28 Apr 2009, leg. J Basahih; two females, Rhodat ul Khoraim, Riyadh, 03, 9 May 2009, leg. J Basahih;, three females, *Citrus* sp., Waseel, Riyadh, 24°48.786'N, 46°31.180'E, 11 Oct 2009, 23 Apr 2010, leg. J Basahih; four females, *Citrus* sp., *Juniperus* sp., and Grasses under *P. dactylifera*, near students housing King Saud University, Riyadh, 24°43.484'N, 46°36.985'E, 20 Sep 2010, 28 Mar 2011, leg. J Basahih; eight females, *P. dactylifera*, Imam Muhammad Ibn Saud University, Riyadh, 24°48.759'N, 46°42.735'E, 13, 27 Dec 2010, 01, 25 Jan 25, 23 Mar 2011, leg. J Basahih ; twelve females, *Citrus* sp., Nijran, 18 Apr 28 Sept 2011, leg. Jaid; six females, *Citrus* sp. Qassim, 26°00.612'N, 044°00.166'E, 26 May 2011, leg. J. Basihih and A. Majeed; two females, *Acacia* sp., and soil under *P. dactylifera* Al-Madina, 24°26.335'N, 39°36.866'E, 19 Jun 13 Oct 2011, leg. M Kamran and W Negm; eleven females, *Datura* sp., and *Citrus* sp., Wadi Namar, Riyadh, 24°34'18.9N, 46°40'40.4E, 14 Oct 2012, leg. M Kamran; two females, *Nerium oleander*, Dariyah, Riyadh, 24°44.866'N, 46°34.624'E, 5 Apr 2014, 18 Mar 2015 leg. M Kamran; two females, *Tamarix* sp. and *Saccharum* sp., Deesa valley, Tabuk, 27°36'049N, 36°25'785E, 17, 18 Oct 2015, leg. M Kamran; two females, *P. dactylifora*, Al-Sail Kabeer, Taif, 21°33.882'N, 040°18.048'E, 15 Oct 2016, leg. M Kamran and M Rehman; two females, *Citrus* sp., Khayber, 25°34.563'N, 39°19.375'E, 1 Nov 2016, leg. M Kamran and E M Khan; nine females, *Citrus* sp., *Ziziphus* sp., and *Albizia* sp., Al-Ula, 26°48.757'N, 37°58.241'E, 2 Nov 2016, leg. M Kamran and E M Khan; twenty five females, *Citrus* sp., *Mangifera* sp., *P. dactylifera*, *Olea* sp., *Psidium* sp., *Azadirachta* sp., and *Ficus* sp., Al-Ula, 26°39.923'N, 37°55.032'E. 3, 4, 5, 6, 7 May 2017, leg. E M Khan and M Rehman.

Discussion. Variations within the different populations of *Eutetranychus orientalis*.

Morphological variations of *Eutetranychus orientalis* in 91 female specimens that were collected from 28 various host plants and 80 different localities in six regions of Saudi Arabia during 2009 to 2017 are shown in Figures 47A–H, 48, and 49. The

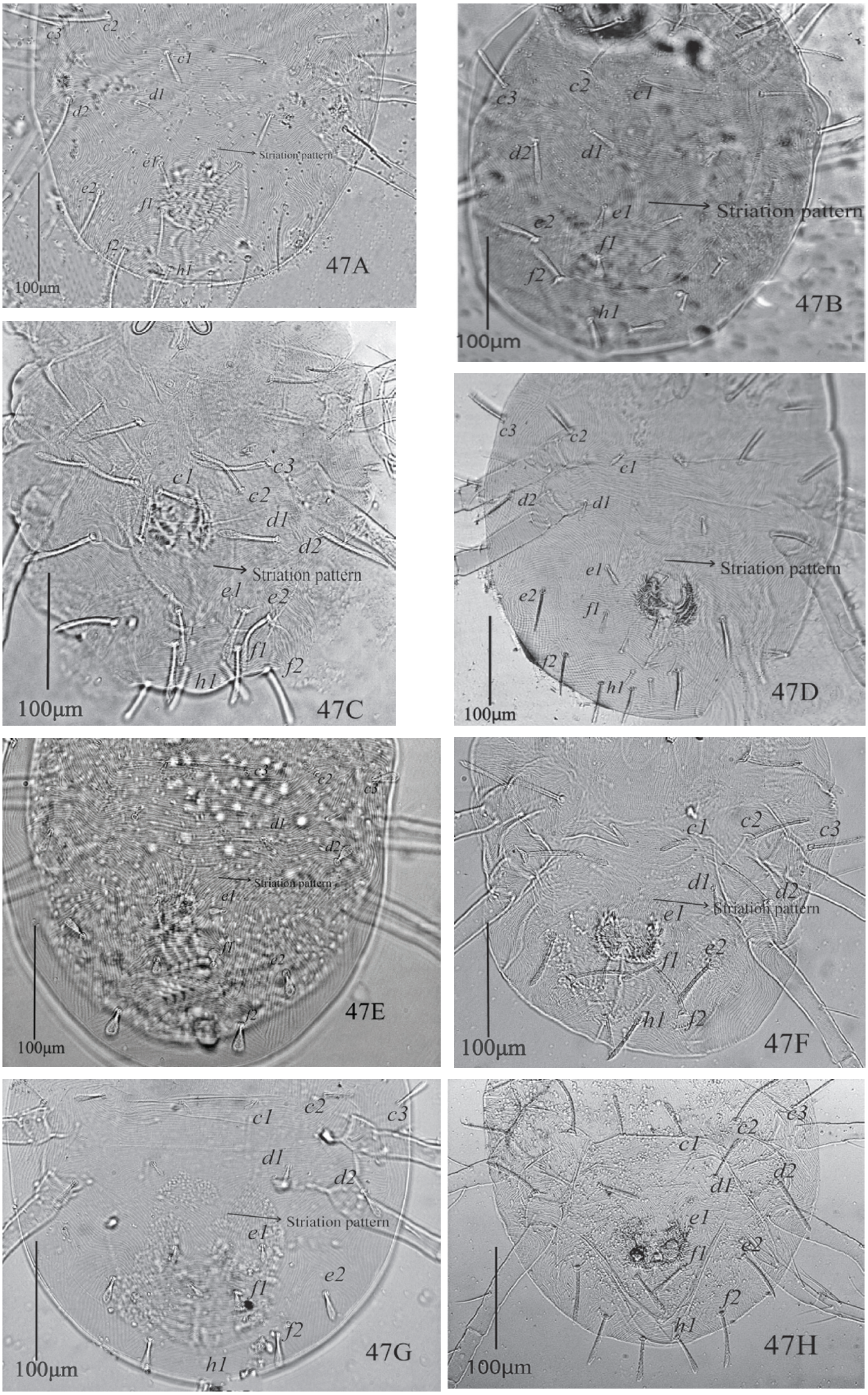


Figure 47. *Eutetranychus orientalis* (Klein), Females, Variation in shape of setae and striations pattern between setae *e1* on dorsum; host plants and regions, **A** Date palms, Riyadh **B** Fig, Al-Ula **C** Guava, Taif **D** Citrus, Riyadh **E** Lemon, Al-Ula **F** Citrus, Riyadh **G** Citrus, Najran **H** Citrus, Riyadh.

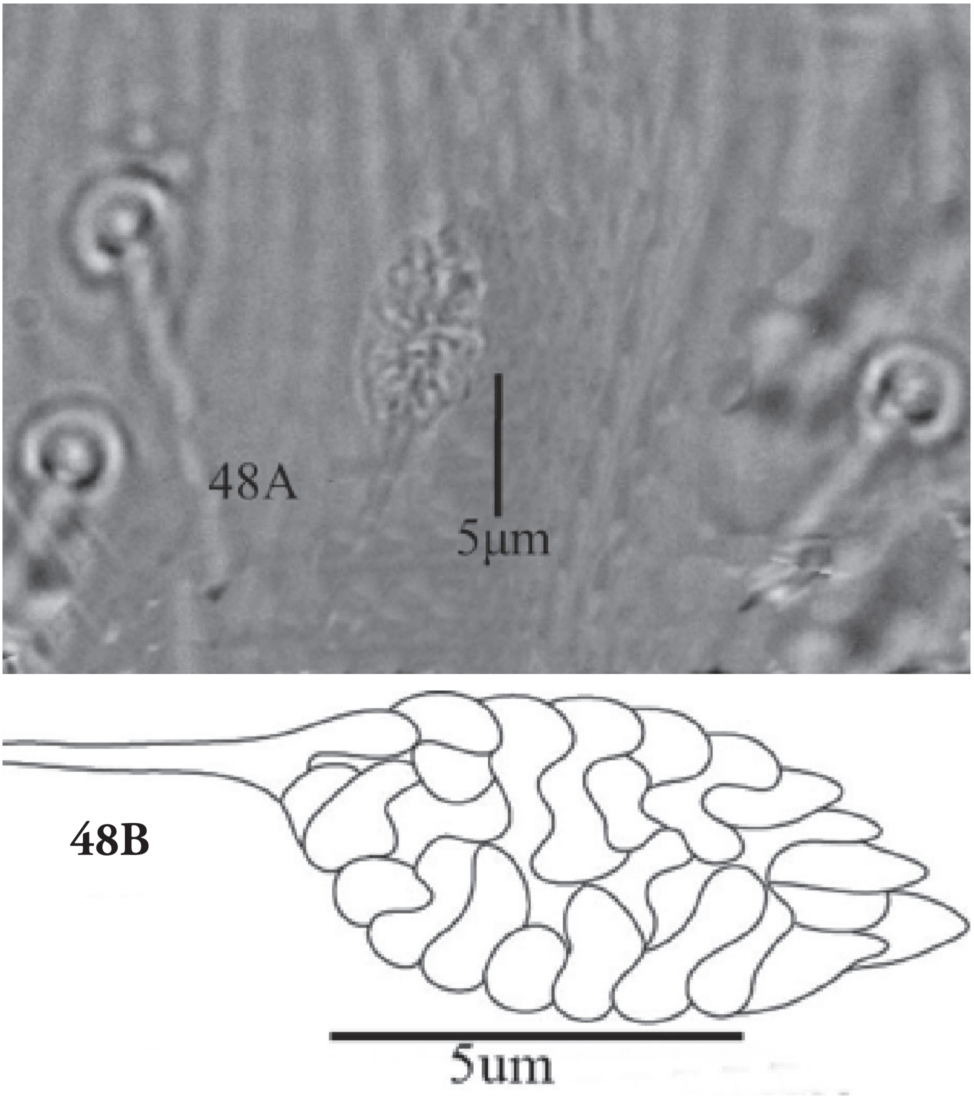


Figure 48. A, B *Eutetranychus orientalis* Female, Variation in shape of spermatheca. Pointed distally.

lengths and shapes of dorsal body setae, striation patterns between setae *d1* and *e1,* and chaetotaxy of leg segments including femora and tibiae have been presented in Table 1.

The most prominent variations within in *E. orientalis* populations are in the length and shape of dorsal setae. These variations including, dorsocentral setae length [*c1* (10–51), *d1* (12–50), *e1* (14–41) and *f1* (10–45)] and shape [oblanceolate, ovate, obovate, subspatulate and spatulate] (Figure 47A–H). Also, these setae were either very short far behind the bases of next consecutive setae (Figure 47B, D, E, G), reaching one third to half (Figure 47A, F) or almost extending to the bases of next consecutive

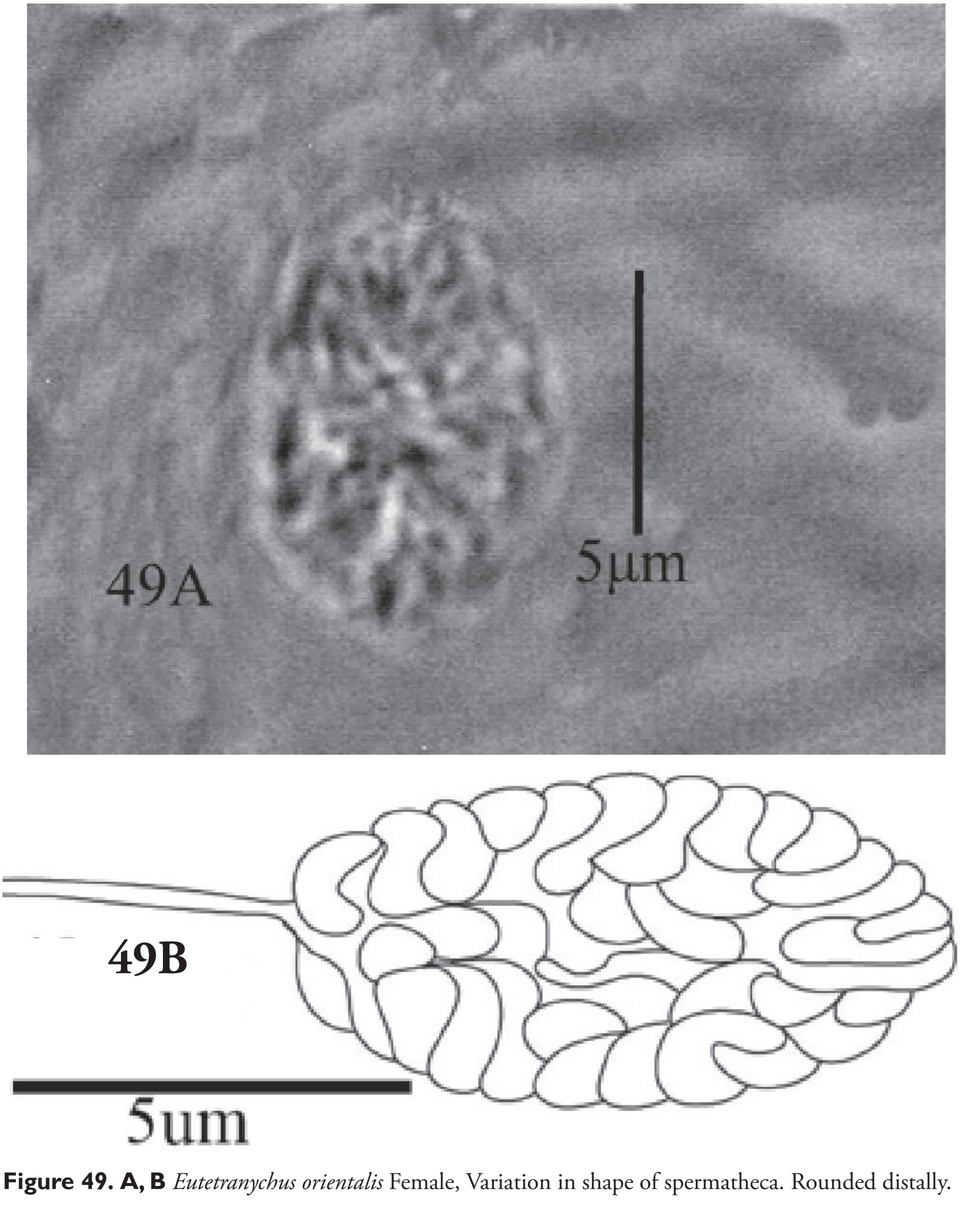


Figure 49. A, B *Eutetranychus orientalis* Female, Variation in shape of spermatheca. Rounded distally.

setae (Figure 47C, F, H). Dorsal setae *sc1, sc2, c2, c3, d2, e2, f2*, and *h1* were also varied in shape (oblanceolate, subspatulate, spatulate, slender), mostly among the specimens of different populations. The same variations in these dorsal setae have been recorded in populations of this species collected from different countries (Baker and Pritchard 1960, Chaudhri et al. 1974, Meyer 1974, Meyer 1987, Khanjani et al. 2017).

Striations patterns between the dorsocentral setae *d1* and *e1* varied either forming "V" shaped pattern (n = 80; Figure 47A-E, G, H) or a longitudinal pattern (n = 11;

Table 2. Variable morphological characters used to differentiate some *Eutetranychus* species suggested as synonyms of *E. orientalis* in the current study.

Suggested synonyms of *E. orientalis*	Characters used to differentiate in original descriptions							Reference
	Dorsocentral setae, short, medium or long	**Shape of dorsal setae**	**Setae on femur II**	**Setae on femur IV**	**Striations pattern b/w *e1* and *d1***	**Spermatheca distally**	**Length of palp spinneret as compared to width**	
E. fici	long, extending to the bases of next setae in line	Spatulate to subspatulate	6	2	V shaped	rounded	4 times	Meyer 1987
E. pruni	Short to medium	Slender	7	1	longitudinal	–*	–*	Smiley and Baker 1995
E. ricinus	Short to medium	oblanceolate to subspatulate	7	2	longitudinal	–*	–	Smiley and Baker 1995
E. sanaae	Short to medium	Slender	7	1	V shaped	–*	–*	Smiley and Baker 1995
E. phaseoli	Short	Subspatulate	7	1	V shaped	–*	–*	Nassar and Ghai 1981
E. guangdongensis	Short to medium	Spatulate to Subspatulate	Mentioned the same as in *E. orientalis*			–*	–*	Ma and Yaun 1981
E. xianensis**	Short	Spatulate to Subspatulate				–*	–*	Ma and Yaun 1981
E. orientalis	Short, medium and long almost extending to the bases of next setae in line	Slender, Spatulate, subspatulate, oblanceolate	6, 6/7, 7 Variable	1, 2,1/2 Variable	V shaped or longitudinal	Pointed or rounded	3 to 4 times	Khanjani et al. 2017; Present study

*Information not available in the original descriptions
**distinguished from *E. banksi* in the original description

Figure 47F) and varied even among the specimens of the same population. Similar variations in dorsal striation patterns have also been observed by Chaudhri et al. (1974), Meyer (1987), and Khanjani et al. (2017).

Moreover, all dorsal setae in *E. orientalis* collected in this study are set on tubercles; lateral setae are on prominent tubercles as compared to dorsocentral setae (*c1*, *d1*, and *e1*) which are mostly set on relatively smaller tubercles (n = 73). However, in some specimens setae *c1*, *d1*, and *e1* are without distinct tubercles (n = 19) as shown in Figure 47D, G. This variation was observed even among the individuals of a single population collected in the current study. A similar variation has been illustrated by Chaudhri et al. (1974). However, *E. orientalis* dorsocentral setae *c1*, *d1*, and *e1* were described and illustrated only on small tubercles (Meyer 1987, Khanjani et al. 2017).

Our observations also showed that legs setal count was fixed in *E. orientalis* on coxae, trochanters, and genua I–IV (2–1–1–1, 1–1–1–1 and 5–5–2–2), respectively (see Table 1). Chaetotaxy on leg femora and tibiae were observed mostly as I–IV (8–6–3–1) and (9(1)–6–6–7), respectively. The differences in legs chaetotaxy of the specimens of *E. orientalis* belonging to the same and different populations were observed on femora I 7 (n = 3), 7/8 (n = 10); femora II 5/6 (n = 2), 6/7 (n = 2); femora III 3/4 (n = 10), 3 (n = 40); 4 (n = 23), 2/3 (n = 3); femora IV 1/2 (n = 8); on tibiae I 8/9 (1) (n = 7), 8 (1); tibia II 6/7 (n = 3); tibia III 6/5 (n = 2); tibia IV 7/6 setae (n = 2) in the current study, similar to the variations on femora and tibiae documented by Khanjani et al. (2017) in *E. orientalis* populations collected from Iran and Australia.

The spermathecal sacculus terminally varied from rounded to slightly pointed in some specimens of this study (Figures 48A, 49A). Also, the length of the spinneret on the palp tarsus varied from three to four times compared to its width. Similarly, Khanjani et al. (2017) reported that shape of spermathecal sacculus varied distally from rounded to pointed and that spinneret length also varied in *E. orientalis*. However, Meyer (1987) considered variations in shape of spermathecal sacculus (rounded or pointed distally) and length of spinneret (3 to 4 times as long as its width) as a method to differentiate *E. fici* Meyer from *E. orientalis*.

The morphological variations in *E. orientalis* have resulted in misidentifications and additions of new species in the genus *Eutetranychus*. Because some morphological variations have now been reported in *E. orientalis*, four species *Anychus ricini* Rahman & Sapra, 1940, *E. monodi* André, 1954, *E. sudanicus* El Badry, 1970, and *E. annecki* Meyer, 1974 were synonymized with *E. orientalis* by Meyer (1987) and Bolland et al. (1998).

Eutetranychus fici Meyer, reported from Africa, was separated from *E. orientalis* by the slightly longer dorsocentral setae, shape of spermathecal sacculus, and length of palp spinneret (Table 2; Meyer 1987). The three species *E. pruni*, *E. ricinus*, and *E. sanaae* reported from Yemen were differentiated from *E. orientalis* by variation in the number of setae on femora I and IV, shapes of dorsal setae, and striation pattern between setae *d1* and *e1* (Smiley and Baker 1995). *Eutetranychus phaseoli* Nassar & Ghai, 1981 reported from India was separated from *E. orientalis* based on the difference in numbers of setae on femur I and distances between dorsal setae *e1* and *f1* (see also Table 2). The two species *E. guangdongensis* and *E. xianensis*, reported from China, were distinguished from *E. orientalis* and *E. banksi*, respectively, based only on differences in lengths of dorsal setae (Ma and

Yuan 1982) (Table 2). However, the leg chaetotaxy of these two species were mentioned in the original descriptions as being similar in *E. orientalis* (Ma and Yuan 1982) (Table 2).

Because these seven species have been differentiated in their original descriptions by only one or more variable characters which have also been observed in *E. orientalis* populations (Chaudhri et al. 1974, Meyer 1987, Khanjani et al. 2017) as well as this study (see Table. 2), these seven *Eutetranychus* species (*E. phaseoli*, *E. guangdongensis*, *E. xianensis*, *E. fici*, *E. pruni*, *E. ricinus*, and *E. sanaae*) are suggested as synonyms of *E. orientalis* in this study.

Species *Inquirenda*

Eutetranychus papayensis Iqbal & Ali, 2008

Eutetranychus papayensis Iqbal & Ali, 2008: 125–130.

Host and Distribution. Female, from *Carica papaya* L. (Caricaceae), Abbottabad, Pakistan.

Eutetranychus papayensis was described with coxae I–IV 2–2–2–2 (whereas they illustrate 2–2–1–1 setae) and three pairs of anal setae. Also, the empodium of this species were neither described nor illustrated. So, based on these characters together, *E. papayensis* can neither be placed in *Eutetranychus* nor even in other genera of the family Tetranychidae.The first author has informed us that type specimens of this species have been lost. Therefore, *E. papayensis* is considered as a species inquirenda.

After excluding those seven species which we suggest as synonyms and one species inquirenda, the genus *Eutetranychus* includes 28 species (including the new species described herein) and is divided into two species groups based on the number of setae (one or two) on coxae II: the species group *orientalis* has one seta on coxa II (12 species) and the species group *banksi* has two setae on coxa II (16 species). The number of setae on coxae II has been considered as a solid morphometric character founded to be strongly constant in all specimens of each *Eutetranychus* species (Pritchard and Baker 1955, Baker and Pritchard 1960, Chaudhri et al. 1974, Meyer 1974, 1987, Khanjani et al. 2017).

Key to the world species of the genus *Eutetranychus* (females)

1	Coxa II with 2 setae	**species group *banksi*–2**
–	Coxa II with 1 seta	**species group *orientalis*–17**
2	Setae *f1* two times more widely spaced as setae *e1* or marginal in position	**3**
–	Setae *f1* equally spaced or slightly more widely spaced as setae *e1*	**5**
3	Hysterosoma with elipitical elevations in between dorsocentral setae *c1* and *e1*; dorsal setae set on strong tubercles	***cratis* Baker & Pritchard, 1960 (Congo)**
–	Hysterosoma without elipitical elevations in between dorsocentral setae *c1* and *e1*, dorsal setae set on small tubercles	**4**

4 Genua I and II with 5 setae, setae *f1* marginal in position ....***anitae* Estebanes-Gonzalez & Baker, 1968 (Mexico)**
– Genua I and II with 4 setae, setae *f1* in normal position ....***banksi* (McGregor, 1914) (USA)**
5 Hysterosoma dorsomedially with transverse striations ....***nomurai* Flechtmann, 1997 (Brazil)**
– Hysterosoma dorsomedially with a band of "V" shaped or longitudinal striae between setae *d1* and *e1* **6**
6 Genua III and IV with 1 seta ....***acaciae* Miller, 1966 (Tasmania)**
– Genua III and IV with more than 1 setae...**7**
7 Genu III with 5 setae ....***concertativus* Meyer, 1974 (Namibia)**
– Genu III with 2 or 3 setae...**8**
8 Genua III and IV with 3 or 4 setae **9**
– Genua III and IV with 2 setae...**12**
9 All dorsal body setae slender, much longer; dorsocentral setae *c1, e1* and *f1* reaching past bases of next consecutive setae .... ***spinosus* sp. n.**
– All dorsal body setae short, oblanceolate to subspatulate, dorsocentral setae *c1, d1* and *f1* reaching at least half distance of next consecutive setae.................**10**
10 Femur I with 7 setae, femur IV with 1 setae...**11**
– Femur I with 8 setae, femur IV with 2 setae.. ....***swazilandicus* Meyer, 1974 (South Africa)**
11 Tibia III with 7 setae ....***rhusi* Meyer & Ueckermann, 1988 (South Africa)**
– Tibia III with 8 setae .... ***namibianus* Meyer, 1987 (Namibia)**
12 Tibia II with 5 setae..**13**
– Tibia II with 6 setae..**14**
13 Setae *v2* as long as to the distance *v2–v2*, setae *f2* reaching past bases of setae *h*; dorsal setae slender; all setae with tubercles ....***bredini* Baker & Pritchard, 1960 (Rwanda)**
– Setae *v2* and *f2* reaching one third to the distances *v2–v2* and *f2–h1* respectively; dorsal setae oblanceolate to subspatulate; only few opisthosomal setae set on tubercles...................................... ***clastus* Baker & Pritchard, 1960 (Congo)**
14 Tibia III with 6 setae, dorsocentral (*c1, d1, e1*) setae on prominent tubercles.... ....***africanus* (Tucker, 1926) (South Africa)**
– Tibia III with 5 setae, dorsocentral (*c1, d1, e1*) setae with small tubercles...........**15**
15 Tibia IV with 7 setae, femur III with 3 setae .... ***enodes* Baker & Pritchard, 1960 (Congo)**
– Tibia IV with 6 setae, femur III with 2 setae **16**
16 Tarsus I with solenidion of loosely associated setae about two third as long as proximal tactile seta, tarsus II with this solenidion slightly longer than proximal tactile setae... ***carinae* Meyer, 1974 (South Africa)**
– Tarsus I with solenidion of loosely associated setae about less than half as long as proximal tactile seta, tarsus II with this solenidion about two third as long as than proximal tactile seta.......................***eliei* Gutierrez & Helle, 1971 (Madagascar)**

17 Entire hysterosoma dorsomedially with transverse striations.......................... **18**
– Hysterosoma dorsomedially in between setae *d1* and *e1* with longitudinal or "V" shaped band of striations **19**
18 Femora I–IV with 5–4–2–1 .... ***neotransversus* sp. n.**
– Femora I–V with 7–7–4–3 .. ***transverstriatus* Smiley & Baker, 1995 (Yemen)**
19 Idiosoma with none of dorsal setae set on tubercles.. ....***palmatus* Attiah, 1967 (Egypt)**
– Idiosoma with most of the dorsal body setae set on tubercles **20**
20 Tibia II with 5 setae **21**
– Tibia II with 6/7 setae.. **24**
21 Most of dorsal setae set on strong tubercles; striae on prodorsum medially tortuous forming crescentic pattern .... ***pyri* Attiah, 1982 (Egypt)**
– Dorsal setae set on relatively small tubercles; striae on prodorsum medially longitudinal and lobed **22**
22 Dorsal body setae slender tapering towards tips, most of dorsal setae longer than the distance between their base and the bases of the next consecutive setae ....***pantopus* (Berlese, 1910) (Australia)**
– Dorsal body setae sub-spatulate to oblanceolate with blunt tips; most of setaeespecially dorsocentrals (*c1, d1, e1, f1*) short far behind the next consecutive setae **23**
23 Tibia I with 8 setae, all dorsal setae set on tubercles ....***caricae* Nassar & Ghai, 1981 (India)**
– Tibia I with 9 setae, setae *c1, d1, e1, f1, sc2* and *c3* without tubercles............... .... ***citri* Attiah, 1967 (Egypt)**
24 Tibia III with 5 setae........................ ***maximae* Nassar & Ghai, 1981 (India)**
– Tibia III usually with 6/7 setae or (sometime 5 setae on one side while on other side of tibia in same specimen of *E. orientalis*) **25**
25 Femur II with 5 setae **26**
– Femur II usually with 6/7 except 5 setae on femur II in some specimens of *E.orientalis*) **27**
26 Peritremes ending in bilobed bulb; setae *e2* short reaching half to the bases of setae *e1* and *f1*................................... ***bilobatus* Nassar & Ghai, 1981 (India)**
– Peritremes ending in a simple bulb-like structure; setae *e2* long reaching the bases of setae *e1* and *f1* .... ***nagai* Nassar & Ghai, 1981 (India)**
27 All dorsal setae long slender with tapering tips, dorsocentral setae *c1*, *e1*, *f1* crossing the bases of next consecutive setae; setae *e1* crossing the bases of *h1* ....***mirpuriensis* Chaudhri, Akbar & Rasool, 1974 (Pakistan)**
– Most of dorsal setae oblanceolate to subspatulate; setae *e1* far behind the bases of *h1* ....***orientalis* (Klein, 1936)**

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SHORT COMMUNICATION

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The easternmost discovery of the Mediterranean weevil *Pachyrhinus lethierryi* (Coleoptera, Curculionidae, Entiminae): Is a further invasion possible?

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Abstract

Pachyrhinus lethierryi (Desbrochers des Loges, 1875) is a Mediterranean weevil species that has become remarkably well known as a result of a series of recent introductions across Western and Central Europe. This species has recently reached Asia Minor and the Crimean Peninsula, as confirmed by several new records. The vectors of invasion in Crimea and possible further expansion are suggested.

Keywords

Asia Minor, Crimea, invasive species, new record, Polydrusini, weevils

Introduction

The native range of *Pachyrhinus lethierryi* is along the Mediterranean coast of France, Corsica, Sardinia, and Sicily (Hoffmann 1950). Since the 1980s, *P. lethierryi* has spread rapidly as an adventive species into many European countries (Germann et al. 2005, 2013; Scholze 2007; Heijerman 2008; Delbol 2009; Barclay and Morris 2011, Yunakov 2013; Çerçi 2016; Germann and Braunert 2018).

Material and methods

For spatial analysis we used occurrence datasets from the Global Biodiversity Information Facility (GBIF 2018) and the Ukrainian Biodiversity Information Network (UkrBIN 2018). The beetle and genitalia were photographed with a Zeiss SteREO Discovery.V20 microscope equipped with Canon EOS 5D Mark III camera. Spatio-temporal data have been mapped in QGIS v. 3.2 using a Google Maps satellite imagery layer. Male genitalia were placed in a transparent polypropylene tube with glycerine and pinned to the underside of the card with the mounted specimen.

Collections

RPQC All-Russian Plant Quarantine Center, Moscow
ZMUN Zoological Museum University of Oslo, Norway

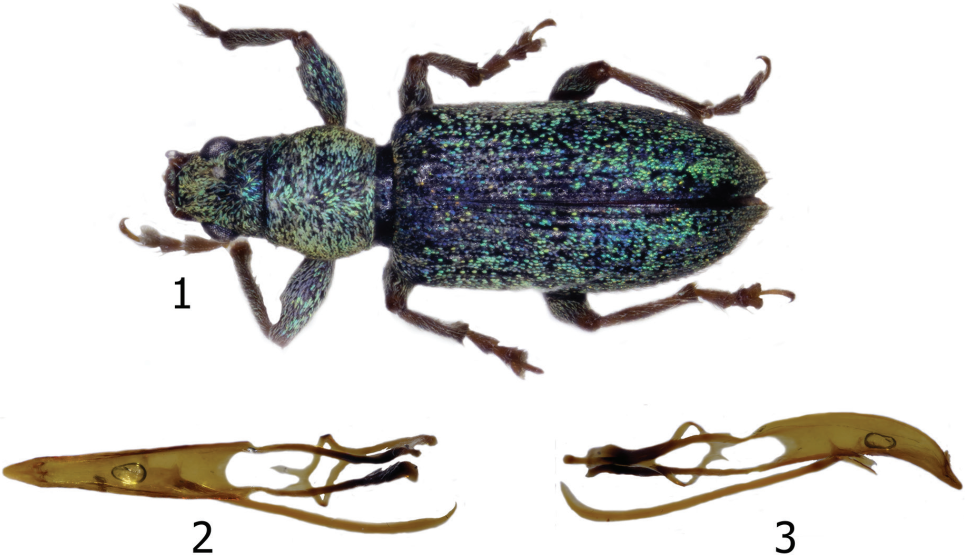
Results and discussion

***Pachyrhinus* (*Pachyrhinus*) *lethierryi lethierryi* (Desbrochers des Loges, 1875)**
Figures 1–3

Material examined. 1 f, Crimea, Yalta, Mt Dorsan, 44.5030N; 34.1601E, beating from *Thuja occidentalis*, N. Yunakov leg., 01.ix.2013 (ZMUN); 1 m, Crimea, Sevastopol, Uchkuyevka, 44.6408N; 33.5367E, E.N. Akulov leg., 1–7.vi.2017 (RPQC).

Recent records indicate that *P. lethierryi* is continuing its expansion to eastward. The northernmost record to date is from Magdeburg, Germany, in 2013. In 2018, it was first recorded in Asia Minor at Urla, İzmir, Turkey (UkrBIN 2018). All specimens were found in urban areas with numerous *Cupressus*, *Thuja*, and *Juniperus* trees in neighbouring properties. These plants are known as the principal hosts for *P. lethierryi* (Hoffmann 1950; Alziar 1977; Germann et al. 2005; Plant et al. 2006) and are considered to be the main vectors for the further spread of *P. lethierryi* (Heijerman 2008). Recent records from Crimea are obviously in line with a general trend of this species' dispersal northward and eastward with commercial ornamental plants. However, we have no proof that *P. lethierryi* has established a viable population in Crimea. Thus, it may be preliminarily characterized as a "Robinson Crusoe species", that is, one that was accidentally introduced without further naturalization. A remarkable feature of adventive populations of *P. lethierryi*, along with some invasive *Otiorhynchus* species, is that no specimens are known from natural habitats.

In Asia Minor and Crimea, *P. lethierryi* can be easily confused with some species of the genera *Dichorrhinus* Desbrochers des Loges, 1875 and *Rhinoscythropus* Desbrochers des Loges, 1895. The following key is given to distinguish *P. lethierryi* from similar species:



Figures 1–3. *Pachyrhinus lethierryi*. **1** Male, dorsal habitus **2** Aedeagus, dorsal view **3** Aedeagus, lateral view.

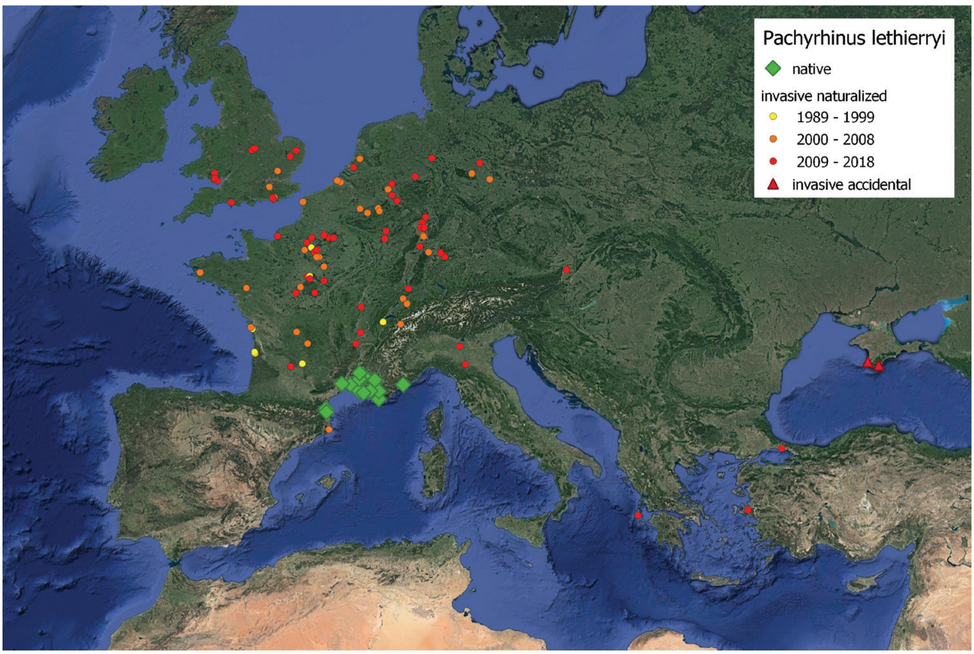


Figure 4. Occurrence pattern of *Pachyrhinus lethierryi*. The yellow through orange to red gradient indicates the chronology of invasion from 1989 to present.

1 Antennal scrobes laterally open. Epifrons (rostral dorsum) between antennal base as wide as distance between eyes. Antennal scape slightly curved. Median lobe regularly narrowed apically, without subapical lateral callosities **2**

– Antennal scrobes dorsally open. Epifrons (rostral dorsum) between antennal base as wide as ½ distance between eyes. Antennal scape strongly curved. Median lobe constricted before apex, with subapical lateral callosities **3**

2 Scales ovate, uniformly green. Frons (nasal plate) squamulate. Body with black erect or suberect pilosity. Body length to 5 mm ....***Pachyrhinus lethierryi*** **(Desbrochers des Loges, 1875)**

– Scales piliform, cupreous, forming spotty pattern on elytra. Body without black erect or suberect pilosity. Body length greater than 6 mm ....***Pachyrhinus squamulosus*** **(Herbst, 1795)**

3 Frons (nasal plate) bare. Longitudinal diameter of eye equals 0.5–0.6 times distance between eyes............. ***Dichorrhinus*** **Desbrochers des Loges, 1875**

– Frons (nasal plate) squamulate. Longitudinal diameter of eye equal to distance between eyes .... ***Rhinoscythropus vespertilio*** **(Faust, 1884)**

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RESEARCH ARTICLE

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Two new species of *Feroperis* Lafer (Carabidae, *Pterostichus*) from China, with a key to all known Chinese species in this subgenus

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Abstract

Two new *Pterostichus* species (Coleoptera, Carabidae) in the subgenus *Feroperis* Lafer, 1979 are described from Zhangguangcai Mountain, northeastern China: *Pterostichus* (*Feroperis*) *silvestris* Sun & Shi, **sp. n.** and *Pterostichus* (*Feroperis*) *maryseae* Sun & Shi, **sp. n.** Detailed descriptions and illustrations of the male endophallus and female reproductive tracts for these new species are provided, along with a key to the five known species of the subgenus in China.

Keywords

China, *Feroperis*, ground beetles, morphology, taxonomy, temperate forest

Introduction

The subgenus *Feroperis* in the genus *Pterostichus* Bonelli, 1810, was erected by Lafer (1979) and originally comprised 17 species. Subsequently, eight species were added to this subgenus (Park and Kwon 1996, Berlov and Berlov 1996, Lafer 2011), all of them now valid. Not long ago, three of the species originally placed by Lafer (1979) into *Feroperis* were downgraded to subspecies rank (Sundukov 2013). Thus, prior to this study, the subgenus *Feroperis* Lafer included 22 species and three subspecies (Bousquet 2017). After its establishment, *Feroperis* has been regarded as synonym of other subgenera of *Pterostichus* by some authors. For example, Kryzhanovskij et al. (1995) placed it as a synonym of *Petrophilus* Chaudoir, 1838. Based on a preliminary phylogenetic analysis on characteristics of the endophallus, Sasakawa and Kubota (2006) confirmed, too, the synonymy of *Feroperis* with *Petrophilus*. Most recently, Sundukov (2013) treated the subgenus in question as a synonym of *Morphnosoma*. In the present work, we follow the dominant view (e.g. Park and Kwon 1996, Lafer 2011) and catalogues (Lorenz 2005, Bousquet 2017), where *Feroperis* is generally regarded as a valid subgenus of *Pterostichus*.

Members of the subgenus *Feroperis* can be distinguished from other subgenera within *Pterostichus* by the following combination of characters: ridge between outer basal foveal groove of pronotum and lateral margin strongly carinate; third elytral interval with three or more setigerous pores which are positioned adjacent to the second stria; fifth elytral interval without setigerous pores; length of metepisternum shorter than its basal width; metatrochanter without seta; fifth tarsomere setose beneath; males without sex-specific differentiation of sternum VI or VII; median lobe of aedeagus with both apical orifice placed on the dorsal surface and apical lamella simple or thickened; right paramere thick, more or less elongate and with apex bent and pointed.

Most species of *Feroperis* hitherto known were recorded from the Russian Far East (15 spp.) and the Korean Peninsula (8 spp.). Only three species: *P. acutidens* (Fairmaire, 1889), *P. melanodes* (Chaudoir, 1878), and *P. rasilis* Park & Kwon, 1996 have been reported from China (Bousquet 2017, Lafer 2011). Compared to the rich fauna in neighboring countries, the number of known species of *Feroperis* in China is conspicuous low, implying a high likelihood of new species to be discovered. Over the last decade, our investigations of forest ground beetle communities in China's regenerating temperate forest landscapes resulted in collections of large numbers of *Feroperis* specimens. This material includes samples from the forests of the Zhangguangcai Mountain, which is situated on the border between Heilongjiang Province and Jilin Province, northeastern China. After detailed studies of these specimens, we ascertained that they belong to two species that are new to science. Hence, in this paper, we are describing and illustrating these two new species, and providing a key to all known Chinese species of the subgenus *Feroperis*.

Methods

A total of 80 pitfall traps were placed at five distinct forest types representing mature, secondary and planted forests, on the Zhangguangcai Mountain range at elevations between 771 and 985 m. All carabid beetles collected in the traps were subsequently pinned and dissected using routine techniques (Shi et al. 2013). All the examined specimens are housed in the collections of the Institute of Zoology, Chinese Academy of Science, Beijing, China (IZAS).

Body length of specimens was measured from the anterior margin of the labrum to the apex of the elytral suture; maximal width of head (HW) was recorded as the greatest width between the lateral margins of the eyes; PW and EW represent the greatest widths of the pronotum and elytra, respectively; the apical width of pronotum (PA) was measured as the width between the tips of pronotal anterior angles; basal width of the pronotum (PB) was recorded as the width between the posterior angles of the pronotum; the pronotum length (PLm) was the respective length along the midline of the pronotum; the total pronotum length (PLt) was the length between the anterior angles and posterior angles of the pronotum; the length of elytra (EL) was measured from the apex of the scutellum to the sutural apex. All measurements were made with the aid of an ocular micrometer under a Nikon SMZ18 stereomicroscope.

Male genitalia were extracted using forceps, and endophalli were prepared for 15 and 21 specimens of the two species, respectively, by microinjection. The median lobe of the aedeagus was soaked in 10% KOH solution at room temperature for 8–20 hours and subsequently stored in 100% ethanol. The basal orifice of the aedeagus was injected with 100% ethanol with a microinjector to fully evert the endophallus. The treated male genitalia were kept in 100% ethanol during the initial investigations, and they were later transferred into glycerol for permanent storage. Female genitalia were prepared from the last one or two abdominal ventrites of 9 and 12 specimens representing the two species, respectively, and immersed in 10% KOH solution at room temperature for 8–20 hours. The female genitalia were then extracted from the abdominal segments and stained in Chlorozol Black E-saturated solution based on 70% ethanol for approximately 10 seconds, before being rinsed and stored in 70% ethanol for imaging and permanent storage. The species examination and subsequent descriptions were made using a Nikon SMZ18 binocular stereoscope, while a Leica205C stereomicroscope equipped with photographic adapters was used to take images of the specimens and their genitalia.

Results

Subgenus *Feroperis* Lafer, 1979

Feroperis Lafer, 1979: 5. Type species: *Feronia jugens* Tschitschérine, 1893, by original designation (Lafer 1979).

Diagnosis. Body of medium size (13.0–17.5 mm), surface completely black and polished, palpi brown, legs and antennae black or dark brown. Head with very weak punctures; eyes large and convex; antennae reaching the base of pronotum. Pronotum more or less round, 1.3–1.6 times wider than the head; anterior angles rounded, moderately or strongly protruding; lateral border gradually widened and then narrowed towards the base, maximum width near anterior third; lateral channel narrow in front but expanding towards the base in the posterior half; basal margin slightly concave in the middle, either rectilinear or obliqued on the sides; basal foveae usually slightly punctate, outer basal foveal groove deep, reaching the basal margin, the inner basal foveal groove shallower and not reaching the basal margin; carinae between lateral margin and outer basal foveae clearly expressed, perpendicular or inclined towards basal margin, well-separated from the lateral channel and approaching to it near the basal margin; pronotum with two lateral setae, one at the posterior angle, the other one near the pronotal maximum width; pronotum disc with transverse wrinkles. Elytra wide, 1.10–1.35 times wider than pronotum, 1.5–1.6 times wider than elytral width; lateral margins subparallel, widest in the middle; basal ridge continuous, forming an indistinct obtuse angle with the elytral lateral margin; humeral teeth small but distinct; striae deeply incised, without or with very fine punctures; intervals moderately convex; parascutellar pore present; scutellar striae present; third interval with three or more setigerous pores, usually 3–4, rarely 5–6, usually adjacent to the second striae; seventh interval with two preapical pores; umbilical setigerous series on the ninth interval, interrupted in the middle. Hind wings very small, not functional. Metepisternum short, its length along inner margin subequal to the width of anterior margin; sterna IV–VI with a pair of central setae; males with one pair, females with two pairs of marginal setae on sternum VII, slightly removed from the apical margin. Mesofemora and metafemora with two setae on posterior margin; metatrochanters without setae; metacoxae with two setae; fifth tarsomeres setose beneath. Median lobe of aedeagus slender, bent usually at about 90 degrees; median lobe almost straight in median portion (between the basal bend and apical lamella); apical orifice opened to the dorsal-left side; the shape of the apical portion of apical lamella shows species-specific differences. Stylomere 2 with two ensiform setae at the outer margin and one ensiform seta in the middle part of its inner margin; two nematiform setae in a short fovea near the apex of inner surface (i.e. Lafer 1979).

Key to Chinese species of subgenus *Feroperis* Lafer

1 Posterior angles of the pronotum obtuse or weakly protruding, lateral border not or only slightly thickened at the posterior angles (Fig. 7A–B) **2**

– Posterior angles of pronotum strongly protruding forming strong denticles, lateral border strongly thickened at the posterior denticles (Fig. 7C–D)...... **3**

2 Pronotal posterior angles obtuse, not forming denticles; carinae between basal foveae and lateral margins shallower; male genitalia unknown (Fig. 14B) .... ***P. melanodes* (Chaudoir, 1878)**

– Pronotal posterior angles weakly protruding, forming small denticles; carinae between basal foveae and lateral margins stronger; apical lamella of aedeagus widened to apex; length approximate 1.5 times as its basal width (Figs 1–2)..... .... ***P. silvestris* sp.n.**

3 Apical lamella of aedeagus distinctly widened to apex, length approximate 1.5 times as basal width (Park and Kwon 1996: fig. 2F–G) .... ***P. rasilis* Park & Kwon, 1996**

– Apical lamella of aedeagus gradually narrowed to apex, length 1.0–1.2 times as basal width.. **4**

4 Pronotal posterior angles with smaller denticles (Fig. 7C–D); in lateral view, ventral margin of apical lamella of aedeagus straight before apex (Fig. 9C); apical lamella apex slightly truncate in dorsal view (Fig. 9A) .... ***P. maryseae* sp.n.**

– Pronotal posterior angles with larger denticles (Fig. 14A); in lateral view, ventral margin of apical lamella of aedeagus slightly curved before apex; apical lamella apex rounded in dorsal view (Lafer 1979: figs 1–3) .... ***P. acutidens* (Fairmaire, 1889)**

***Pterostichus* (*Feroperis*) *silvestris* Sun & Shi, sp. n.**
http://zoobank.org/FE776971-524A-4E86-A73C-FF0AEE663226
Figs 1–6

Type locality. CHINA: Heilongjiang Province, Hailin County, Taipinggou Forest Farm (44°24.6168'N, 128°24.5570'E), altitude 985 m.

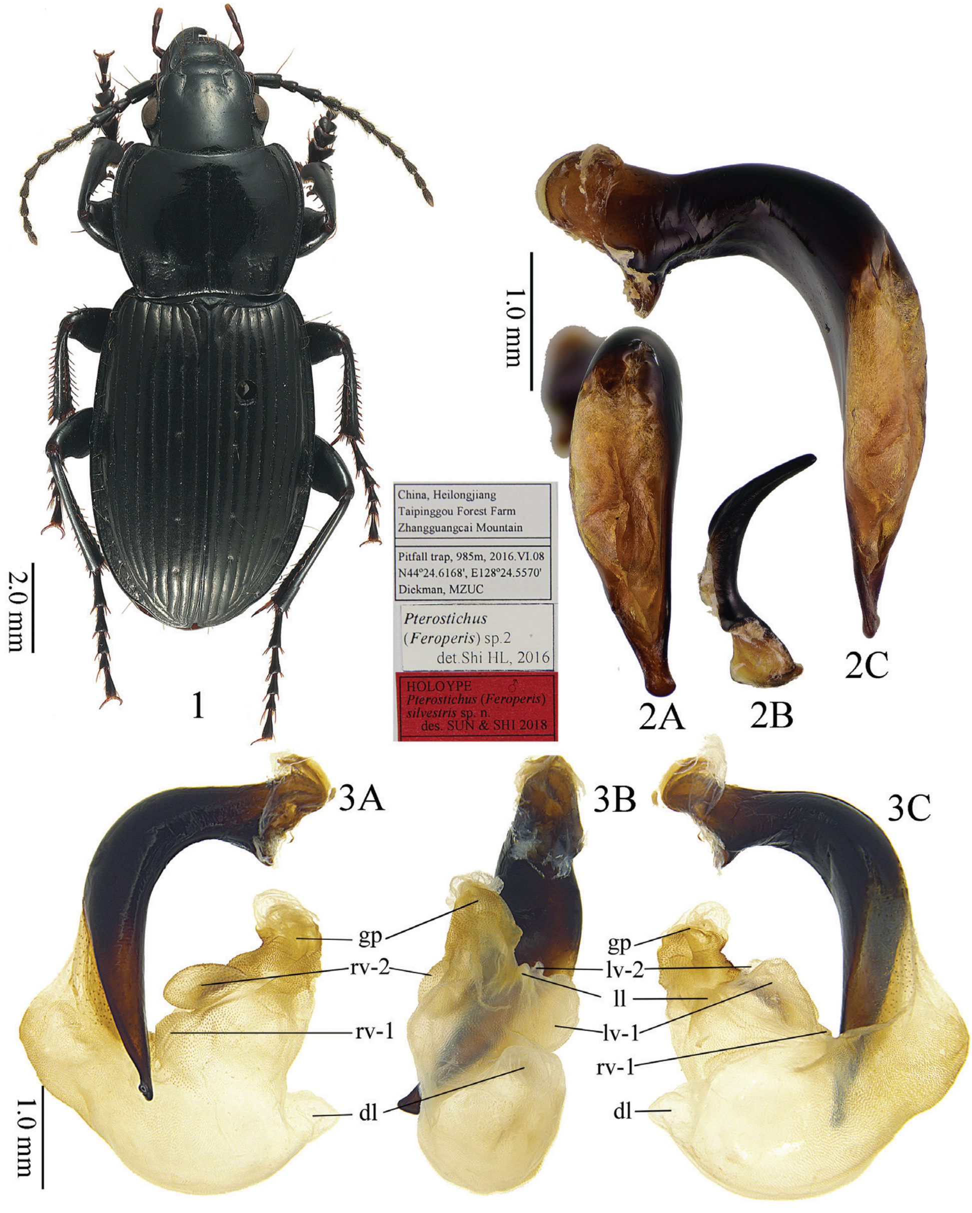
Type materials. Holotype (IZAS): male, body length 12.9 mm, board mounted, genitalia dissected and glued on plastic film pinned under specimen, "China, Heilongjiang / Taipinggou Forest Farm / Zhangguangcai Mountain"; "Pitfall trap, 985 m, 2016.VI.08 / 44°24.6168'N, 128°24.5570'E / Diekman, MZUC"; "HOLOTYPE ♂ / *Pterostichus* (*Feroperis*) / *silvestris* sp. n. / des. SUN & SHI 2018" [red label]. Paratypes (a total of 1643 specimens [906 males and 737 females], all in IZAS): 247 males and 132 females, the same data as holotype, but labeled as paratype. 126 males and 227 females, "China, Heilongjiang / Taipinggou Forest Farm / Zhangguangcai Mountain"; "Pitfall trap, 985 m, 2016.VI.21 / 44°24.6168'N, 128°24.5570'E / Sun Xiaojie, MZUC"; "PARATYPE / *Pterostichus* (*Feroperis*) / *silvestris* sp. n. / des. SUN & SHI 2018" [red label]. 284 males and 160 females, "China, Heilongjiang / Taipinggou Forest Farm / Zhangguangcai Mountain"; "Pitfall trap, 985 m, 2016.VII.05 / 44° 24.6168'N, 128°24.5570'E / Sun Xiaojie, MZUC"; "PARATYPE / *Pterostichus* (*Feroperis*) / *silvestris* sp. n. / des. SUN & SHI 2018" [red label]. 192 males and 156 females, "China, Heilongjiang / Taipinggou Forest Farm / Zhangguangcai Mountain"; "Pitfall trap, 985 m, 2016.VIII.03 / 44°24.6168'N, 128°24.5570'E / Sun Xiaojie, MZUC"; "PARATYPE / *Pterostichus* (*Feroperis*) / *silvestris* sp. n. / des. SUN & SHI 2018" [red label]. 57 males and 62 females, "China, Heilongjiang / Taipinggou Forest Farm / Zhangguangcai Mountain"; "Pitfall trap, 985 m, 2016.VIII.31 / 44°24.6168'N, 128°24.5570'E / Sun Xiaojie, MZUC"; "PARATYPE / *Pterostichus* (*Feroperis*) / *silvestris* sp. n. / des. SUN & SHI 2018" [red label].

Diagnosis. This new species can be distinguished from all other species of the subgenus by the combination of following characters: (1) lateral margins of pronotum evenly convex at about anterior two thirds, then gradually contracted and almost straight before posterior angles; (2) pronotum posterior angles weakly protruding, forming indistinct denticles, lateral border not widened at posterior angles, its width subequal to the lateral border of pronotum; (3) apical lamella of the aedeagus as long as 1.5 times its basal width; apex capitate in dorsal view, widened at both left and right margins, but only slightly thickened in lateral view; apical lamella distinctly oblique to the right in dorsal view, with ventral margin slightly twisted dorsally in lateral view (Fig. 2A).

The new species is special in the subgenus for its male genitalia with apical lamella capitate, both margins widened near apex in dorsal view, and not strongly thickened in lateral view. These aedeagal characters can distinguish it from most species of *Feroperis* except for the five species *P. chechcirensis* Lafer, 1979, *P. vladivostokensis* Lafer, 1979, *P. rasilis* Park & Kwon, 1996, *P. seungmoi* Park & Kwon, 1996, and *P. pawlowskii* Lafer, 2011. Among them, *P. chechcirensis* can be readily distinguished by its pronotal posterior angles being obtuse, without any trace of denticle; *P. vladivostokensis* and *P. rasilis* are different in their pronotal posterior angles being strongly pointed, forming very large denticles. From the remaining two species, *P. seungmoi* can be easily identified by its characters that widest of pronotal lateral channels at about 1/3 length to the posterior margin, so *P. silvestris* is considered to be closer to *P. pawlowskii* (North Korea: Nampotesan, 41°44'N, 128°24'E), based on their more similar external characteristics and close areas of distributions.

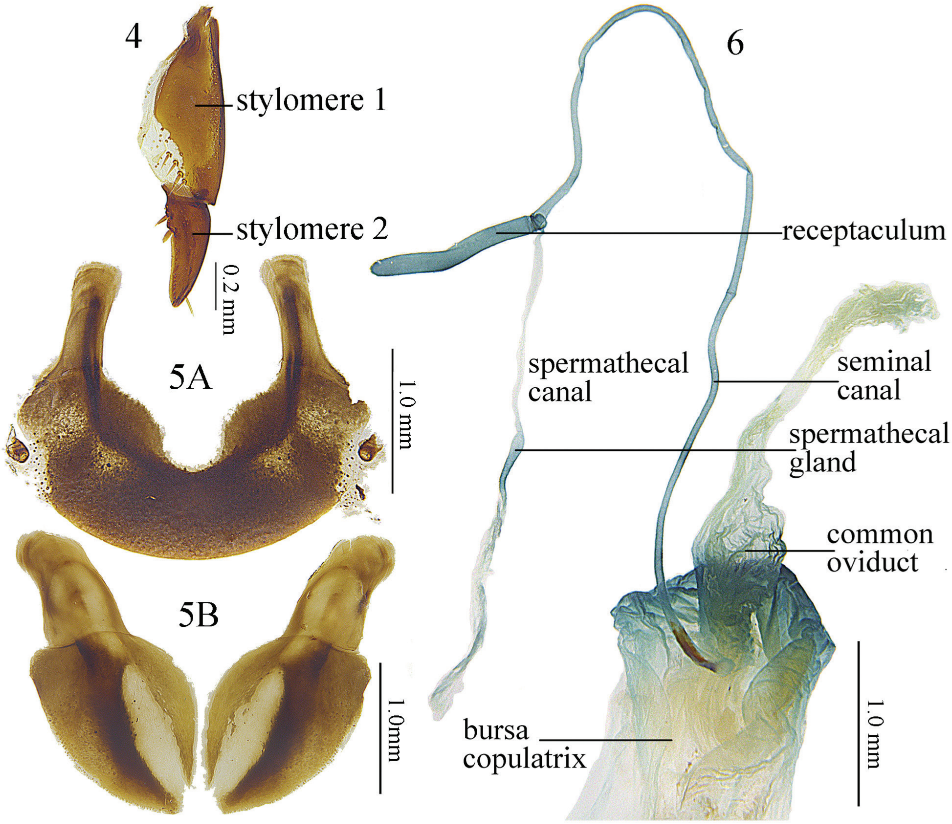
Considering *P. pawlowskii*, the new species is distinguishable from it by the presence of micro-punctures on vertex and by the pronotal disc with very fine punctures rather than reticular traces. Furthermore, these two species can be also distinguished by: (1) the pronotum widest at about basal 2/3 in *P. pawlowskii*, vs widest at about 3/5 in *P. silvestris*; (2) in *P. silvestris*, the pronotum less constricted to the base; (3) in *P. pawlowskii*, the apical lamella of aedeagus shorter, its length reaching as long as 1.2 times the basal width, apex almost straight or very weakly bent to the left in dorsal view; while in *P. silvestris*, the apical lamella of the aedeagus is distinctly longer, its length about 1.5 times the basal width, apex distinctly bent to the right in dorsal view.

Description. Body length 12.8–14.9 mm (mean ± SD: 13.8 ± 0.65, n = 20), both sexes with similar body shape. Dorsal surface black and shiny; tarsi and antennae dark brown; head and pronotum without microsculpture; elytra with very fine and isodiametric microsculpture. **Head** mostly smooth, polished, with very fine and sparse punctures on vertex and occiput; eyes moderately convex; antennae reaching the base of pronotum. **Pronotum** wider than the head (PW/HW =1.11–1.52, mean ± SD: 1.44 ± 0.09, n = 20); rounded in shape, widest at about 3/5 length to the posterior margin (PW/PLt = 1.11–1.38, mean ± SD: 1.27 ± 0.07, n = 20; PW/PLm = 1.22–1.52, mean ± SD: 1.40 ± 0.07, n = 20); lateral margins evenly convex from apex to about basal 1/3, then gradually contracted and almost straight before the posterior angles (PW/PA = 1.27–1.47, mean ± SD: 1.37 ± 0.05, n = 20; PW/PB = 1.23–1.43, mean ± SD: 1.32 ± 0.05, n = 20); apical width of pronotum nearly same as its basal width (PB/PA = 0.94–1.14, mean ± SD: 1.04 ± 0.05, n = 20). Anterior angles obtuse and rounded, distinctly contracted inward; lateral channels narrow in front of midpoint and gradually expanded towards the base, with flatten and sparse punctures on them. Posterior angles obtuse, weakly protruding and forming weak denticles of angle exceeding to 100° (147.4°–166.8°, mean ± SD: 155.1° ± 5.10°, n = 18, Fig. 7A–B); pronotal lateral border not widened at posterior angles, width



Figures 1–3. *Pterostichus* (*Feroperis*) *silvestris* sp. n. **1** Habitus and labels of holotype **2** Male genitalia of holotype **A** dorsal view of median lobe, **B** right paramere, **C** left lateral view of median lobe **3** Endophallus of a paratype **A** right lateral view, **B** ventral view, **C** left lateral view.

similar or less wide as lateral border of the pronotum anterior to the posterior angles; carinae between lateral margins and pronotal basal foveae strong, parallel to the fine median line. Basal foveae moderately deep, clearly defined throughout except at the basal area, outer basal foveal groove long and deep, reaching the posterior margin of the pronotum, inner basal foveal groove short and weakly incised, not reaching the posterior margin of the pronotum; basal foveae slightly rugose and sparsely punctate; disc moderately convex and smooth, only very finely and sparsely punctate. **Elytra** oviform (EL/EW = 1.35–1.56, mean ± SD: 1.43 ± 0.05, *n* = 20; EL/PLt = 2.03–2.31, mean ± SD: 2.21 ± 0.08, *n* = 20; EW/PW = 1.17–1.29, mean ± SD: 1.22 ± 0.03, *n* = 20), widest near the middle; elytral base slightly depressed in the middle; striae deeply impressed, with fine and sparse punctures; parascutellar striae long, apex free, short or connected with first stria; parascutellar pore present on the base of first stria. Third interval generally with 3–6 setigerous pores, situated mostly closer to the second stria (location and number of discal pores variable in some individuals: additional pores occasionally present at the first, second, third and fifth intervals, same specimen may has different discal pore placement on left and right elytron); umbilicate series of pores on the ninth interval, each side composed of 16–20 pores, sparser in the middle, denser anteriorly and posteriorly. Hind wings reduce as leathery wing bud. **Ventral side:** pro- and mesoepisternum sparsely punctate and shallowly rugose; metepisternum with coarse punctures; abdominal sterna glabrous in the middle, with shallow wrinkles laterally; sterna IV and V with sparse coarse punctures and shallow rugosity laterally. **Legs** long and slender; first meso- and metatarsomeres with distinct carina on the outer surface, these occur also near the base of the second tarsomeres; fifth tarsomeres with 2–4 pairs of setae on ventral surface. **Male genitalia:** median lobe of aedeagus bent more than 90 degrees at basal 2/5 (Fig. 2C); in lateral view, ventral margin straight in the middle, apical portion not bent to the ventral side; apical orifice slightly turned to the left; apical lamella long and strongly oblique to the right, length about 1.5 times as it basal width; apex strongly widened in dorsal view, widened with similar angles at both left and right margins (Fig. 2A); apex slightly thickened in lateral view. Right paramere very long and strongly bent, gradually narrowed to apex, apical portion thick, apex sharp (Fig. 2B). **Endophallus** (Fig. 3) extending from the dorsal-left side of aedeagus to ventral side, major parts of endophallus located on the ventral side of the aedeagus, basal portion strongly swollen to the dorsal direction; gonopore (**gp**) located near the basal-ventral direction of the aedeagus, pointing towards the aedeagal base. Six distinct recognizable lobes: left lateral lobe (**ll**) compressed, forming a widening triangular shape towards the base of gp when viewed dorsally, surface with fine scales; left ventral lobe (**lv**) divided into two separate sub-lobes; **lv-1** trochoid, apex positioned towards aedeagal base, base adjacent to rb; **lv-2** very small, situated at about half the height of lv-1; right ventral lobe (**rv**) composed of two sub-lobes: **rv-1** small and compressed, on the base of left-ventral surface of endophallus, close to the aedeagal apex, surface with fine scales; **rv-2** large and oblate, between the base of gp and rv-1, surface with fine scales; dorsal lobe (**dl**) very large and strongly bulging, apex coniform and pointing to the ventral direction. **Female genitalia:** spermatheca with the seminal canal as long as about six times the length of the receptaculum; receptaculum tubiform, with round apex; spermathecal gland very long; the seminal canal inserted at the base of the common



Figures 4–6. *Pterostichus* (*Feroperis*) *silvestris* sp. n., a female paratype **4** Stylomere of female ovipositor, ventral view **5 A** tergum VIII, **B** sternum VIII **6** Female reproductive tracts.

oviduct, base of the seminal canal sclerotized (Fig. 5). Stylomere 1 (Fig. 4) with thick setae ventro-apically, stylomere 2 with two ensiform setae at the outer margin and with one ensiform seta at the upper middle part of its inner-ventral margin. Tergum VIII (Fig. 5A) with major portion chitinized, two small semi-chitinized patches with dense spots on each side; anterior margin with a wide, U-shaped notch in middle. Sternum VIII (Fig. 5B) with sparse setae on posterior margin; posterior margin curved, deeply notched in the center; posterior region chitinized, anterior region semi-chitinized, with a V-shaped transparent region on the center, adjacent to the central posterior notch.

Distribution. This species is known only from the type locality, Taipinggou Forest Farm, Zhangguangcai Mountain in Heilongjiang Province of China.

Etymology. The name "*silvestris*" derives from the Latin adjective "*silvestris*", which means "pertaining to a forest or wood", as well as "living in forest". This species is named for its distinct habitat, with all individuals collected in natural forest types such as mixed secondary forest and mature forest habitats.

***Pterostichus* (*Feroperis*) *maryseae* Sun & Shi, sp. n.**
http://zoobank.org/F019330F-BD6C-4368-8330-83E992D85A53
Figs 7–13

Type locality. CHINA: Heilongjiang Province, Hailin County: Taipinggou Forest Farm (44°24.7459'N, 128°24.4753'E), altitude 958 m.

Type materials. Holotype (IZAS): male, body length 13.4 mm, board mounted, genitalia dissected and glued on plastic film pinned under specimen, "China, Heilongjiang / Taipinggou Forest Farm / Zhangguangcai Mountain"; "Pitfall trap, 958 m, 2016.VI.20 / 44°24.7459'N, 128°24.4753'E / Sun Xiaojie, MZUC"; "HOLOTYPE ♂ / *Pterostichus* (*Feroperis*) / *maryseae* sp. n. / des. SUN & SHI 2018" [red label]. Paratypes (a total of 942 specimens [440 males and 502 females], all in IZAS): 67 males, 162 females, the same data as holotype, but labeled as paratype. 96 males and 97 females, "China, Heilongjiang / Taipinggou Forest Farm / Zhangguangcai Mountain"; "Pitfall trap, 958 m, 2016.VI.08 / 44°24.7459'N, 128°24.4753'E / Sun Xiaojie, MZUC"; "PARATYPE / *Pterostichus* (*Feroperis*) / *maryseae* sp. n. / des. SUN & SHI 2018" [red label]. 89 males and 160 females, "China, Heilongjiang / Taipinggou Forest Farm / Zhangguangcai Mountain"; "Pitfall trap, 958 m, 2016.VII.05 / 44°24.7459'N, 128°24.4753'E / Sun Xiaojie, MZUC"; "PARATYPE / *Pterostichus* (*Feroperis*) / *maryseae* sp. n. / des. SUN & SHI 2018" [red label]. 167 males and 46 females, "China, Heilongjiang / Taipinggou Forest Farm / Zhangguangcai Mountain"; "Pitfall trap, 958 m, 2016. VIII.03 / 44°24.7459'N, 128°24.4753'E / Sun Xiaojie, MZUC"; "PARATYPE / *Pterostichus* (*Feroperis*) / *maryseae* sp. n. / des. SUN & SHI 2018" [red label]. 21 males and 36 females, "China, Heilongjiang / Taipinggou Forest Farm / Zhangguangcai Mountain"; "Pitfall trap, 958 m, 2016.VIII.31 / 44°24.7459'N, 128°24.4753'E / Sun Xiaojie, MZUC"; "PARATYPE / *Pterostichus* (*Feroperis*) / *maryseae* sp. n. / des. SUN & SHI 2018" [red label]. 1 female, "China, Jilin, Jiaohe City / Forest Ecology Stations"; "Pitfall trap, 397 m, 2018.IX.01 / 43°57'20"N, 127°41'50"E / Shi Hongliang, Beijing Forestry University"; "PARATYPE / *Pterostichus* (*Feroperis*) / *maryseae* sp. n. / des. SUN & SHI 2018" [red label].

Diagnosis. This new species can be distinguished from all the other species in the subgenus by the combination of the following characters: (1) lateral margins of pronotum evenly convex before basal third, then strongly contracted and straight before posterior angles; (2) pronotum posterior angles strongly protruding, forming strong denticles, lateral border strongly widened at posterior denticles, its width about two times wider than the lateral border of pronotum; (3) apical lamella of aedeagus about quadrate, length approx 1.1 times its basal width; slightly widened forming truncate apex, not thickened in lateral view; apical lamella weakly bent to the right in dorsal view.

This new species is distinguishable in the subgenus for its apical lamella of the aedeagus not being capitate or widened to apex, and ventral margin straight before apex in lateral view. These aedeagal characters can distinguish it from most species of *Feroperis* except these following six species and subspecies: *P. procax procax* Morawitz, 1862, *P. procax decastriensis* Lafer, 1979, *P. shingarevi maichensis* Lafer,

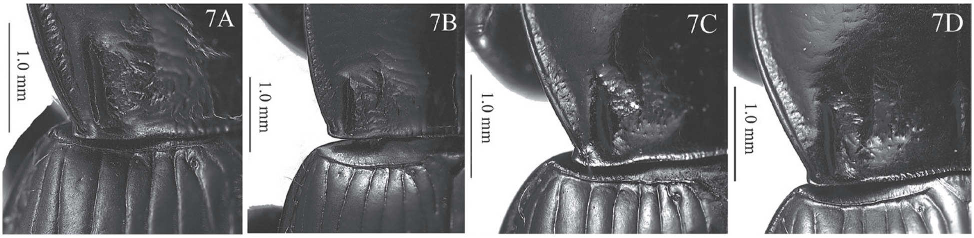


Figure 7. Pronotum left posterior angle and basal area of *Pterostichus* (*Feroperis*) spp. n. **A–B** *P. silvestris* **C–D** *P. maryseae*.

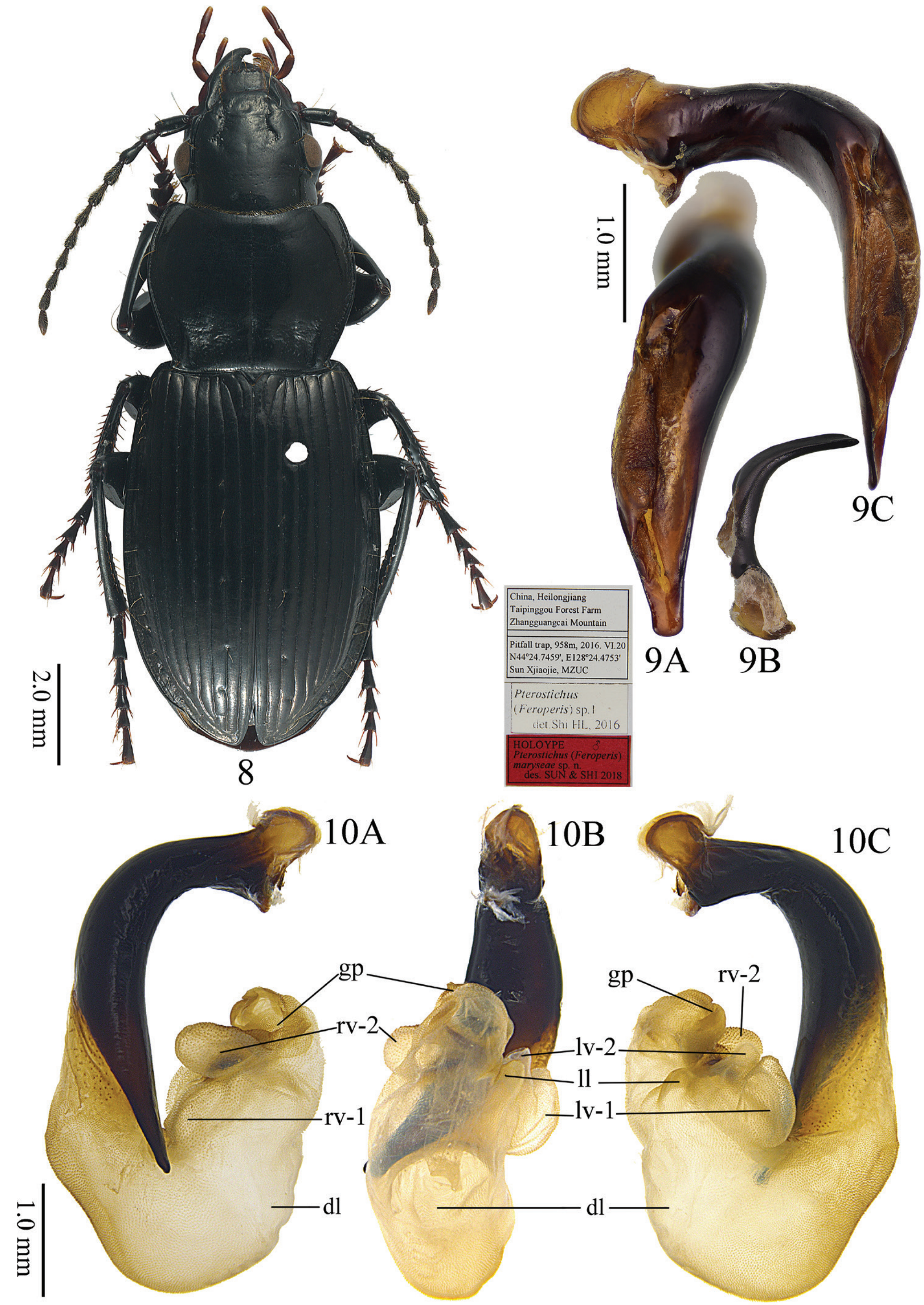
1979, *P. shingarevi shingarevi* Lafer, 1979, *P. arsenjevi* Lafer, 1979, *P. odaesanensis* Lafer, 2011. Besides *P. shingarevi shingarevi*, all other five taxa are different from the new species by the pronotum posterior angle being rounded, obtuse or only weakly dentate, but the lateral border never widened at posterior denticles. Therefore, *P. shingarevi shingarevi* (Primorsky Krai: Evseevka, 44°24'N, 132°52'E) is considered to be the most similar species to *P. maryseae* sp. n.

When compared with *P. shingavrevi shingavrevi* Lafer, 1979, *P. maryseae* sp. n. can be differentiated by: (1) in *P. maryseae*, the pronotum being widest at about basal 2/3, while it is widest near the middle in *P. shingavrevi*; (2) in *P. maryseae*, the apical lamella of aedeagus more obviously truncate, its left margin abruptly bent at about apical third of the apical lamella, while in *P. shingavrevi*, the apical lamella is less truncate, its left margin slightly bent near the middle of the apical lamella.

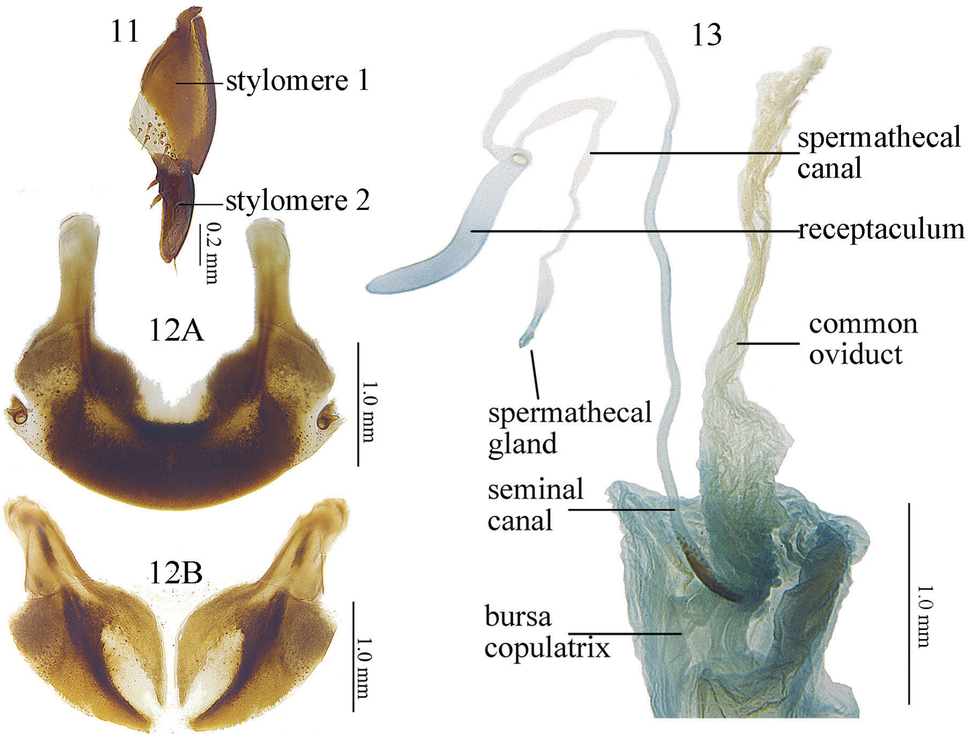
P. maryseae sp. n. is sympatric to the second new species, *P. silvestris*. These two new species can be readily distinguished by their differences in their pronotal posterior angles: in *P. silvestris*, the posterior angles of the pronotum are weakly protruding and dentate, lateral border not widened at the posterior denticles, its width similar to or less than the lateral border of the pronotum; in *P. maryseae*, posterior angles of the pronotum are strongly protruding and dentate, lateral border distinctly widened at the posterior denticles, its width at least twice as wide as the lateral border of the pronotum. They also strongly differ in their male genitalia (Figs 2, 9): apical lamella of aedeagus much longer and apex distinctly widened in *P. silvestris*; endophallus with a large coniform dorsal lobe in *P. silvestris*, with such a lobe being absent in *P. maryseae*. Moreover, these two species are also different in their female genitalia: the female reproductive tract with seminal canal shorter in *P. maryseae*, about four times length as the receptaculum (versus six times length as the receptaculum in *P. silvestris*); sternum VIII with the V-shaped transparent region shorter and wider in *P. maryseae*.

Description. Body length 12.6–14.9 mm (mean ± SD: 13.5 ± 0.56, n = 20), both sexes with similar body shape. Dorsal surface black and shiny; head and pronotum without obvious microsulpture; elytra with very fine and isodiametric microsculpture. **Head** mostly smooth, frons and vertex shiny, with scattered micro-punctures; eyes moderately convex; antennae just reaching the pronotum base. **Pronotum** approximately 1.4 times wider than head (PW/HW =1.26–1.52, mean ± SD: 1.40 ± 0.05, n = 20); rounded in shape, widest at about 2/3 length to the posterior margin (PW/PLt = 1.21–

1.36, mean ± SD: 1.28 ± 0.04, *n* = 20; PW/PLm = 1.37–1.59, mean ± SD: 1.46 ± 0.05, *n* = 20); lateral margins evenly convex from apex to about basal 1/3, then strongly contracted and almost straight before the posterior angles (PW/PA = 1.29–1.48, mean ± SD: 1.36 ± 0.05, *n* = 20; PW/PB = 1.29–1.43, mean ± SD: 1.36 ± 0.04, *n* = 20); apical width of pronotum nearly same as its basal width (PB/PA = 0.93–1.07, mean ± SD: 1.00 ± 0.04, *n* = 20). Anterior angles obtuse and rounded, distinctly contracted inward; lateral channels narrow in front of midpoint and gradually expanded towards the base, with flatten and sparse punctures on them. Posterior angles strongly protruding, forming strong denticles, lateral border at the posterior denticles strongly widened, at least twice as wide as the lateral broder of the pronotum anterior to the posterior angles; lateral border interrupted before posterior denticles; the posterior denticles about 90° (Fig. 7C–D), commonly with a side edge (128.6°–152.6°, mean ± SD: 140.7° ± 8.98°, *n* = 10); carinae between lateral margins and pronotal basal foveae clearly defined, parallel to the median line. Basal foveae moderately deep, clearly defined throughout except at the basal area, outer basal foveal groove long and deep, reaching the posterior margin of pronotum, inner basal foveal groove short and weakly incised, base separated from the posterior margin; basal foveae slightly rugose and sparsely punctate; disc moderately convex and smooth, only very finely and sparsely punctate. **Elytra** oviform (EL/EW = 1.30–1.47, mean ± SD: 1.39 ± 0.05, *n* = 20; EL/PLt = 2.09–2.33, mean ± SD: 2.17 ± 0.07, *n* = 20, EW/PW = 1.16–1.30, mean ± SD: 1.21 ± 0.03, *n* = 20), widest near the middle; elytra base slightly depressed in the middle; striae deeply impressed, with fine and sparse punctures; parascutellar stria long, apex free, short and incomplete or connected with first stria, normally located between the first stria and elytra suture, occasionally between first and second stria; parascutellar pore present on the base of first stria. Third interval generally with 3–6 setigerous pores, situated mostly closer to the second stria, occasionally 1–2 additional pores may present on the first and fifth intervals; umbilicate series of pores on the ninth interval, each side composed of 16–20 pores, sparser in the middle and denser anteriorly and posteriorly. Hind wings strongly vestigial, only developed as leathery wing bud. **Ventral side:** pro- and mesoepisternum sparsely punctate and shallowly rugose; metepisternum with coarse punctures; abdominal sterna glabrous in the middle, with sparse coarse punctures laterally; lateral area of sterna IV and V densely rugose. **Legs** long and slender; first meso- and metatarsomeres with distinct carina on the outer surface, these occur also near the base of the second tarsomeres; fifth tarsomere with 2–4 pairs of setae on ventral surface. **Male genitalia:** median lobe of male genitalia bent more than 90 degrees at basal 2/5 (Fig. 9C); in lateral view, ventral margin almost straight in the middle, apical portion not bent to the ventral side, apical lamella slightly depressed from dorsal to ventral side; on dorsal view (Fig. 9A); apical orifice slightly turned to the left; apical lamella sub-quadrate, slightly narrowed to apex, about 1.1 times as its basal width, slightly oblique to the right; apex a little truncate, left margin of the apical lamella abruptly bent at about apical 1/3. Right paramere very long and strongly bent, a little narrowed to apex, apical portion thick, apex obliquely truncate (Fig. 9B). **Endophallus** (Fig. 10) extending from the dorsal-left side of aedeagus to ventral side, major parts of the endophallus



Figures 8–10. *Pterostichus* (*Feroperis*) *maryseae* sp. n. **8** Habitus of holotype **9** Male genitalia of holotype **A** dorsal view of median lobe, **B** right paramere, **C** left lateral view of median lobe **10** Endophallus of a paratype **A** right lateral view, **B** ventral view, **C** left lateral view.



Figures 11–13. *Pterostichus* (*Feroperis*) *maryseae* sp. n., a female paratype **11** Stylomere of female ovipositor, ventral view **12 A** tergum VIII, **B** sternum VIII **13** Female reproductive tracts.

located on the ventral side of the aedeagus, basal portion slightly swollen to the dorsal direction; gonopore (**gp**) located near the basal-ventral direction of the aedeagus, pointing towards the aedeagal base. Five distinct recognizable lobes: left lateral lobe (**ll**) compressed, forming a widening triangular shape towards the base of gp when viewed dorsally, surface with fine scales; left ventral lobe (**lv**) divided into two separate sub-lobes; **lv-1** round, apex positioned towards aedeagal base, base adjacent to rb; **lv-2** very small, situated at about half the height of lv-1; right ventral lobe (**rv**) composed of two sub-lobes: **rv-1** small and compressed, on the base of left-ventral surface of endophallus, close to the aedeagal apex, surface with fine scales; **rv-2** large and round, between the base of gp and rv-1, surface with fine scales; dorsal lobe absent. **Female genitalia:** spermatheca with the seminal canal as long as about four times the length of the receptaculum; receptaculum tubiform, apical slightly pointed; spermathecal gland long; the seminal canal inserted at the base of the common oviduct, base of the seminal canal sclerotized (Fig. 13). Stylomere 1 (Fig. 11) with thick setae ventro-apically, stylomere 2 with two ensiform setae at the basal half of outer margin and with one ensiform seta at the upper middle part of its inner-ventral margin. Tergum VIII (Fig. 12A) with major portion chitinized, two small semi-chitinized patches with dense spots on each side; anterior margin with large quadrate middle notch. Sternum VIII (Fig. 12B) with sparse seta the on posterior margin; posterior margin curved, deeply notched in the center; posterior region chitinized, anterior region semi-chitinized, with a V-shaped transparent region on the center, shorter and wider than the previous species, adjacent to the central posterior notch.

Distribution. This species is only known form the Zhangguangcai Mountain range on the border of Jilin and Heilongjiang Provinces of China. Two localities in the Hailin County of Heilongjiang Province and Jiaohe County of Jilin Province were recorded.

Etymology. This species is named after Miss Maryse Diekman, who collected many specimens of both new species.

***Pterostichus* (*Feroperis*) *acutidens* (Fairmaire, 1889)**

Fig. 14A

Omaseus acutidens Fairmaire, 1889: cc (original: *Omaseus*; syntype in Muséum National d'Histoire Naturelle, Paris, France; type locality: "Pékin"); Jedlička 1962: 251; Lafer 1979: 8.

Type locality. Beijing.

Type material examined. Syntype of *Omaseus acutidens* Fairmaire, 1 male (MNHN), "*Omaseus* / *acutidens* / *Fairm.* / *Pekin*"; "SYNTYPE" [red label]; "*Omaseus* / *acutidens* / *Fairmaire* / Det. Shi H.L. 2011"; "Muséum Paris / 1906; Coll. Léon Fairmaire".

Other material examined. 7 specimens (IZAS), "China, Hebei Province, Xinglong County, Wuling Mountain. 1994.V.23, YU Peiyu"; 5 specimens (IZAS), "China, Beijing, Huairou District, Yunmeng Mountain. 800 m, 2005.VII.13, LIU Ye"; 628 specimens (IZAS), "China, Beijing, Dongling Mountain. Pit fall trap, 1160–1410 m, 2011.VI.10–2012.IX.13, ZOU Yi".

Diagnosis. Body length 14–17 mm, blackish, elytra shiny without metallic lustre. Pronotum subcordate, widest at approximately anterior 2/5; lateral margins of pronotum strongly constricted to the base; posterior angles strongly protruding and forming very strong denticles, lateral border at the posterior denticles strongly widened, at least twice as wide as the lateral broder anterior to the posterior angles; lateral border not interrupted before posterior denticles; basal foveae with a few large punctures. Elytra with humeral teeth faint; the third interval usually with 3–4 setigerous pores close to the second stria, but position variable. Apical lamella of aedeagus approximately triangular, gradually narrowed to apex, apex not widened or thickened; in lateral view, apical lamella distinctly bent downwards. Right paramere long and bent, apex distinctly compressed.

This species can be distinguished from all the other species of the subgenus by its male genitalia: aedeagus with apical lamella simple and distinctly bent downwards. From the external appearance, this species is superficially similar to *P. jungens* Tschitschérine, 1893; they can be distinguished by: the pronotal lateral channel before posterior angles wider in *P. acutidens* than in *P. jungens*; and quite different shape of apical lamella of aedeagus.

Distribution. This species is only known from Beijing and adjacent regions in the north part of Hebei Province.

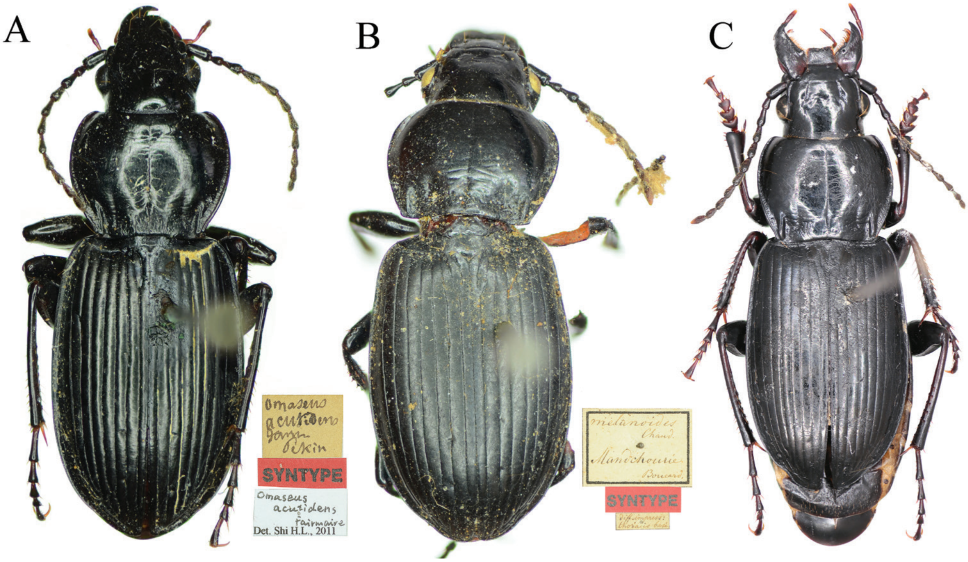


Figure 14. Habitus of *Pterostichus* (*Feroperis*) spp. from China. **A** *P. acutidens* (Fairmaire), male syntype (MNHN) **B** *P. melanodes* (Chaudoir), female syntype (MNHN) **C** *P. rasilis* Park & Kwon, male from Changbai Mountain (IZAS).

Pterostichus (*Feroperis*) *melanodes* (Chaudoir, 1878)

Fig. 14B

Feroperis melanodes Chaudoir, 1878: 69 (original: *Feronia*; syntype in Muséum National d'Histoire Naturelle, Paris, France; type locality: "Mandchourie"). Jedlička 1962: 249; Lafer 1979: 29.

Type locality. Manchuria, without reference to the exact type locality.

Type material examined. Syntype of *Feronia melanodes* Chaudoir, 1 female (MNHN), "*melanoides / Chaud. / Manchourie / Bouchard*"; "SYNTYPE" [red label]; "*Diffimpress / thoracis basi*".

Diagnosis. Body length about 15 mm, blackish, elytra shiny without metallic lustre. Pronotum round, widest at approximately anterior 1/3; lateral margins of pronotum strongly constricted to the base; lateral margins straight before posterior angles; posterior angles obtuse, with indistinct small denticles, lateral border at the posterior denticles less widened than the lateral broder anterior to the posterior angles; basal foveae rugose and convex, without punctures; basal foveae faintly defined, outer basal foveal groove short, inner basal foveal groove invisible, carinae between basal foveae and lateral margin shallower than other species. Elytra without humeral teeth; the third interval usually with 3 setigerous pores close to the second stria. Fifth tarsomere of all legs setose on ventral side. Male genitalia unknown.

Distribution. Only known by the type materials from "Manchuria", referring to the northeastern Provinces of China, without specified exact locality.

Remark.. *P. melanodes* was described on a female specimen from "Manchuria" that refers to a large area including Provinces Liaoning, Jilin, Heilongjiang and eastern parts of Inner Mongolia of present administrative divisions in China. While the exact type locality remains unspecified, *P. melanodes* is one of the earliest described, but also least known species in the subgenus, because neither its male genitalia nor the exact type locality are known. Lafer (1979) included *P. melanodes* as a dubious species in his work on *Feroperis* and extensively discussed its possible distribution and taxonomical position. Compared with other species from China and Russia, the species in question appears most similar to *P. sungariensis* Lafer, 1979 and *P. chechcirensis* Lafer, 1979 for their similar pronotum shape. Further distinctions between these species remain problematic as long as the male genitalia of *P. melanodes* remain unknown.

***Pterostichus* (*Feroperis*) *rasilis* Park & Kwon, 1996**

Fig. 14C

Pterostichus (*Feroperis*) *rasilis* Park & Kwon, 1996: 3 (holotype in Systematic Entomology Laboratory, Department of Agricultural Biology, Kyungpook National University, Republic of Korea; type locality: northern slopes of Changbai Mountain, Jilin, China); Lafer 2011: 434.

Type locality. Northern slopes of Changbai Mountain, Jilin, China.

Material examined. 46 specimens (IZAS),"China, Jilin, Changbaishan Nature Reserve; 2011.VII.14, 42°3'15"N, 128°4'2"E–42°10'47"N, 128°8'15"E, 870–2000 m, Zou Yi"; 83 specimens (IZAS),"China, Jilin, Changbaishan Nature Reserve; 2011.VII.27, 42°3'15"N, 128°4'2"E–42°7'16"N, 128°6'27"E, 1330–2000 m, Zou Yi"; 39 specimens (IZAS),"China, Jilin, Changbaishan Nature Reserve; 2011.VIII.08, 42°3'15"N, 128°4'2"E–42°7'15"N, 128°6'26"E, 1330–2000 m, Zou Yi"; 30 specimens (IZAS),"China, Jilin, Changbaishan Nature Reserve; 2012. VII.14, 42°3'15"N, 128°4'2"E–42°5'41"N, 128°4'3"E, 1520–2000 m, Zou Yi"; 94 specimens (IZAS),"China, Jilin, Changbaishan Nature Reserve; 2012.VII.12, 42°3'15"N, 128°4'2"E–42°7'9"N, 128°6'17"E, 1350–2000 m, Zou Yi"; 62 specimens (IZAS),"China, Jilin, Changbaishan Nature Reserve; 2012.VII.30, 42°3'15"N, 128°4'2"E–42°7'9"N, 128°6'17"E, 1330–2000 m, Zou Yi".

Diagnosis. Body length 13–15 mm, blackish, elytra shiny without metallic lustre. Pronotum subcordate, widest at approximately anterior 1/3; lateral margins of pronotum strongly constricted to the base; posterior angles strongly protruding and forming very prominent denticles, lateral border at the posterior denticles strongly widened, at least twice as wide as the lateral broder of the pronotum anterior to the posterior angles; lateral border interrupted before posterior denticles; basal foveae rugose. Elytra with faint humeral teeth; the third interval usually with 3 or 4 setigerous pores close to the second stria, but position variable. Apical lamella of aedeagus elongate, apex slightly widened at both left and right margins in dorsal view; not thickened or bent downwards in lateral view. Right paramere long and bent, gradually narrowed to apex, apex pointed.

This species can be distinguished from most species of the subgenus by: male genitalia with apical lamella of aedeagus rectangular, apex widened in dorsal view, but not thickened in lateral view, and pronotal posterior angles with strong denticles. From the above characters, this species is superficially similar to *P. vladivostokensis* Lafer. They can be distinguished by: in *P. rasilis*, the apical lamella of aedeagus shorter, length approximate 1.2 times as basal width, apex less widened, not capitate; while in *P. vladivostokensis* the apical lamella of aedeagus longer, length approximate 1.5 times as basal width, apex strongly widened, distinctly capitate.

Distribution. This species is known only from the northern slopes of Changbai Mountain, Jilin province in China, and it is a locally abundant species. It is probably also distributed within the DPR Korea, on the eastern slopes of Paektusan (the Korean name of Changbai Mountain).

Remark. This species was originally described based on 14 specimens from Paektusan, Hamgyeongbuk-do, DPR Korea. Lafer (2011) examined the type specimens and specified that the true type locality was on the northern slopes of the Changbai Mountain in the territory of China, based on a personal communication with Y.J. Kwon in 1994.

Discussion

The two new species described here conform to the commonly observed trend for relatively small geographic distribution ranges in Chinese members of the genus *Pterostichus*, forming two sibling species that are very similar in their external morphology, but that strongly differ in the structure of their genitalia. These two new species were initially difficult to identify, particularly with regards to some female specimens that are superficially similar in their external morphological features, but the male genitalia can readily distinguish them as distinct species. Based on the morphological features, we subsequently ascertained their identity based on the species' distribution patterns. It appears that *P. maryseae* occurs in plantation forests and secondary poplar-dominated humid forests. While *P. silvestris* is also encountered in secondary poplar-dominated forests, its main distribution appears to be in secondary mixed forests and remnants of mature forest that have persisted in the large-scale deforestation campaigns across temperate eastern China before the middle of the last century. This pattern highlights the need for detailed ecological information to be provided when collecting specimens, which will greatly facilitate their subsequent identification.

A total of 2587 specimens of the two new species in 80 pitfall trap sample plots were collected in the present study. Using a stereoscope to examine every specimen and dissecting genitalia of 56 male and 48 female specimens, we established that *Pterostichus* (*Feroperis*) *silvestris* accounted for 737 female and 907 male individuals, while *Pterostichus* (*Feroperis*) *maryseae* accounted for 502 female and 441 male specimens.

Based on in-depth investigations of specimens representing the new species, we found that the number of setigerous pores and their location on the interval of the elytron are highly variable. The exceptions were pores on the third elytral interval, where we commonly encountered 3 or 4 setigerous pores adjacent to the second stria. The number of setigerous pores and their location has been described in great detail for some species in *Feroperis* (i.e. Park and Kwon 1996, Lafer 2011). In our view, the structure of pronotum, the apical lamella of median lobe, and the geographic distribution represent the most important features to determine the different species in *Feroperis*, which was also stressed by Lafer (1979).

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Systematics of the new genus *Spinosuncus* Chen, Zhang & Li with descriptions of four new species (Lepidoptera, Crambidae, Pyraustinae)

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Abstract

The new genus *Spinosuncus* **gen. n.** is proposed for three known species, *S. contractalis* (Warren, 1896), **comb. n.**, *S. praepandalis* (Snellen, 1890), **comb. n.,** and *S. aureolalis* (Lederer, 1863), **comb. n.** and four new species, *S. rectacutus* **sp. n.**, *S. brevacutus* **sp. n.**, *S. curvisetaceus* **sp. n.,** and *S. quadracutus* **sp. n.** from the Oriental Region. An identification key is provided for all species. The habiti and genitalia of all species are figured. The monophyly of the genus is well supported by a phylogenetic analysis based on sequence data of the COI, 16S rRNA, and EF-1α genes. The potential sister groups of the new genus, the interspecific relationships and some intraspecific variations within the genus are discussed.

Keywords

Aglaops, China, molecular phylogeny, new combinations, *Ostrinia*, *Paratalanta*, *Placosaris*, *Pseudebulea*, *Pseudopagyda*, *Thliptoceras*

Introduction

Pyraustinae is the third largest subfamily in the family Crambidae, containing 173 genera that include more than 1176 described species (Nuss et al. 2003–2018). The monophyly of the Pyraustinae is well supported by phylogenetic analyses based on both morphological characters and molecular data (Solis and Maes 2002, Regier et al.

2012). Based on specialized genitalic characters, e.g. the valva bearing sella and editum in the male genitalia and a rhomboidal signum in the female genitalia, pyraustine species are easily distinguished from members of its sister group, Spilomelinae (Regier et al. 2012). However, the taxa belonging to Pyraustinae *sensu stricto* still have not been all associated on a worldwide basis (Solis and Maes 2002), partly because they were for a long time placed into Pyraustinae *sensu lato* along with various Spilomelinae. This group has been relatively well studied in Europe and North America. In other regions, however, particularly the Oriental Region, this work is far from complete. One of the major contributions to the knowledge of the Pyraustinae of East Asia is a series of papers by Munroe and Mutuura (1968, 1969, 1970, 1971) treating many pyraustine genera of temperate East Asia, a historical milestone in the study of the Pyraustinae of this area. Both authors' generic concepts, however, were narrow, so that many genera recognized by these authors were united by Tränkner et al. (2009) in a wider concept of the genus *Anania* Hübner.

In recent years, a series of similar yellowish specimens collected from the south of China, all superficially resembling species of *Pseudopagyda* Slamka, 2013, attracted our attention. By examining the genitalia, three described species, *Paliga contractalis* Warren, 1896, *Botys aureolalis* Lederer, 1863, *Botys praepandalis* Snellen, 1890 and four unknown species were recognized. According to characters of male and female genitalia, they are congeneric, but obviously do not match the genitalic morphology of *Pseudopagyda* or *Paliga* Moore, 1886. Bänziger (1995) placed *Paliga contractalis* and *Botys aureolalis* in genus *Microstega* Meyrick, 1890 along with *Pionea acutangulata* Swinhoe, 1901 and *Microstega homoculorum* Bänziger, 1995. Bänziger (1995) also pointed out that *M. homoculorum* and *M. acutangulata* are congeneric, but that *M. contractalis* and *M. aureolalis* probably each belong to a different genus, and that *Pionea praepandalis* resembles *M. aureolalis* superficially, without giving any details. *Microstega* was synonymized with *Paratalanta* Meyrick, 1890 by Kirpichnikova (1986) and Maes (1994) based on "the characteristic sclerotized hook (spicula-shaped sella) on the valvae of the male genitalia". This taxonomic decision is commonly accepted, but Zhang et al. (2014) excluded the above five species from *Paratalanta* because they share no generic synapomorphies with *Paratalanta*. Almost at the same time, Slamka (2013) proposed genus *Pseudopagyda* for *M. homoculorum*. Subsequently, *M. acutangulata* was transferred to *Pseudopagyda* (Chen and Zhang 2017). Slamka (2013) also suggested that *Paliga contractalis* and *Botys aureolalis* should belong to *Pseudopagyda*. However, in a revision of *Pseudopagyda* (Chen and Zhang 2017), several putative synapomorphic characters of the genus were summarized, and it was found that *Paliga contractalis* and *Botys aureolalis* are not congeneric with species of *Pseudopagyda* based on genitalia characters.

After comparing these species with taxonomic treatments, faunal surveys, and checklists of Spilomelinae and Pyraustinae (Hampson 1893, 1896, 1898, 1899, Caradja 1925, Shibuya 1928, 1929, Munroe and Mutuura 1968, 1969, 1970, 1971, Munroe 1976a, 1976b, Wang 1980, Inoue 1982, Heppner and Inoue 1992, Munroe 1995, Speidel 1996, Shaffer et al. 1996, Kirpichnikova 1999, 2009, Wang and Speidel 2000, Mathew 2006, Shaffer and Munroe 2007, Bae et al. 2008, Leraut 2012, Slamka

2013, Yamanaka et al. 2013, Scholtens and Solis 2015) and type specimens deposited in the Natural History Museum, London, the Zoological Institute, Academy of Sciences of Russia, St. Petersburg, the Australian National Insect Collection and the National Museum of Natural History Grigore Antipa, Bucharest, Romania, our efforts of placing these species in a suitable genus were unsuccessful. Moreover, they can't be placed in any African pyraustine genus (Dr Koen VN Maes, pers. comm.). The seven species treated here, currently with no appropriate generic placement, could be easily separated from other pyraustine taxa by several genital traits in both males and females, especially the peculiar uncus, for which the erection of a new genus is considered warranted.

Thus, the aim of this study is to propose a new genus, provide several synapomorphic characters, present an identification key based on external features and genitalia, redescribe three known species, and describe four new ones. A preliminary phylogenetic analysis of the genus and of several potentially related genera, is also proposed based on molecular data.

Materials and methods

Molecular material and methods

All species of the genus *Spinosuncus*, two species of the genus *Pseudopagyda*, and four species of other genera of Pyraustinae were included for molecular phylogenetic analysis (Table 1). *Pseudebulea fentoni* Butler, 1881 was chosen as outgroup because it was considered as a basal lineage of the Pyraustinae (Zhang 2003).

Total DNA was extracted from one hindleg and one midleg of 24 specimens using the TIANGEN DNA extraction kit following the manufacturer's instructions. The nucleotide sequences of two mitochondrial genes, cytochrome c oxidase subunit I (COI) and 16S ribosomal RNA (16S rRNA), and one nuclear gene, elongation factor-1 alpha (EF-1α), were selected for study. Primers used in this study were chosen according to Simon et al. (2006), Wahlberg and Wheat (2008) and Hundsdörfer et al. (2009). PCR cycle conditions were an initial denaturation of 5 min at 95 °C, 30 s at 94 °C, 30 s at 48 °C (COI and 16S rRNA) or 51 °C(EF-1α), and 1 min at 72 °C for 35 cycles, and a final extension at 72 °C for 10 min. All amplifications were confirmed by gel electrophoresis on a 1.5% W/V agarose gel in TAE buffer. PCR products were direct-sequenced at Majorbio Bio-pharm Technology Co., Ltd (Guangzhou), utilizing the same primers used for PCR amplification.

The sequences were aligned using Clustal W (Thompson et al. 1994) under default settings. Gaps were treated as missing data in all analyses. Phylogenetic analyses were conducted using Bayesian inference (BI) method and Maximum likelihood (ML). The BI analysis was run in MrBayes 3.2.6 (Ronquist et al. 2012) with independent parameters for the gene partitions for COI and 16S rRNA under the GTR+G model and for the EF-1α gene partition under the SYM+I+G model as suggested by jModelTest 0.1.1

Table 1. Species sampled for the molecular phylogenetic analysis.

Genus	Species	Voucher number	Locality	GenBank accession number			Reference
				COI	16S	EF-1α	
Pseudebulea	*fentoni*	SYSU-LEP0074	Hunan Prov.	MG739570	MG739582	MG739594	Chen et al. 2018
Paratalanta	*ussurialis*	SYSU-LEP0158	Hunan Prov.	MK000093	MK000070	MK000116	present study
Ostrinia	*furnacalis*	SYSU-LEP0157	Jiangxi Prov.	MK000094	MK000071	MK000117	present study
Placosaris	*rubellalis*	SYSU-LEP0087	Jiangxi Prov.	MK000095	MK000072	MK000118	present study
Thliptoceras	*sinense*	SYSU-LEP0080	Jiangxi Prov.	MK000096	MK000073	MK000119	present study
Aglaops	*youboialis*	SYSU-LEP0068	Jiangxi Prov.	MK000097	MK000074	MK000120	present study
Pseudopagyda	*homoculorum*	SYSU-LEP0116	Yunnan Prov.	MK000098	MK000075	MK000121	present study
	acutangulata	SYSU-LEP0011	Jiangxi Prov.	MK000099	MK000076	MK000122	present study
	acutangulata	SYSU-LEP0126	Jiangxi Prov.	MK000100	MK000077	MK000123	present study
Spinosuncus	*aureolalis*	SYSU-LEP0132	Yunnan Prov.	MK000101	MK000078	MK000124	present study
	aureolalis	SYSU-LEP0146	Yunnan Prov.	MK000102	MK000079	MK000125	present study
	quadracutus	SYSU-LEP0001	Hainan Prov.	MK000103	MK000080	MK000126	present study
	quadracutus	SYSU-LEP0002	Hainan Prov.	MK000104	MK000081	MK000127	present study
	curvisetaceus	SYSU-LEP0129	Jiangxi Prov.	MK000105	MK000082	MK000128	present study
	praepandalis	SYSU-LEP0006	Guizhou Prov.	MK000106	MK000083	MK000129	present study
	praepandalis	SYSU-LEP0131	Yunnan Prov.	MK000107	MK000084	MK000130	present study
	brevacutus	SYSU-LEP0009	Guizhou Prov.	MK000108	MK000085	MK000131	present study
	brevacutus	SYSU-LEP0010	Guizhou Prov.	MK000109	MK000086	MK000132	present study
	brevacutus	SYSU-LEP0156	Jiangxi Prov.	MK000110	MK000087	MK000133	present study
	rectacutus	SYSU-LEP0134	Guizhou Prov.	MK000111	MK000088	MK000134	present study
	rectacutus	SYSU-LEP0155	Guizhou Prov.	MK000112	MK000089	MK000135	present study
	contractalis	SYSU-LEP0133	Yunnan Prov.	MK000113	MK000090	MK000136	present study
	contractalis	SYSU-LEP0135	Yunnan Prov.	MK000114	MK000091	MK000137	present study
	contractalis	SYSU-LEP0153	Yunnan Prov.	MK000115	MK000092	MK000138	present study

(Posada 2008). Two independent runs, each with four Markov Chain Monte Carlo (MCMC) simulations, were performed for 3 million generations sampled every 1000th step. The first 25% of the trees were discarded as burn-in, and posterior probabilities (PP) were determined from remaining trees. The ML analysis was executed in RAxML 8.2.10 (Stamatakis 2014) for all gene partitions under the GTR + G model proposed by jModelTest 0.1.1 (Posada 2008) and with 1000 iterations for bootstrap test. The pairwise Kimura 2-Parameter (K2P) distances between species were calculated from the COI gene using MEGA 6 (Tamura et al. 2013).

Morphological materials and methods

The specimens studied, including the types of the newly described species, are all deposited at the Museum of Biology, Sun Yat-sen University, Guangzhou (**SYSBM**) except those specified as being in the Insect Collection of the College of Life Sciences, Nankai University (**NKU**), the Natural History Museum, London, United Kingdom (**NHMUK**) and the Forest Canopy Ecology Lab, Yunnan (**FCEL**). Slides of genitalic dissections were prepared according to Robinson (1976) and Li and Zheng (1996), with some modifications. Genitalia terms follow Klots (1970), Munroe (1976a), Maes (1995), and Kristensen (2003). Specimen images at different focal levels were made using a Canon EOS 1DX camera (provided with a Canon 100 mm macro lens) in combination with Helicon Remote. Genitalia pictures were taken using a Zeiss Axio Scope.A1 in combination with a Zeiss AxioCam camera and the Axio Vision SE64 program on a Windows PC; source images were then aligned and stacked on Helicon Focus to obtain a fully sharpened composite image. All the pictures were edited using Adobe Photoshop CS5.

Results

Phylogenetic relationships

The concatenated dataset of three genes consisted of 1863 nucleotide positions (658 for COI, 434 for 16S rRNA and 771 for EF-1α, respectively). Pairwise distances of the barcode region (COI) are given in Table 2. The genetic distances between the genus *Spinosuncus* (described below) and the other genera range from 9.0% (*Aglaops*) to 17.0% (*Pseudebulea*). Interspecific genetic distances within *Spinosuncus* range from 2.5% (*S. contractalis* to *S. rectacutus*) to 13.8% (*S. aureolalis* to *S. rectacutus*) while intraspecific genetic distances in *Spinosuncus* range from 0% (*S. contractalis*) to 2.7% (*S. aureolalis*).

The BI and ML analyses of the concatenated dataset inferred congruent topologies with only subtle differences in posterior probability and bootstrap values probability (Figure 1). The monophyly of *Spinosuncus* is robustly supported (PP = 1.00, BS = 98). Within *Spinosuncus*, three well-supported clades are identified. The clade *S. aureolalis* + *S. quadracutus*, clade *S. curvisetaceus* + *S. praepandalis* and clade *S. brevacutus* + (*S. rectacutus* + *S. contractalis*) are each recovered with robust supports (PP = 1.00, BS = 100). Clade *Aglaops youboialis* + (*Pseudopagyda homoculorum* + *P. acutangulata*) is in a sister position to clade *Spinosuncus* with robust support as well (PP = 1.00, BS = 77). Distances between *Spinosuncus* and *Pseudopagyda* range from 10.2% to 13.3%, and between *Spinosuncus* and *Aglaops* from 9.0% to 12.9%.

Since the monophyly of *Spinosuncus* is well-supported and species within the clade are morphologically and genetically distinct from the potential sister groups, a new genus is proposed. The taxonomic details are provided below.

Taxonomy

***Spinosuncus* gen. n.**
http://zoobank.org/AF399C02-2BDC-48D6-9A57-384D3DD6F5AD

Type species. *Paliga contractalis* Warren, 1896

Diagnosis. Species of *Spinosuncus* can be recognized externally by the yellow to fulvous wing ground colour, the fulvous to brown lines, the distinct subterminal

Table 2. Pairwise distances of the COI barcode region based on Kimura-2-parameter model (intraspecific distances are highlighted in bold).

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	**LEP0132** ***Spinosuncus aureolalis***																							
2	**LEP0146** ***Spinosuncus aureolalis***	**0.027**																						
3	**LEP0001** ***Spinosuncus quadracutus***	0.044	0.037																					
4	**LEP0002** ***Spinosuncus quadracutus***	0.046	0.035	**0.002**																				
5	**LEP0129** ***Spinosuncus curvisetaceus***	0.111	0.092	0.109	0.107																			
6	**LEP0006** ***Spinosuncus praepandalis***	0.115	0.100	0.107	0.105	0.041																		
7	**LEP0131** ***Spinosuncus praepandalis***	0.117	0.107	0.105	0.107	0.050	**0.024**																	
8	**LEP0009** ***Spinosuncus brevacutus***	0.129	0.104	0.118	0.116	0.083	0.101	0.109																
9	**LEP0010** ***Spinosuncus brevacutus***	0.131	0.106	0.120	0.118	0.085	0.103	0.111	**0.002**															
10	**LEP0156** ***Spinosuncus brevacutus***	0.125	0.104	0.114	0.116	0.083	0.101	0.105	**0.003**	**0.005**														
11	**LEP0134** ***Spinosuncus rectacutus***	0.138	0.112	0.120	0.118	0.094	0.100	0.109	0.049	0.047	0.049													
12	**LEP0155** ***Spinosuncus rectacutus***	0.138	0.112	0.120	0.118	0.094	0.100	0.109	0.047	0.046	0.047	**0.005**												
13	**LEP0133** ***Spinosuncus contractalis***	0.131	0.106	0.118	0.116	0.089	0.095	0.099	0.049	0.048	0.049	0.027	0.025											
14	**LEP0135** ***Spinosuncus contractalis***	0.127	0.106	0.114	0.112	0.089	0.095	0.095	0.049	0.048	0.049	0.027	0.025	**0.003**										
15	**LEP0153** ***Spinosuncus contractalis***	0.127	0.106	0.114	0.112	0.089	0.095	0.095	0.049	0.048	0.049	0.027	0.025	**0.003**	**0.000**									

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
16	**LEP0068** ***Aglaops youboialis***	0.129	0.112	0.118	0.116	0.090	0.100	0.104	0.094	0.096	0.094	0.098	0.098	0.100	0.100	0.100								
17	**LEP0116** ***Pseudopagyda homoculorum***	0.131	0.124	0.133	0.130	0.102	0.114	0.114	0.124	0.126	0.124	0.118	0.118	0.120	0.116	0.116	0.085							
18	**LEP0011** ***Pseudopagyda acutangulata***	0.129	0.122	0.126	0.126	0.108	0.122	0.120	0.124	0.126	0.122	0.130	0.130	0.122	0.118	0.118	0.092	0.058						
19	**LEP0126** ***Pseudopagyda acutangulata***	0.129	0.122	0.126	0.126	0.108	0.122	0.120	0.124	0.126	0.122	0.130	0.130	0.122	0.118	0.118	0.092	0.058	0.000					
20	**LEP0080** ***Thliptoceras sinen*se**	0.149	0.138	0.135	0.133	0.129	0.138	0.134	0.131	0.133	0.131	0.137	0.135	0.131	0.129	0.129	0.096	0.118	0.123	0.123				
21	**LEP0087** ***Placosaris rubellal*is**	0.133	0.124	0.135	0.137	0.100	0.110	0.119	0.114	0.116	0.110	0.116	0.120	0.116	0.116	0.116	0.087	0.112	0.112	0.112	0.127			
22	**LEP0157** ***Ostrinia furnacalis***	0.142	0.124	0.120	0.118	0.126	0.130	0.137	0.116	0.118	0.116	0.133	0.133	0.130	0.130	0.130	0.108	0.114	0.132	0.132	0.120	0.112		
23	**LEP0158** ***Paratalanta ussurialis***	0.143	0.126	0.143	0.141	0.122	0.133	0.139	0.122	0.124	0.122	0.124	0.128	0.124	0.124	0.124	0.102	0.120	0.112	0.112	0.135	0.106	0.102	
24	**LEP0074** ***Pseudebulea fentoni***	0.148	0.135	0.148	0.146	0.159	0.161	0.159	0.161	0.158	0.161	0.170	0.170	0.161	0.158	0.158	0.158	0.133	0.143	0.143	0.161	0.145	0.145	0.157

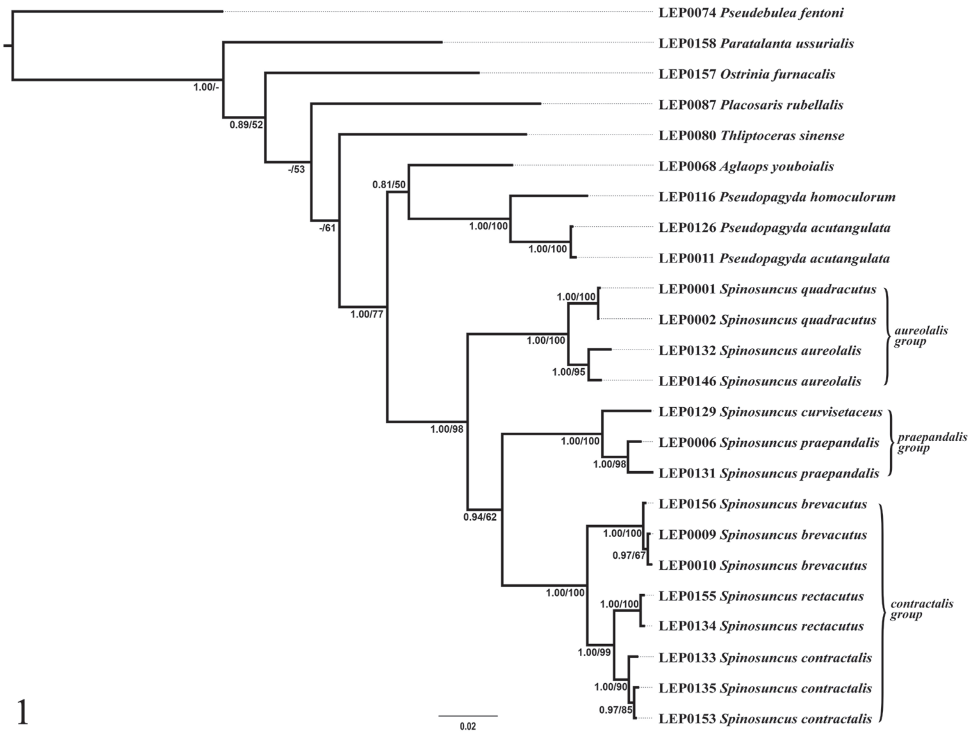


Figure 1. Phylogenetic hypothesis inferred from Bayesian inference. Numbers on branches indicate Bayesian posterior probabilities (values ≥ 0.8 are labelled) and ML bootstrap values probabilities (values ≥ 50% are labelled), respectively.

lines usually arched to CuA_2 then obviously angled or concave near the tornus. Diagnostic characters in the male genitalia are the short and stout, strongly sclerotized uncus distally with two spines or teeth, the lamellate, distally inflated sella set with fin-shaped setae forming editum, the dorsally inflated sacculus with the dorsal margin sclerotized and usually spinulose, the distally broad and usually spinulose phallus, and the spine-like cornuti appear funnel-shaped in the distal end of the vesica. The female genitalia are characterized by the strongly sclerotized lamella postvaginalis always extended dorsolaterally, and the sclerotized transverse band posteriorly in the cup-shaped antrum.

Spinosuncus moths are most similar in appearance to *Pseudopagyda* Slamka, 2013. Some species of *Spinosuncus* can be distinguished by the much smaller wingspan (usually less than 24 mm). However, some *Spinosuncus* species have a similar body size to *Pseudopagyda*, but they can still be differentiated by the wavy or dentate lines on the wings dorsally, especially the sinuate (rather than oblique, or slightly curved as in *Pseudopagyda*) anterior part of the postmedial line near the costa. In the male genitalia, the sclerotized uncus, the fin-shaped setae (editum) of the sella, and the inflated sacculus distinguish *Spinosuncus* from *Pseudopagyda*. In the female genitalia, the long and slender ductus bursae is distinct from the extremely short ductus bursae of *Pseudopagyda*.

Description. *Head*. Frons oblique, yellowish brown, with white lateral bands. Vertex with moderately raised scales projecting between antennae. Labial palpus obliquely upturned, exceeding frons by 2/3 length of head or slightly less, third palpomere porrect, yellowish brown with base contrastingly white. Maxillary palpus small, yellowish brown, tips pale yellow, sometimes mixed with white. Proboscis well developed, with basal scaling white. Antenna pale yellow, with cilia as long as width of corresponding flagellomeres in male. *Thorax*. With appressed scales, yellow. Legs unmodified. Foreleg brown, tibia white with brown cross band medially, tarsus white; midleg pale brown, tibia and tarsus white ventrally; hind leg pale yellow, tinged with white, basal inner spur longer than apical inner spurs. Forewing subtriangular, termen gently arched; retinaculum a tuft of curved bristles from below base of discal cell. Hindwing fan-shaped, costal margin translucent whitish; frenulum simple in male, with two acanthae in female. Wing venation (Figure 2) in forewing with cell about half length of wing; R_1 free, from 4/5 of anterior margin of cell, R_2 free but adjacent to stem of R_3+R_4 in about basal half, R_3 and R_4 stalked to about 2/3, R_4 to just before apex, R_5 parallel to stalked R_3+R_4 at base then diverging; M_1 moderately close to R_5 at base, M_2 widely separate from M_1, closing vein concavely curved; M_2, M_3 and CuA_1 from posterior angle of cell, M_3 closer to M_2 at base than to CuA_1, then diverging; CuA_2 from 3/5 of posterior margin of cell; 1A faintly sinuate to tornus, 2A forming complete loop and distally recurved before joining 1A, sometimes disconnected. Hindwing with cell about 1/3 length of wing; Sc+R_1 and Rs anastomosing for 1/3 beyond end of discal cell, Rs and M_1 short-stalked, closing vein concave, angled medially; M_3 closer to M_2 at base than to CuA_1, parallel with M_2 at base, then diverging; 1A complete but weak, 3A curved. *Abdomen*. Slender, usually yellowish, sometimes dark brown, apical margin of segments usually tinged with white. *Male genitalia.* Uncus short and stout, nearly quadrate, with wide base; usually strongly sclerotized; distal end with two or four sharp spines laterally or distally bifid forming two teeth; glabrous or ventrolaterally set with few setae, or densely setose at base of teeth. Tegumen quadrate. Vinculum U-shaped. Saccus short, near triangular, rounded at apex. Valva tongue-shaped, varying in width, tapering towards apex, set with hair-like setae on inner side; transtilla sub-triangular, meeting in middle, usually with setae on dorsal margin; costa simple, costal sclerotized band narrow to broad, extended to beyond 2/3 of dorsal margin; sacculus broad, expanded except basal part, with dorsal margin strongly sclerotized and often spinose; sella slender to broad, lamellate, distally inflated, set with modified setae (editum), varying from fin-shaped to thick, needle-shaped. Juxta heart-shaped to nearly pentagonal. Phallus with distal part broad and moderately setose, usually spinulose; vesica in distal part with numerous spine-like cornuti appear funnel-shaped, sometimes with several large spicules. *Female genitalia*. Ovipositor lobes flat, densely setose. Sinus vaginalis well developed, membranous, usually with sclerotized, streak-like or hook-like notches anterolaterally (absent in *S. praepandalis* and *S. curvisetaceus*); lamella postvaginalis band-shaped, sclerotized (weakly sclerotized in *S. contractalis*, *S. rectacutus* and *S. brevacutus*), always extended dorsolaterally. Antrum membranous or sclerotized and granulated, cup-shaped, with sclerotized transverse band posteriorly. Ductus seminalis originating from anterior end

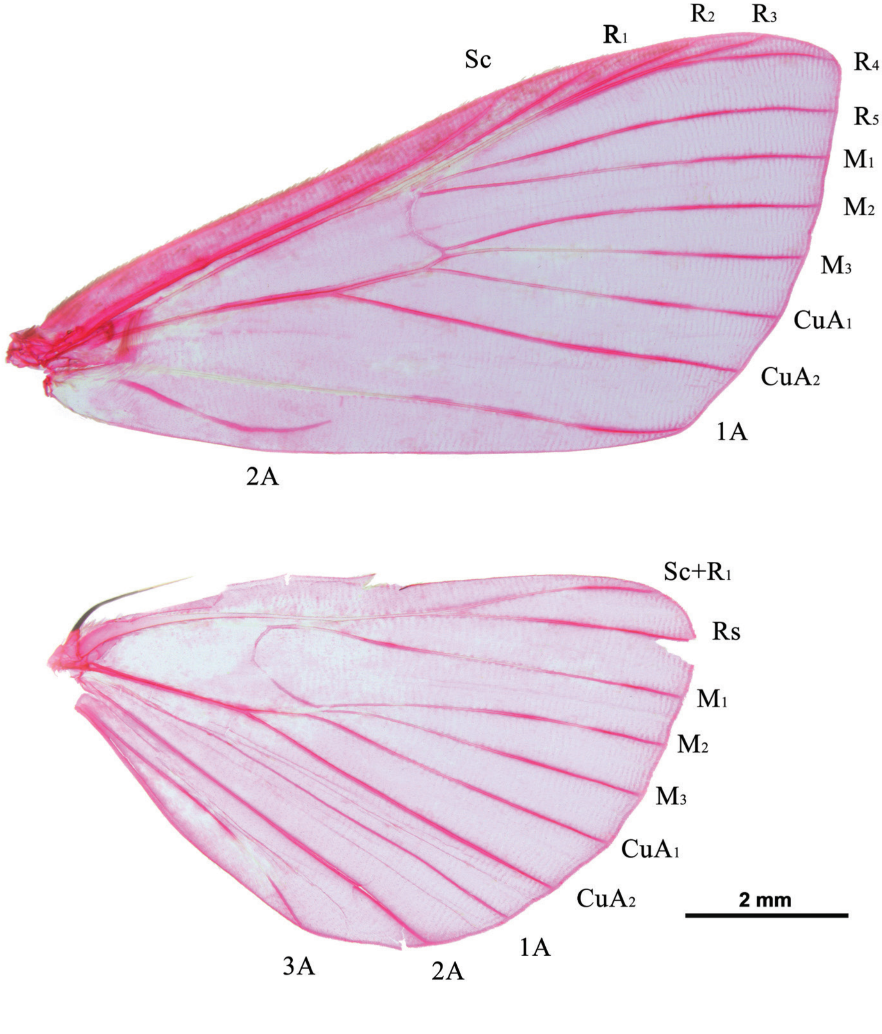


Figure 2. Wing venation of *Spinosuncus praepandalis*.

of colliculum. Ductus bursae with base slightly rotated, as long as or longer than length or diameter of corpus bursae; colliculum ring-shaped, sclerotized. Corpus bursae drop-shaped or globular; accessory bursa present, sometimes with second signum at base; main signum rhomboid.

Biology. All of the Chinese material has been collected during the night at light. Host information is currently unavailable. *Spinosuncus aureolalis* and *S. contractalis* occur sympatrically with species of *Pseudopagyda* in some places. According to Bänziger (1995), they are not lachryphagous.

Distribution. *Spinosuncus* occurs in South China (Figure 28), India, and Thailand.

Etymology. The generic name is a compound word that refers to the uncus distally with spines ("*spinosus*" in Latin). The resultant name is masculine in gender.

Spinosuncus contractalis **(Warren, 1896), comb. n.**
Figs 3, 10, 19, 28

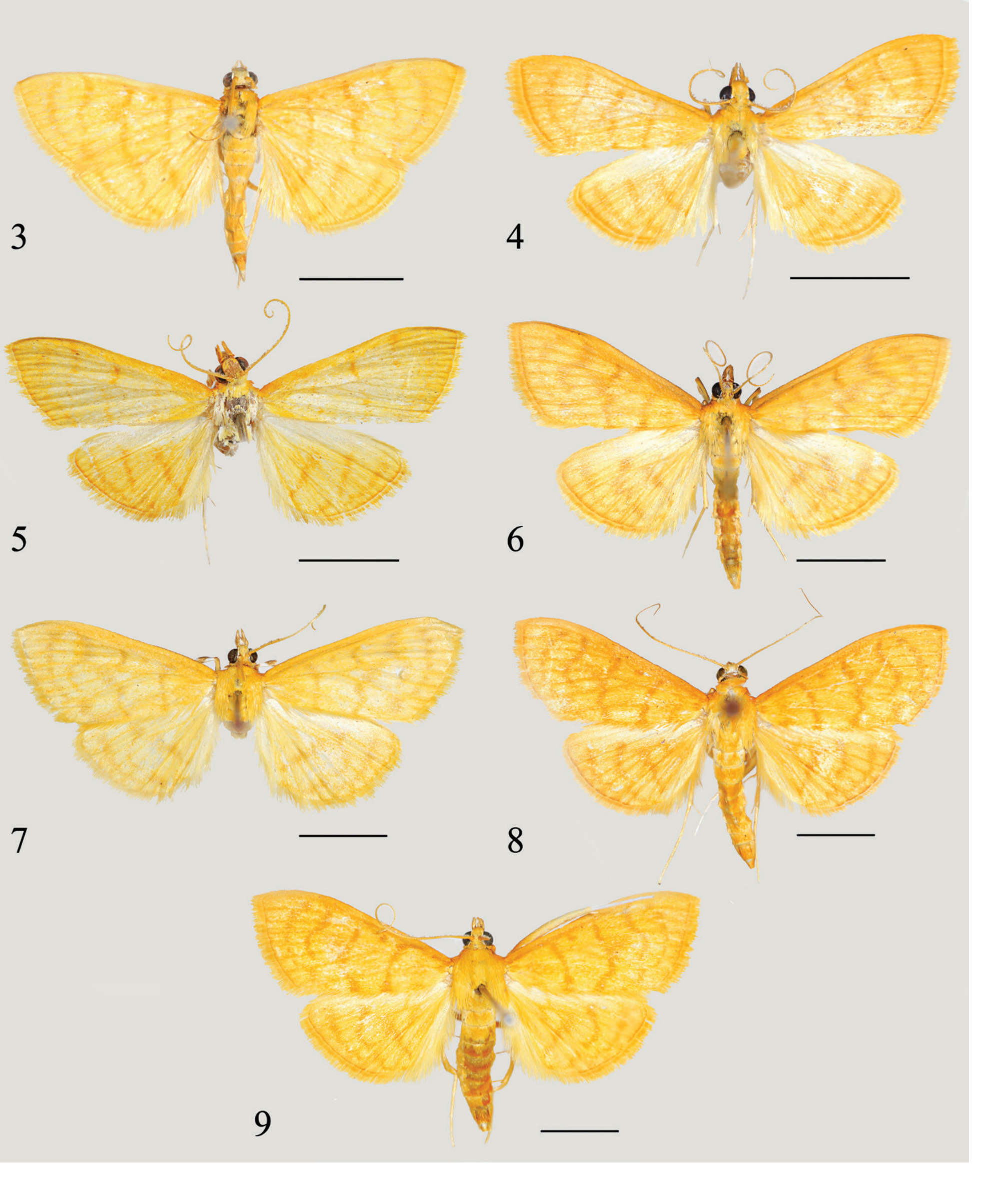
Paliga contractalis Warren, 1896, 18(6): 123.
Microstega contractalis (Warren) Bänziger, 1995: 270.

Material examined. Type material. Lectotype, 1♂; Khasis, Warren Type, Pyralidae Brit. Slide No. 8677 (NHMUK), designated by Bänziger (1995).

Other material examined. CHINA, Hainan: 2♂, 1♀, Bawangling, Changjiang, 19.12N, 109.08E, alt. 161 m, 22.VII.2014, leg. Cong Peixin, Hu Sha and Liu Linjie, genitalia slide no. ZDD12049 (♂) (NKU); 1♀, Bawangling, 11.VI.2010, leg. Kang Li, genitalia slide no. SYSU0185; 1♂, 1♀, Jianfengling, 5.VI.2010, leg. Kang Li, genitalia slide no. SYSU0174 (♂); 1♀, Jianfengling, 18.75N, 108.85E, alt. 969 m, 12.IX.2013, leg. Xie Weicai, genitalia slide no. SYSU0067; 1♂, Bangxi Reserve, 19.37N, 109.10E, alt. 97 m, 2.IX.2013, leg. Chen Xiaohua, genitalia slide no. SYSU0017; 1♂, Nankai Town, Baisha, 19.05N, 109.40E, alt. 294 m, 19.V.2013, leg. Li Jinwei, genitalia slide no. SYSU0065; 1♂, Sanya Village, Fanjia, 19.25N, 109.65E, alt. 302 m, 27.X.2013, leg. Chen Kai and Chen Xiaohua, genitalia slide no. SYSU0040; 1♀, Mt. Diaoluoshan, alt. 500 m, 24.V.2014, leg. Xu Dan and Xu Lijun, genitalia slide no. SYSU0914; 1♀, Wuzhishan Natural Reserve, 18.88N, 109.65E, alt. 742 m, 21.V.2015, leg. Cong Xinpei, Guan Wei and Hu Sha (NKU); **Yunnan:** 3♂, Bawan, Baoshan, alt. 1040 m, 9.VIII.2007, leg. Zhang Dandan, genitalia slide no. SYSU0019; 5♂, 1♀, Baihualing, Baoshan, alt. 1520 m, 11,13.VII.2007, leg. Zhang Dandan, genitalia slides no. CXH12155 (♂), SYSU0039 (♂), SYSU0047 (♂), SYSU0073 (♀); 2♂, Baihualing, Mt. Gaoligongshan, Baoshan City, 25.30N, 98.80E, alt. 1473 m, 29.VII.2013, leg. Liu Shurong, Teng Kaijian and Wang Yuqi (NKU); 1♂, Baihualing, Mt. Gaoligongshan, Baoshan City, 25.30N, 98.80E, alt. 1473 m, 7.VIII.2014, leg. Liu Shurong, Rong Hua and Teng Kaijian (NKU); 1♂, Dahaoping, alt. 2020 m, 6.VIII.2007, leg. Zhang Dandan; 1♂, Jingpozhai, Nabang, Yingjiang, 24.71N, 97.39E, alt. 231 m, 3.VIII.2013, leg. Liu Shurong, Teng Kaijian and Wang Yuqi (NKU); 2♂, 1♀, 55 km site, Xishuangbanna Natural Reserve, 23.V.2015, leg. Zhang Zhenguo, genitalia slide no. ZDD12053 (♂, molecular voucher no. SYSU-LEP0153) (NKU); 1♂, Yexiang Valley, Xishuangbanna, 22.17N, 100.87E, alt. 762 m, 18.VII.2014, leg. Guan Wei, Liu Shurong and Wang Xiuchun (NKU); 2♂, 1♀, Yexiang Valley, Xishuangbanna, 22.17N, 100.87E, alt. 762 m, 10–12.VII.2015, leg. Bai Xia and Teng Kaijian, genitalia slide no. ZDD12048 (♂, molecular voucher no. SYSU-LEP0135) (NKU); 1♂, Guanping, Mengyang, alt. 1200 m, 20.VIII.2005, leg. Ren Yingdang, genitalia slide no. CYP12056 (NKU); 1♂, Nanla River, Bubang, Mengla, 21.59N, 101.58E, alt. 652 m, 15.VII.2013, leg. Liu Shurong, Teng Kaijian and Wang Yuqi (NKU); 1♀, Yaoqu Town, Xishuangbanna, alt. 780 m, 26.V.2015, leg. Tao Manfei, genitalia slide no. SYSU0913, molecular voucher no. SYSU-LEP0133; **Tibet:** 1♀, Medog, alt. 1103 m, 8.VII.2013, leg. Li Jinwei, genitalia slide no. SYSU0915.

Diagnosis. Within the genus, *S. contractalis* resembles *S. rectacutus* and *S. brevacutus* in the relatively small wingspan, the almost indistinguishable wing pattern, the glabrous uncus, a row of dense setae on the transtilla dorsally, the two sclerotized notches anterolaterally on the sinus vaginalis and the short ductus bursae (approximately as long as the length of the corpus bursae). However, it can be differentiated from *S. rectacutus* by the somewhat more sinuate postmedial line of the forewing near costa, in the male genitalia by the shorter, excurved spines of the uncus and the acinaciform, densely spinous extension of the sacculus distally. In the female genitalia, it is characterized by the curved sclerotized notches anterolaterally on the sinus vaginalis. The differences between *S. contractalis* and *S. brevacutus* are given in the diagnosis of the latter species.

Redescription. *Head*. As for the genus. *Thorax*. Yellow. Legs as described for the genus. Wingspan 18–22 mm. Wings yellow, lines fulvous. Forewing broadly triangular with moderately arched termen; antemedial line weakly sinuate from about 1/4 of costa to 2/5 of posterior margin; orbicular stigma small, sometimes faint; reniform stigma a fulvous, slightly curved streak; posterior angle of cell outwardly followed by a fulvous mark; postmedial line from 3/5 of costa slightly sinuate to beyond basal half of CuA_1, bent inwardly to 1/3 of CuA_2, then to 2/3 of posterior margin; subterminal line from distal end of R_2, arched to about 4/5 of CuA_2, then concave to 4/5 of posterior margin; fringe yellowish brown. Hindwing with costa and posterior margin translucent whitish; posterior angle of cell outwardly followed by a fulvous mark; postmedial line straight from basal half of M_1 to distal third of CuA_2, bent inwardly to basal third of CuA_2, then straight to near end of 2A; subterminal line from distal third of R_S, arched, tapering to CuA_2, then concave to distal end of 1A; fringe as in forewing. *Abdomen*. Yellow dorsally, apical margin of segments tinged with white. *Male genitalia* (Figure 10). Uncus with lateral margin strongly bulging near distal end, with a sharply widened base; without setae; with two outwardly curved, pointed spines, weakly dentate between the spines. Valva of medium width, slightly narrowing towards apex, length approximately 2× its maximal width; transtilla dorsally strongly sclerotized and set with dense setae; costal sclerotized band narrow, slightly expanded to 2/3 of dorsal margin; sacculus with distal half expanded, forming acinaciform sclerotized process, dorsally set with dense spines; sella long and slender, rod-like, distal end strongly inflated, set with several narrow, fin-shaped setae forming editum, each seta with apex evenly divided into several filaments. Juxta heart-shaped, deeply divided distally. Phallus with distal 1/3 expanded and spinulose; vesica in distal part with numerous spine-like cornuti appear funnel-shaped (Figure 10C). *Female genitalia* (Figure 19). Posterior apophysis with small expansion at basal third; anterior apophysis with small expansion beyond basal half. Sinus vaginalis with two curved, sclerotized notches anterolaterally; lamella postvaginalis weakly sclerotized medially, most strongly sclerotized dorsolaterally. Antrum membranous. Ductus bursae moderately broad, nearly as long as length of corpus bursae; colliculum narrow medially. Corpus bursae approximatively drop-shaped; accessory bursa arising from posterior 1/3 of corpus bursae,



Figures 3–9. Adults of *Spinosuncus* spp. **3** *S. contractalis*, male (Dahaoping, Yunnan) **4** *S. rectacutus*, holotype, male (Weng'ang Town, Guizhou) **5** *S. brevacutus*, holotype, male (Weng'ang Town, Guizhou) **6** *S. praepandalis*, male (Weng'ang Town, Guizhou) **7** *S. curvisetaceus*, paratype, male (Tongmu Village, Fujian) **8** *S. aureolalis*, male (Bubang, Yunnan) **9** *S. quadracutus*, paratype, male (Mt. Limu, Hainan). Scale bars: 5.0 mm.

with small, densely spinulose second signum beside its base; rhombic signum with two opposing angles bearing well developed carinae and closely separated medially, the other two angles bearing dense spines.

Distribution.(Figure 28). China (Hainan, Yunnan, Tibet), India, Thailand.

***Spinosuncus rectacutus* sp. n.**
http://zoobank.org/B77B43A4-3F97-4157-ACD1-BD646B953C4D
Figs 4, 11, 20, 28

Material examined. Type material. Holotype ♂ (Fig. 4); **CHINA, Guizhou:** Weng'ang Town, Maolan Reserve, Libo, 25.25N, 107.90E, alt. 814 m, 25.VII.2015, leg. Chen Kai, genitalia slide no. SYSU0060. Paratypes: **Hubei:** 1♂, Pingbaying, Xianfeng, alt. 1280 m, 21.VII.1999, leg. Li Houhun et al., genitalia slide no. ZDD12055 (NKU); 3♂, Mahe Town, Xianfeng, alt. 400 m, 24–26.VII.1999, leg. Li Houhun et al., genitalia slide no. ZDD12056 (NKU); 1♂, Maobaqu, Lichuan, alt. 700 m, 29.VII.1999, leg. Li Houhun et al., genitalia slide no. ZDD12057 (NKU); **Guangxi:** 1♂, Nanchao, Yachang Forest Farm, Leye, alt. 1160 m, 26.VII.2004, leg. Xu Jiasheng (NKU); 1♂, Huaping, Yachang Forest Farm, Leye, alt. 910 m, 28.VII.2004, leg. Xu Jiasheng, genitalia slide no. CYP12058 (NKU); 15♂, 2♀, Nonggang, Longzhou, 22.47N, 106.96E, alt. 271 m, 19.IV.2012, leg. Li Jinwei, genitalia slides no. SYSU0036 (♀), 0188 (♀), 0009, 0014, 0024, 0041, 0042, 0043, 0044, 0054, 0055; 8♂, 2♀, Nonggang, Longzhou, alt. 188 m, 25,27,28,31.VII.2011, leg. He Guiqing, genitalia slides no. SYSU0189 (♂), 0194 (♀), 0979 (♀); 1♂, Nonggang Reserve, 21.VIII.2011, leg. Yang Lijun, genitalia slide no. SYSU0053; 1♂, Nonggang Reserve, 21.VIII.2011, leg. Cheng Muchun, genitalia slide no. CXH12165; 1♂, Nonggang, Longzhou, 20.VIII.2011, leg. Cheng Muchun; 1♂, Nonggang, Longzhou, alt. 280 m, 29.VII.2012, leg. Yang Xiaofei (NKU); 1♂, Sanlian, Longzhou, alt. 180 m, 1.VIII.2011, leg. He Guiqing; 1♂, Tongling Valley, 23.02N, 106.65E, alt. 535 m, 22.VII.2013, leg. Chen Xiaohua, genitalia slide no. SYSU0259; 1♂, Longrui Reserve, 18.VIII.2011, leg. Li Jinwei, genitalia slide no. SYSU0021; 1♂, Longrui Reserve, 19.VIII.2011, leg. Zhang Dandan; 2♂, Bangliang, Jingxi, 1,5.VIII.2010, leg. Huang Jianhua, genitalia slide no. ZDD12047 (NKU); **Guizhou:** 2♂, Xian'nv'dong, Dashahe, Daozhen, alt. 600 m, 28–29.V.2004, leg. Hao Shulian, genitalia slide no. CYP12057 (NKU); 1♂, Baishao Village, Qinggangtang, Suiyang, alt. 800 m, 11.VIII.2010, leg. Du Xicui, genitalia slide no. CYP12063 (NKU); 1♂, Baishao, Kuankuoshui, alt. 800 m, 10.VIII.2010, leg. Du Xicui, genitalia slide no. SYSU0187; 1♂, Mt. Leigongshan, 26.35N, 108.15E, alt. 1198 m, leg. Chen Xiaohua, genitalia slide no. SYSU0057, molecular voucher no. SYSU-LEP0155; 1♂, Dongdai, Shuizu Town, Limingguan, Libo, alt. 720 m, 19.VII.2015, leg. Li Jia'en and Yang Meiqing, genitalia slide no. ZDD12050, molecular voucher no. SYSU-LEP0134 (NKU); 1♀, Weng'ang Town, Maolan Reserve, Libo, 25.25N, 107.90E, alt. 814 m, 25.VII.2015, leg. Chen Kai, genitalia slide no. SYSU0072; **Chongqing:** 2♂, 1♀, Xiaonanhai, Qianjiang, alt. 370 m, 21.VII.2012, Xu Lijun and Zhang Jun, genitalia slides no. SYSU0186 (♂), 0193 (♀).

Diagnosis. *Spinosuncus rectacutus* resembles *S. contractalis* and *S. brevacutus*, for which details are provided in the diagnosis of *S. contractalis*. It can be best distinguished from *S. brevacutus* by the dorsally densely setose transtilla (moderately setose in *S. brevacutus*), and the saddle-shaped sacculus with sclerotized margin densely set with a row of spinules. The distal spines of the uncus are straight and longer than those of *S. brevacutus*, and the lateral margin near the distal end of the uncus is less bulging. In the female genitalia, the length of the colliculum is approximately 1.5× as long as its minimal width and the notches on the sinus vaginalis are strongly sclerotized whereas in *S. brevacutus*, the length of the colliculum is approximately as long as its minimal width and the notches on the sinus vaginalis are weakly sclerotized.

Description. *Head*. As for the genus. *Thorax*. Yellow. Legs as described for the genus. Wingspan 18–22.5 mm. Wing pattern as in *S. contractalis*. *Abdomen*. Yellow dorsally, apical margin of segments tinged with white. *Male genitalia* (Figure 11). Uncus with lateral margin slightly bulging near distal end, with base sharply widened; setae absent; distal two corners with straight, pointed spines, outer margin between spines dentate. Valva of medium width, length approximately 2.3× its maximal width; transtilla with dorsal margin strongly sclerotized and set with dense setae; costal sclerotized band wide, slightly expanded to 2/3 of dorsal margin; distal half of sacculus expanded to a saddle-shaped structure, with sclerotized margin, basal half of margin slightly twisted, set with dense spines; sella long and slender, rod-like, distal end slightly inflated, set with several narrow, fin-shaped setae forming editum, each seta with apex evenly divided into several filaments. Juxta heart-shaped. Phallus as in *S. contractalis*. *Female genitalia* (Figure 20). Posterior apophysis with small expansion at basal third; anterior apophysis with small expansion beyond basal half. Sinus vaginalis with two straight, sclerotized notches anterolaterally; lamella postvaginalis weakly sclerotized medially, most strongly sclerotized dorsolaterally. Antrum membranous. Ductus bursae slender, nearly as long as length of corpus bursae; colliculum narrow medially. Corpus bursae drop-shaped, slightly spinulose; accessory bursa arising from posterior 1/3 of corpus bursae, with small, densely spinulose second signum beside its base; rhombic signum with carinae almost connected.

Etymology. The specific name is derived from the Latin *recti-* for straight and *acutus,* pointed, referring to the straight, pointed spines of the uncus.

Distribution.(Figure 28). China (Hubei, Guangxi, Guizhou, Chongqing).

Spinosuncus brevacutus **sp. n.**

http://zoobank.org/D2E5D324-0CEB-46A5-B31E-4B520E704B72

Figs 5, 12, 21, 28

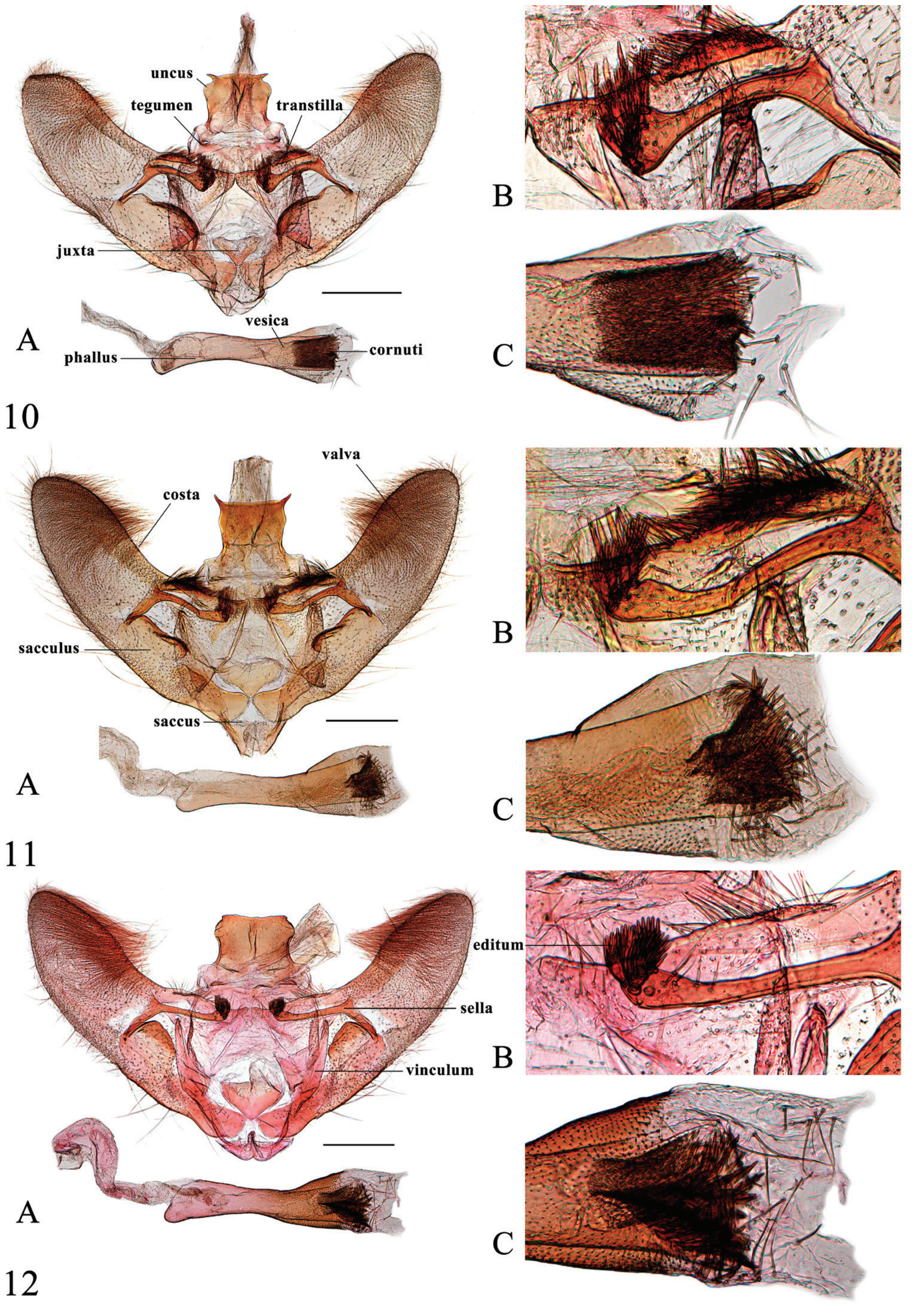
Material examined. Type material. Holotype ♂ (Fig. 5); **CHINA, Guizhou:** Weng'ang Town, Maolan Reserve, Libo, 25.25N, 107.90E, alt. 814 m, 25.VII.2015, leg. Chen Kai, genitalia slide no. SYSU0056, molecular voucher no. SYSU-LEP0009. Paratypes: **Jiangxi:** 1♂, Main Peak, Mt. Jinggangshan, 28.IV.2011, leg. Liu Ping and Mei Yan, genitalia slide no. CXH12192; 1♂, Main Peak, Mt. Jinggangshan, 30.VI.2011, leg. Yang Lijun, genitalia slide no. CXH12161; 1♂, Main Peak, Mt. Jinggangshan, 1.IX.2011, leg. Cheng Muchun, genitalia slide no. SYSU0064; 1♂, 1♀ (Abdomen lost), Reservoir of Mt. Jinggangshan, 19.IX.2010, leg. Tong Bo, Zhang Dandan and Zhao Shuang; 1♂, 1♀, Mt. Guanggushan, Wuzhifeng Town, Shangyou, 25.92N, 114.05E, alt. 846 m, 22.VI.2015, leg. Chen Kai, genitalia slides no. SYSU0015 (♂), 0062 (♀, molecular voucher no. SYSU-LEP0156); 1♂, Mt. Jiulianshan, Longnan, 24.54N, 114.46E, alt. 625 m, 28.IV.2012, leg. Li Jinwei, genitalia slide no. SYSU0049; **Hunan:** 1♀, Visitors' center, Taoyuandong, 26.47N, 114.04E, alt. 870 m, 20.V.2014, leg. Chen Xiaohua, genitalia slide no. SYSU0063; **Guizhou:** 1♂, Maolan Reserve, 1.IX.2011, leg. Li Jinwei, genitalia slide no. CXH12162; 4♂, Maolan Reserve, 25.13N, 107.87E, alt. 797 m, 12.VII.2013, leg. Chen Xiaohua, genitalia slides no. SYSU0020, 0023, 0074, 0910; 1♂, 2♀, Weng'ang Town, Maolan Reserve, Libo, 25.25N, 107.90E, alt. 814 m, 25.VII.2015, leg. Chen Kai, genitalia slides no. SYSU0046 (♂), 0071 (♀, molecular voucher no. SYSU-LEP0010), 0978 (♀).

Diagnosis. *Spinosuncus brevacutus* is similar to *S. contractalis* and *S. rectacutus*. Differences with *S. rectacutus* are given in the diagnosis of *S. rectacutus*. It can be distinguished from *S. contractalis* by the minute and weakly outwardly curved spines of the apical uncus, the concave margin between those spines, the moderately setose transtilla and the semicircular sacculus distally with sclerotized, sparsely toothed margin in the male genitalia, by the straight, weakly sclerotized notches of the sinus vaginalis (curved, strongly sclerotized in *S. contractalis*) and the relatively broad ductus bursae in the female genitalia.

Description. *Head*. As for the genus. *Thorax*. Yellow. Legs as described for the genus. Wingspan 19–24 mm. Wing pattern as in *S. contractalis*. *Abdomen*. Yellow dorsally, apical margin of segments tinged with white. *Male genitalia* (Figure 12). Uncus with the lateral margin strongly bulging near distal end, with base sharply widened; setae absent; distal two corners slightly extended, forming minute spines. Valva of medium width, length approximately 2.5× its maximal width; transtilla with dorsal margin slightly sclerotized, set with few setae; costal sclerotized band rather wide, slightly expanded to 2/3 of dorsal margin; distal half of sacculus expanded, semicircular, with strongly sclerotized margin, sometimes set with few tiny teeth, distal third of margin twisted; sella long and slender, rod-like, distal end slightly inflated and upcurved, set with several narrow, fin-shaped setae forming editum, each seta with apex evenly divided into several filaments. Juxta heart-shaped, distal half divided. Phallus as in *S. contractalis*. *Female genitalia* (Figure 21). Posterior apophysis with small expansion at basal third; anterior apophysis with small expansion beyond basal half. Sinus vaginalis with two straight, weakly sclerotized notches anterolaterally; lamella postvaginalis weakly sclerotized medially, most strongly sclerotized dorsolaterally. Antrum membranous. Ductus bursae moderately broad, as long as length of corpus bursae; colliculum somewhat constricted medially. Corpus bursae drop-shaped; accessory bursa arising from posterior 1/3 of corpus bursae, with small, weakly spinulose second signum beside its base; rhombic signum with two opposing angles bearing weak, narrow carinae almost connected medially, the other two angles set with spines.

Etymology. The specific name is derived from the Latin *brevi-*, short, and *acutus* for pointed, referring to the short, pointed spines of the uncus.

Distribution. (Figure 28). China (Jiangxi, Hunan, Guizhou).



Figures 10–12. Male genitalia of *Spinosuncus* spp. **10** *S. contractalis*, Hainan (genitalia slide no. SYSU0017) **11** *S. rectacutus*, Guangxi (genitalia slide no. SYSU0044) **12** *S. brevacutus*, Guizhou (genitalia slide no. SYSU0910). **A**: Whole genitalia. **B**: Base of valva dorsally. **C**: Apex of phallus. Scale bars: 0.5 mm.

Spinosuncus praepandalis **(Snellen, 1890), comb. n.**
Figs 6, 13, 22, 28

Botys praepandalis Snellen, 1890: 573–574.

Material examined. Type material. Lectotype, 1♀; Sikkim, O. Miller., [18]89, collection of H. J. Elwes, Pyralidae Brit. Slide no. 9711 (NHMUK).

Other material examined. CHINA, Hubei: 1♂, 1♀, Shayuan, Hefeng, alt. 1260 m, 15,17.VII.1999, leg. Li Houhun, genitalia slides no. ZDD02388 (♂), 02389 (♀) (NKU); Hunan: 1♀, Jiangping, Mt. Hupingshan, Shimen County, alt. 480 m, 6.V.2002, leg. Yu Haili (NKU); **Sichuan:** 1♂, Wannian Temple, Mt. E'meishan, 29.59N, 103.38E, alt. 830 m, 14.VII.2014, leg. Guan Wei, Liu Shurong and Wang Xiuchun (NKU); **Chongqing**: 1♂, Dawopu, Mt. Simianshan, 28.58N, 106.35E, alt. 1059 m, 12.VII.2016, leg. Chen Kai; 1♂, Tiantangba, Mt. Simianshan, 28.64N, 106.35E, alt. 921 m, 13.VII.2016, leg. Chen Kai; 1♂, Mt. Jinfoshan, alt. 1700 m, 13.VII.2010, leg. Du Xicui and Shi Shengwen, genitalia slide no. SYSU0191; 1♀, Wuli Town, Qianjiang, alt. 870 m, 23.VII.2012, leg. Xu Lijun and Zhang Jun, genitalia slide no. SYSU0196; **Guizhou:** 1♂, Heiwan, Jiangkou, alt. 600 m, 28.VII.2001, leg. Li Houhun and Wang Xinpu, genitalia slide no. ZDD02061 (NKU); 2♂, Huguo Temple, Mt. Fanjingshan, alt. 1390 m, 28.V.2002, leg. Wang Xinpu, genitalia slide no. CYP12041 (NKU); 3♂, Weng'ang Town, Maolan Reserve, Libo, 25.25N, 107.90E, alt. 814 m, 25.VII.2015, leg. Chen Kai, genitalia slide no. SYSU0038, molecular voucher no. SYSU-LEP0006; 1♂, Weng'ang Town, Libo, alt. 1345 m, 18.VII.2015, leg. Wan Jiping; **Yunnan:** 4♂, 2♀, Mt. Jizushan, Binchuan, 25.93N, 100.38E, alt. 1831 m, 29.VI.2012, leg. Li Jinwei, genitalia slides no. CXH12156 (♂), SYSU0045 (♂), 0076 (♀), 0980 (♀); 5♂, 1♀, Mt. Gaoligongshan, Baoshan, 24.82N, 98.78E, alt. 1700 m, 22.V.2016, leg. Duan Yongjiang, genitalia slides no. SYSU0190 (♂), 0195 (♀, molecular voucher no. SYSU-LEP0131); 2♀, Dahaoping, Tengchong, alt. 2020 m, 6.VIII.2007, leg. Zhang Dandan, genitalia slides no. SYSU0078, 0183; 1♂, Pianma Village, Lushui, Nujiang, alt. 1889 m, 16.VIII.2015, leg. Wei Xueli; 1♀, Malipo County, alt. 1098 m, 4.VI.2015, leg. Tao Manfei, genitalia slide no. SYSU0911; **Tibet:** 1♂, 1♀, Hanmi, Medog, alt. 2380 m, 9.VIII.2003, leg. Wang Xinpu and Xue Huaijun, genitalia slide no. CYP12062 (♂) (NKU); 1♂, Shangzayü, Nyingchi, alt. 1936 m, 16.VIII.2015, leg. Xu Dan. **INDIA:** 1♂, India, Sikkim, Elwes, collection of H. J. Elwes, Pyralidae Brit. Slide no. 8674 (NHMUK); 1 ♂, Sikkim, O. Miller., [18]89, collection of H. J. Elwes (NHMUK).

Diagnosis. *Spinosuncus praepandalis* has a larger wingspan (24–30 mm) than in the species described above. It has a wingspan similar to that of *S. aureolalis*, but can be differentiated by the dentate lines and the thickened anterior part of the postmedial line of the forewing near the costa. In the male genitalia, it is distinguished by the distally bifid uncus, forming two sclerotized, large outwardly curved teeth with a hairy basal margin (as in *S. curvisetaceus*), the two to three straight, thick needle-shaped setae dorsally set on each side of the transtilla and the semicircular sacculus distally with the margin sclerotized and with a small process distally. In the female genitalia, it is distinguished by the sinus vaginalis without sclerotized, streak-like or hook-like notches (as in *S. curvisetaceus*) and the long and slender ductus bursae, which is more than twice as long as the diameter of the corpus bursae, differs from that of the species described above (the ductus bursae is almost as long as the length of the corpus bursae). The differences between *S. praepandalis* and *S. curvisetaceus* are given in the diagnosis of the latter species.

Redescription. *Head*. As for the genus. *Thorax*. Yellow. Legs as described for the genus. Wingspan 24–30 mm. Wing pattern as in *S. contractalis*, apart from: wings yellowish brown; lines brown and wavy; postmedial line of forewing thickened near costa, strongly sinuate to half of CuA_1; postmedial line of hindwing curved to distal third of CuA_2. *Abdomen*. Yellowish to brown, apical margin of segments tinged with white. *Male genitalia* (Figure 13). Uncus tapering towards apex; distal 3/4 bifid, forming two outwardly curved, strongly sclerotized teeth, medially set with dense setae, arranged in a curved line. Valva of medium width, ventral margin beyond sacculus slightly concave, length approximately 2.3× its maximal width; transtilla extended ventrally into a projection, each lobe set with two to three straight, thick needle-shaped setae at dorsal base (one seta occasionally falls off), with one much bigger than other(s); costal band moderately wide, slightly expanded to 2/3 of dorsal margin; distal half of sacculus expanded, semicircular, with dorsal margin sclerotized, apically with small, triangular process; sella long and slender, rod-like, upcurved (bent in Figs 13A–B), distal end slightly inflated, set with a few broad, fin-shaped setae forming editum, each seta with apex evenly divided into several filaments. Juxta pentagonal, weakly bifid distally. Phallus with distal 1/4 slightly expanded and spinulose; vesica in distal part with numerous spine-like cornuti appear funnel-shaped (Figure 13C). *Female genitalia* (Figure 22). Posterior apophysis with distinct hook-like expansion at basal 2/5. Sinus vaginalis without sclerotized, streak-like or hook-like notches; lamella postvaginalis band-shaped, well developed, extended to cover entire eighth segment ventrally. Antrum membranous, with a narrow sclerotized transverse band posteriorly. Ductus bursae long and slender, more than three times as long as diameter of corpus bursae; colliculum almost evenly wide. Corpus bursae small, globular; accessory bursa arising from posterior 1/3 of corpus bursae; rhombic signum with well developed, moderately separated carinae, other two angles bearing spines medially, the anterior angle smaller than the posterior angle; second signum absent.

Distribution. (Figure 28). China (Hubei, Hunan, Sichuan, Chongqing, Guizhou, Yunnan, Tibet), India.

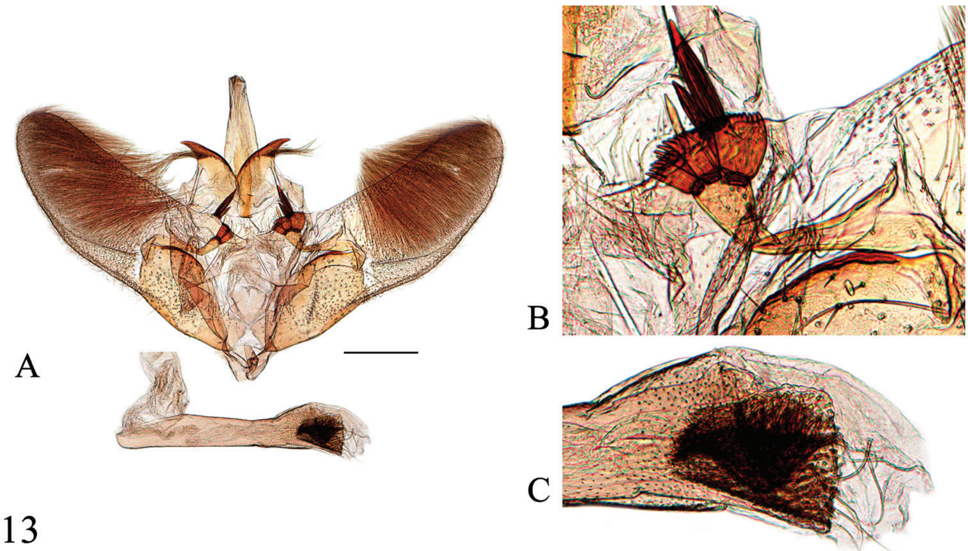
***Spinosuncus curvisetaceus* sp. n.**

http://zoobank.org/5E9A3861-D420-43A5-9B85-343125D46FCB
Figs 7, 14, 23, 28

Material examined. Holotype ♂; **CHINA, Jiangxi:** Mt. Sanqingshan, Jinsha County, Shangrao, alt. 380–390 m, 20.IV.2007, leg. Bai Haiyan and Du Xicui, genitalia slide no. ZDD12058 (NKU). Paratypes: **Fujian:** 1♂, Tongmu Village, Mt. Wuyishan, 3.V.2014, leg. Yang Xiaofei, genitalia slide no. ZDD12051 (NKU); **Jiangxi:** 1♂, Shiguling Power Plant, Mt. Sanqingshan, Jinsha County, Shangrao, alt. 410–420 m, 15.IV.2007, leg. Bai Haiyan and Du Xicui, genitalia slide no. CYP12066 (NKU); 6♂, Mt. Sanqingshan, Jinsha County, Shangrao, alt. 380–390 m, 19, 20.IV.2007, leg. Bai Haiyan and Du Xicui, genitalia slides no. CYP12060, 12074, ZDD12026 (NKU); 1♂, Shixi Town, Fengxin, 28.44N, 114.54E, alt. 506 m, 22.IX.2012, leg. Yang Lijun, genitalia slide no. CXH12167; 1♀, Nanfengmian Reserve, Qianmo Village, Suichuan, 26.28N, 114.06E, alt. 816 m, 19.VI.2015, leg. Chen Kai, genitalia slide no. SYSU0061, molecular voucher no. SYSU-LEP0129; **Guangxi:** 1♂, Jiuniutang, Mt. Mao'ershan, alt. 550 m, 20.IV.2002, leg. Hao Shulian and Xue Huaijun, genitalia slide no. ZDD02245 (NKU); 1♂, Huawang Villa, Jinxiu, alt. 550 m, 13.IV.2002, leg. Hao Shulian and Xue Huaijun, genitalia slide no. ZDD02241 (NKU).

Diagnosis. *Spinosuncus curvisetaceus* resembles *S. praepandalis* in wing pattern. The wingspan of *S. curvisetaceus* is usually smaller than that of *S. praepandalis*, *S. aureolalis* and *S. quadracutus*, but larger than in *S. contractalis*, *S. rectacutus* and *S. brevacutus*. The ground colour of the wings is paler than that of *S. praepandalis*. In the male genitalia, it can be differentiated from *S. praepandalis* by the straight mediobasal margin of the distal teeth of the uncus (curved in *S. praepandalis*), the curved setae on the transtilla dorsally (straight in *S. praepandalis*) and the expanded, rectangular distal half of sacculus, with sclerotized and densely spinulose dorsal margin. In the female genitalia, the anterior apophysis is thicker than that of *S. praepandalis*. It can be distinguished from other *Spinosuncus* species (except *S. praepandalis*) by the distally strongly bifid uncus, forming two sclerotized, large excurved teeth bearing hair-like setae basally, two thick needle-shaped setae on the transtilla dorsally and the absence of sclerotized, streak-like or hook-like notches anterolaterally on the sinus vaginalis.

Description. *Head*. As for the genus. *Thorax*. Yellowish brown. Legs as described for the genus. Wingspan 24–26 mm. Wing pattern as in *S. praepandalis*, ground colour paler than that of *S. praepandalis*. *Abdomen*. Yellowish to brown, apical margin of segments tinged with white. *Male genitalia* (Figure 14). Uncus sharply tapering towards apex; distal half bifid, forming two slightly outwardly curved and sclerotized teeth, basally set with dense setae, arranged in a curved line. Valva of medium width, ventral margin beyond sacculus slightly concave, length approximately 2.1× its maximal width; transtilla extended ventrally into long and curved projection, set with two thick and curved, needle-shaped setae at base dorsally; costal sclerotized band moderately wide, slightly expanded to 3/4 of dorsal margin; distal half of sacculus expanded, rectangular, with dorsal margin strongly sclerotized and densely spinulose, distally twisted; sella long and slender, rod-like, upcurved, distally set with few broad, fin-shaped setae, each seta with apex evenly divided into several filaments. Juxta shield-shaped, distal half divided medially. Phallus as in *S. praepandalis*. *Female genitalia* (Figure 23). Posterior apophysis with hook-like expansion at basal 2/5. Sinus vaginalis without sclerotized, streak-like or hook-like notches; lamella postvaginalis band-shaped, well developed, extended to cover entire eighth segment ventrally. Antrum membranous. Ductus bursae long and slender, more than two



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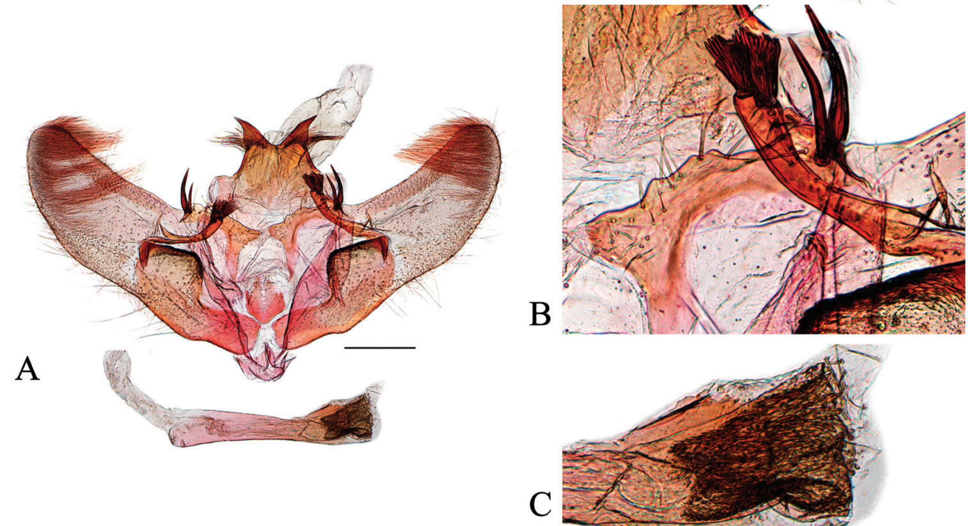

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Figures 13–14. Male genitalia of *Spinosuncus* spp. **13** *S. praepandalis*, Guizhou (genitalia slide no. SYSU0038) **14** *S. curvisetaceus*, Fujian (genitalia slide no. ZDD12051). **A**: Whole genitalia. **B**: Base of valva dorsally. **C**: Apex of phallus. Scale bars: 0.5 mm.

times as long as length of corpus bursae; colliculum narrower at anterior end. Corpus bursae small, ovoid; accessory bursa arising from posterior 1/3 of corpus bursae; rhombic signum as in *S. praepandalis*; second signum absent.

Etymology. The specific name is derived from the Latin *curv-* (curved) and *setaceus* (setaceous), referring to the curved setae set at the dorsal base of the transtilla.

Distribution. (Figure 28). China (Fujian, Jiangxi, Guangxi).

Spinosuncus aureolalis **(Lederer, 1863), comb. n.**
Figs 8, 15–16, 24–25, 28

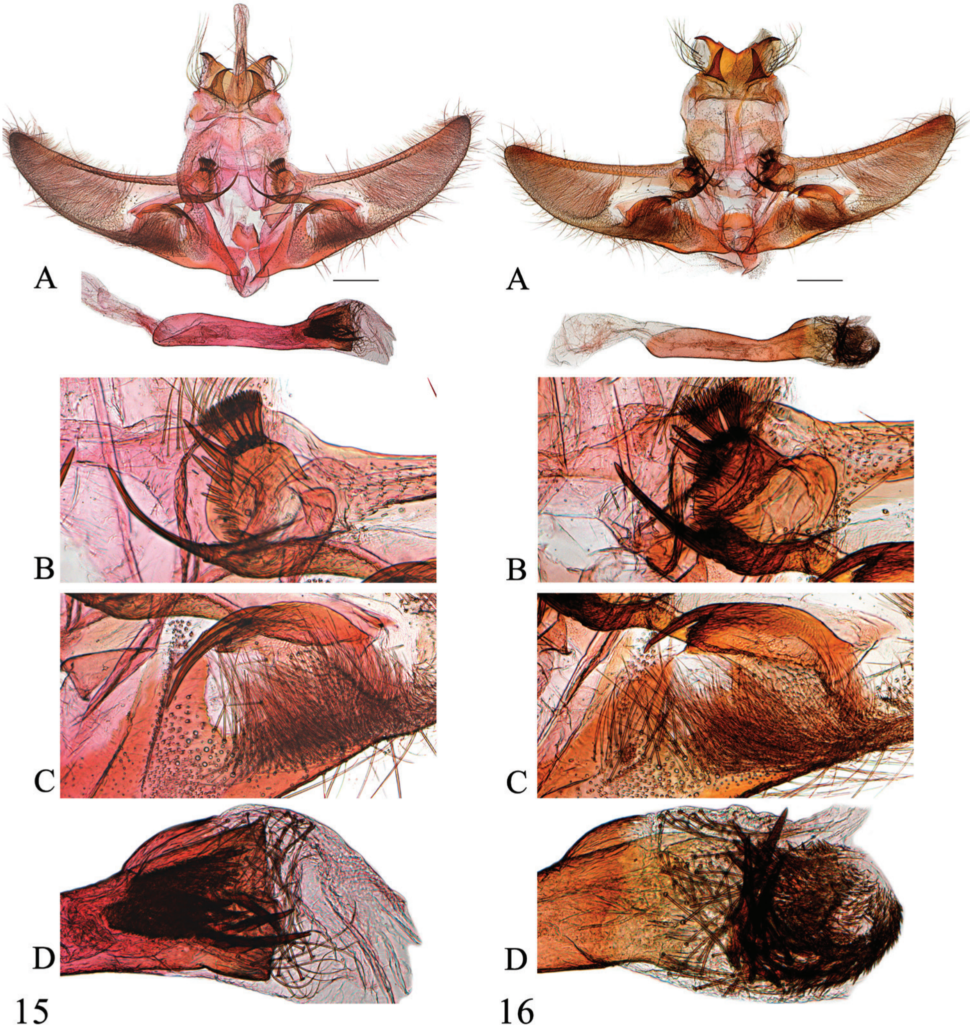
Botys aureolalis Lederer, 1863: 473.
Pyralis ochrealis Moore, 1877: 614.
Microstega aureolalis (Lederer): Bänziger, 1995: 270.

Material examined. Type material. Lectotype of *Pyralis ochrealis*: 1♂; Sikkim, Moore Coll. 94-106, Pyralidae Brit. Slide No. 8678 (NHMUK), designated by Bänziger (1995).

Other material examined. CHINA, Guangxi: 2♂, Nonggang, Longzhou, alt. 188 m, 26.VII.2011, leg. He Guiqing, genitalia slide no. SYSU0909; **Yunnan:** 1♀, Baihualing, Baoshan, alt. 1251 m, 13.VIII.2007, leg. Zhang Dandan, genitalia slide no. SYSU0075; 2♂, Baihualing, Baoshan, alt. 1520 m, 11,13.VIII.2007, leg. Zhang Dandan, genitalia slides no. SYSU0050, 0066; 1♂, 1♀, Mengla, alt. 800 m, 6,8. VII.2012, leg. Kitching and Ashton, genitalia slide no. FCEL0002 (♀) (FCEL); 2♂, 1♀, Bubang, Xishuangbanna, 21.60N, 101.59E, alt. 656 m, 23.VII.2014, leg. Guan Wei, Liu Shurong, Teng Kaijian and Wang xiuchun, genitalia slide no. ZDD12052 (♀, molecular voucher no. SYSU-LEP0146), ZDD12054 (♂) (NKU); 1♂, Nabang, Yingjiang County, 24.75N, 97.56E, alt. 239 m, 27.V.2016, leg. Duan Yongjiang, genitalia slide no. SYSU0958, molecular voucher no. SYSU-LEP0132; 1♂, Pianma Village, Lushui, Nujiang, alt. 1889 m, 16.VIII.2015, leg. Wei Xueli, genitalia slide no. SYSU0959; 1♂, Daxichang, Malipo County, alt. 1465 m, 7.VI.2015, leg. Tao Manfei, genitalia slide no. SYSU0173.

Diagnosis. *Spinosuncus aureolalis* has a large wingspan (more than 26 mm). The ground colour of the wings is the darkest within the genus. Though *S. aureolalis* has a similar wingspan as *S. praepandalis*, it can be distinguished by the sinuate but not thickened anterior part of the postmedial line of the forewing near costa and the smooth, not dentate wing lines. In the male genitalia, it is characterized by the uncus distally with two large spines, the cheliform sacculus projections, and the fin- and needle-shaped setae forming editum on the sella distally (as in *S. quadracutus*). In the female genitalia, the two large, hook-like notches anterolaterally on the sinus vaginalis and the laterally broad, granulated antrum (as in *S. quadracutus*) are diagnostic. The appearance of *S. aureolalis* is most similar to that of *S. quadracutus*, both having the same wing pattern. The differences between these two species are given in the diagnosis of *S. quadracutus*.

Redescription. *Head*. As for the genus. *Thorax*. Yellow. Legs as described for the genus. Wingspan 26–32 mm. Wings yellow, with fulvous tinge, lines fulvous to yellowish brown, venation somewhat darker than the ground colour, making wings impressively reticulated. Wing pattern as in *S. contractalis*, apart from: postmedial line of forewing more sinuate, of hindwing more curve. *Abdomen*. Fulvous dorsally, apical margin of segments tinged with white. *Male genitalia* (Figs 15, 16). Uncus gradually tapering from base to middle; laterally membranous and set with several se-



Figures 15–16. Male genitalia of *Spinosuncus aureolalis*. **15** Yunnan (genitalia slide no. ZDD12054) **16** Yunnan (genitalia slide no. SYSU0173). **A**: Whole genitalia. **B**: Base of valva dorsally. **C**: Projections of sacculus. D: Apex of phallus. Scale bars: 0.5 mm.

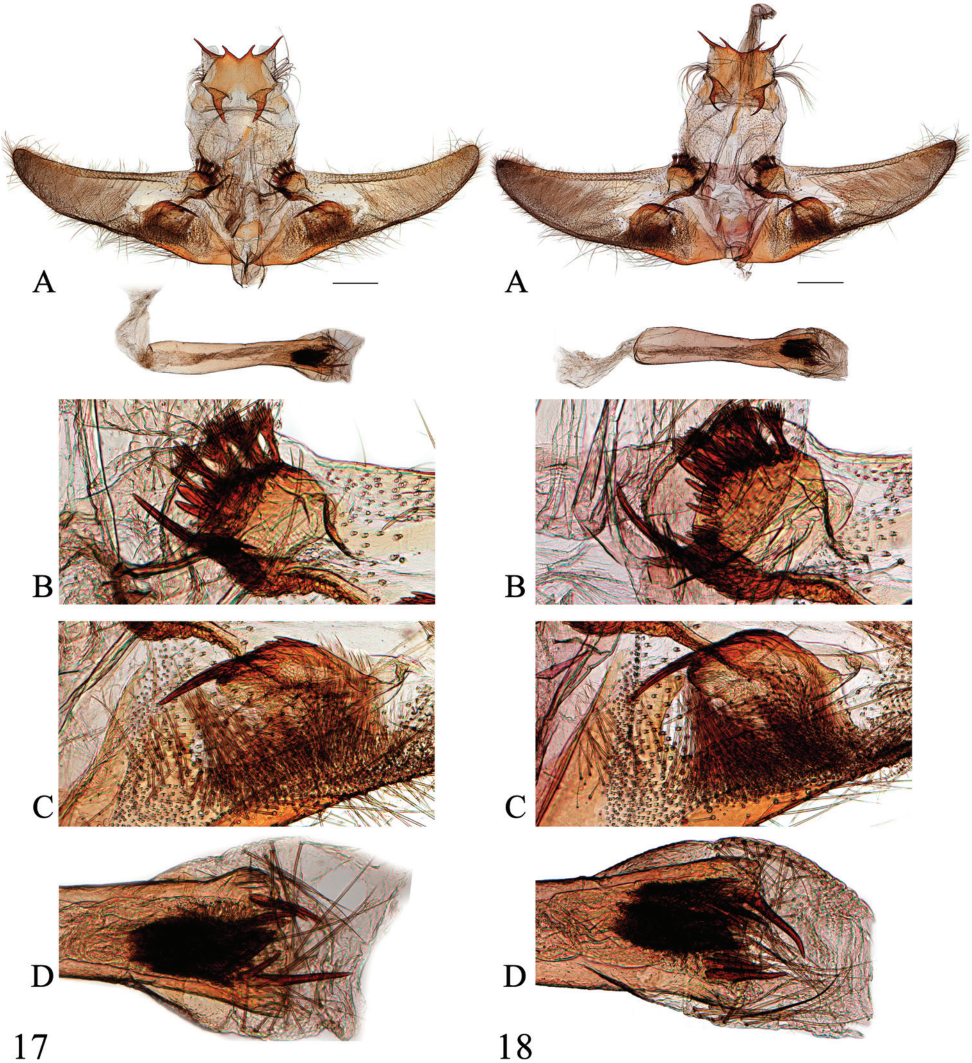
tae ventrally, other areas strongly sclerotized; distal 1/3 divided into two sharp teeth, thick, straight or slightly curved (weakly folded in Figs 15A, 16A), between two teeth usually two small and short spines (Figure 16A), sometimes invisible (Figure 15A) (longish, distinct in *S. quadracutus*, Figs 17A, 18A); with two caniniform teeth medioventrally. Valva narrow, length approximately 2.7× its maximal width; transtilla extended ventrally into long and narrow projection, dorsal margin with sparse setae; costal sclerotized band rather narrow, extended to near distal end of valva; sacculus with median caniniform projection and distal cheliform projection, distal half set with dense setae ventrally, distal projection with dorsal margin strongly sclerotized, set with dense and flat-lying spines (except distal half, Figs 15C, 16C) and two moderately downcurved spines pointing towards juxta (sometimes the longer one absent, Figure 16C); sella short and broad, distally inflated, set with modified setae forming editum, varying from fin-shaped to thick needle-shaped, ventral margin upcurved, thickened and sclerotized, distally spinose, ended in long, curved spine. Juxta shield-shaped, pentagonal, distal margin sometimes slightly indented medially. Phallus with distal 1/4 slightly expanded, vesica distally with numerous spinules and several large spicules arranged into funnel-shaped bunch of cornuti (Figs 15D, 16D, rotated in Figure 16D). *Female genitalia* (Figs 24, 25). Anterior apophysis sclerotized, slightly sinuate at distal third; posterior apophysis oblong, slender, strongly sclerotized. Sinus vaginalis with two large, thick, hook-like notches anterolaterally; lamella postvaginalis sclerotized, band-shaped, extended dorsolaterally to about 1/4 width of sinus vaginalis. Antrum granulated and broad. Ductus bursae long and wide, about two times as long as diameter of corpus bursae; colliculum well-developed, with anterior end narrower. Corpus bursae globular; accessory bursa arising from posterior end of corpus bursae; rhombic signum with carinae weak and widely separated, other two angles bearing dense spines; second signum absent.

Distribution. (Figure 28). China (Guangxi, Yunnan), India (Sikkim), Thailand (Chiang Mai).

***Spinosuncus quadracutus* sp. n.**
http://zoobank.org/181BC4CF-DC36-4D53-9084-4AC91688D188
Figs 9, 17–18, 26–28

Material examined. Type material. Holotype ♂; **CHINA, Hainan:** Mt. Limushan, 19.16N, 109.73E, alt. 662 m, 20.V.2013, leg. Li Jinwei, genitalia slide no. SYSU0048, molecular voucher no. SYSU-LEP0002. Paratypes: **CHINA, Fujian:** 1♂, Guadun, Mt. Wuyishan, 27.74N, 117.64E, alt. 1220 m, 17.V.2012, leg. Li Jinwei, genitalia slide no. SYSU0034; **Hainan:** 2♂, Mt. Limushan, 19.16N, 109.73E, alt. 662 m, 20.V.2013, leg. Li Jinwei, genitalia slide no. SYSU0032; 1♂, 1♀, Jianling Reserve, 18.87N, 110.27E, alt. 143 m, 8.IX.2013, leg. Chen Xiaohua, genitalia slides no. SYSU0029 (♂), SYSU0035 (♀, molecular voucher no. SYSU-LEP0001); 1♀, Mt. Diaoluoshan, 18.65N, 109.93E, alt. 98 m, 3.XI.2013, leg. Chen Kai and Chen Xiaohua, genitalia slide no. SYSU0912; 1♀, Nankai Town, Baisha, 19.05N, 109.24E, alt. 294 m, 19.V.2013, leg. Li Jinwei, genitalia slide no. SYSU0077.

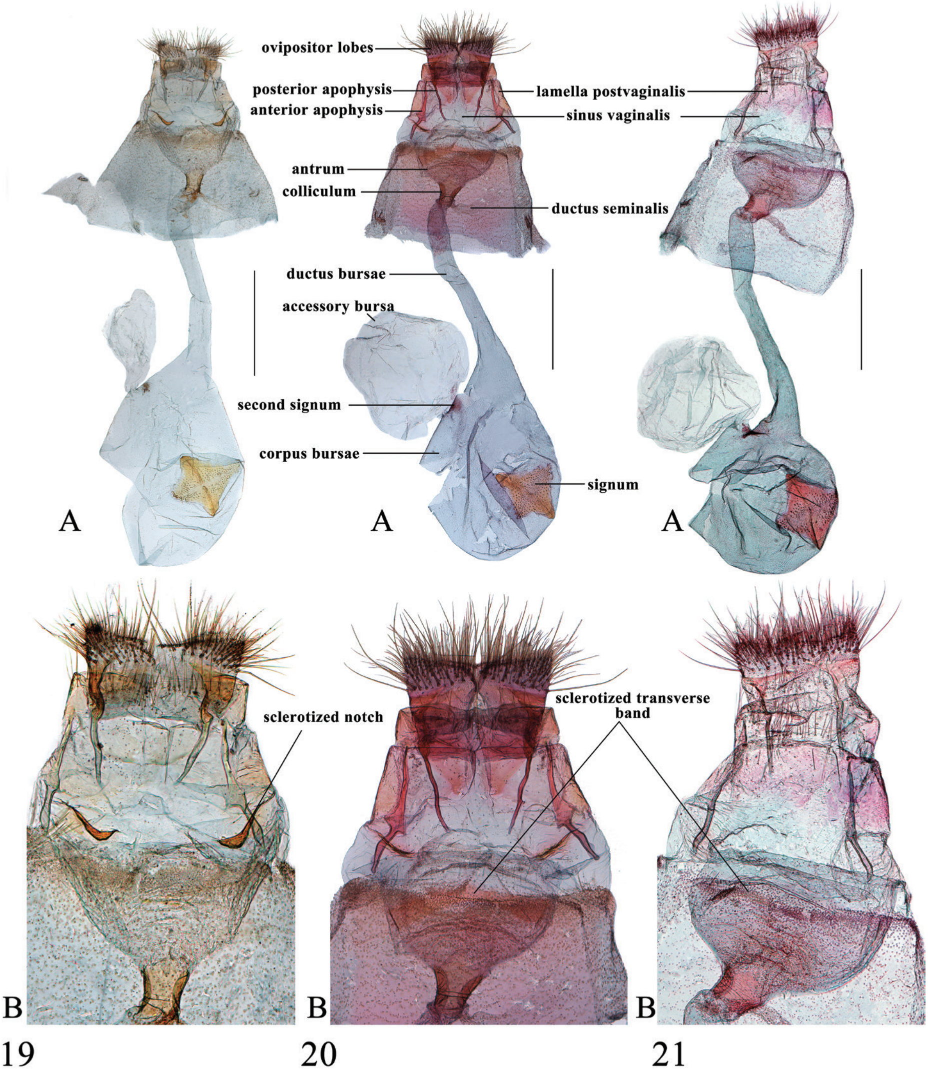
Diagnosis. This species is indistinguishable from *S. aureolalis* in wing pattern. In the male genitalia, it can be distinguished from *S. aureolalis* by the uncus with four prominent pointed spines distally (the median two small and indistinct in *S. aureolalis*), the blunt distal projection of sacculus (pointed in *S. aureolalis*) always set with one long spine pointing towards juxta (often with two long spines in *S. aureolalis*, Figure 15C) and the more spinulose and with arched dorsal margin distal projection (smooth, less arched in *S. aureolalis*, Figs 15C, 16C). In the female genitalia, it can



Figures 17–18. Male genitalia of *Spinosuncus quadracutus*. **17** Fujian (genitalia slide no. SYSU0034) **18** Hainan (genitalia slide no. SYSU0048). **A**: Whole genitalia. **B**: Base of valva dorsally. **C**: Projections of sacculus. **D**: Apex of phallus. Scale bars: 0.5 mm.

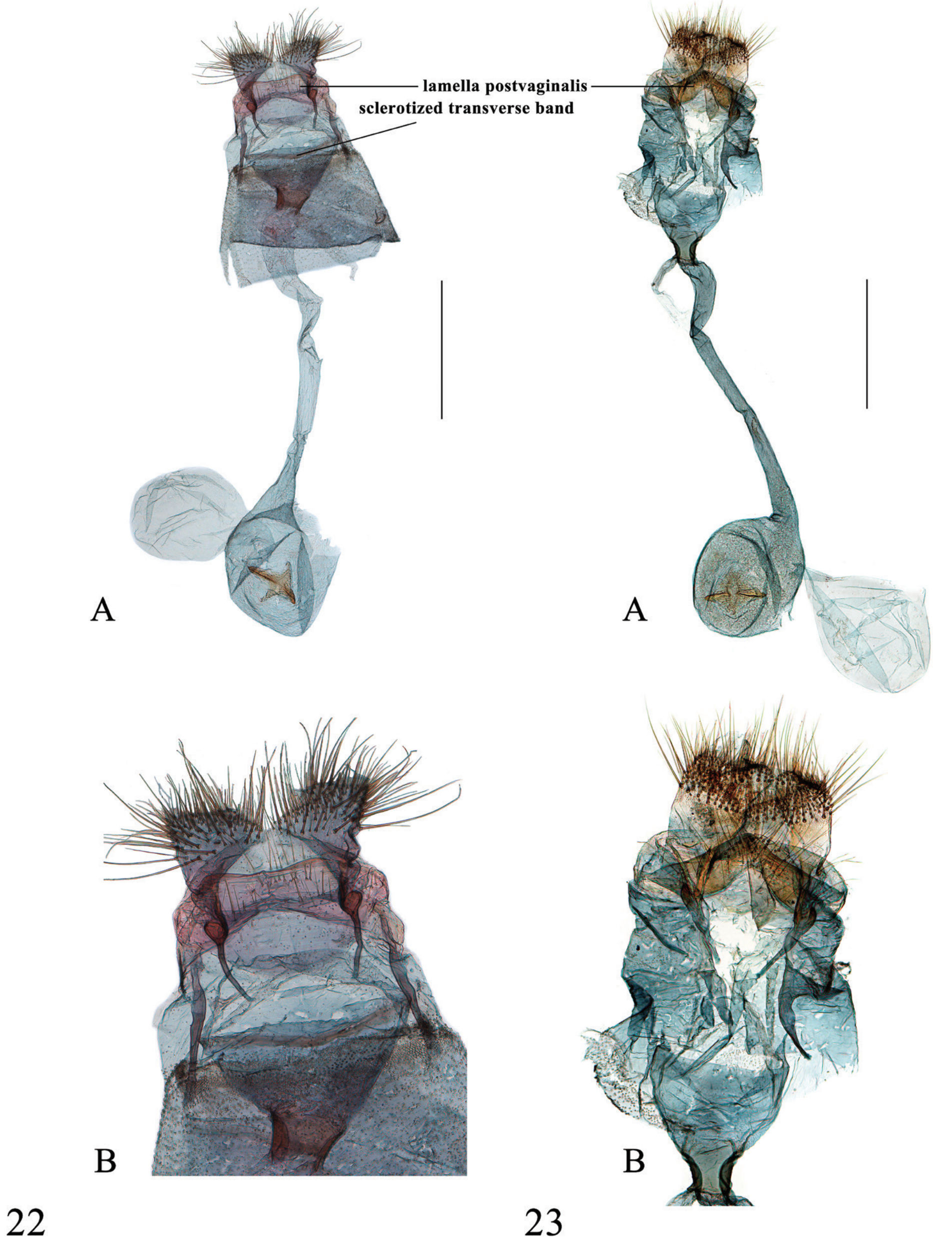
be differentiated from *S. aureolalis* by the more closely set dorsolateral extensions of lamella postvaginalis and relatively larger and more closely set hook-like notches of the sinus vaginalis anterolaterally (Figs 26B, 27B).

Description. *Head*. Frons brown, vertex with moderately raised scales projecting between antennae, labial palpus brown, white at base ventrally. Maxillary palpus brown, with apex pale yellow. *Thorax*. Yellow. Legs as described for the genus. Wingspan 26–30 mm. Wing pattern as in *S. aureolalis*. *Abdomen*. Fulvous dorsally, apical margin of segments tinged with white. *Male genitalia* (Figs 17, 18). Uncus tapering



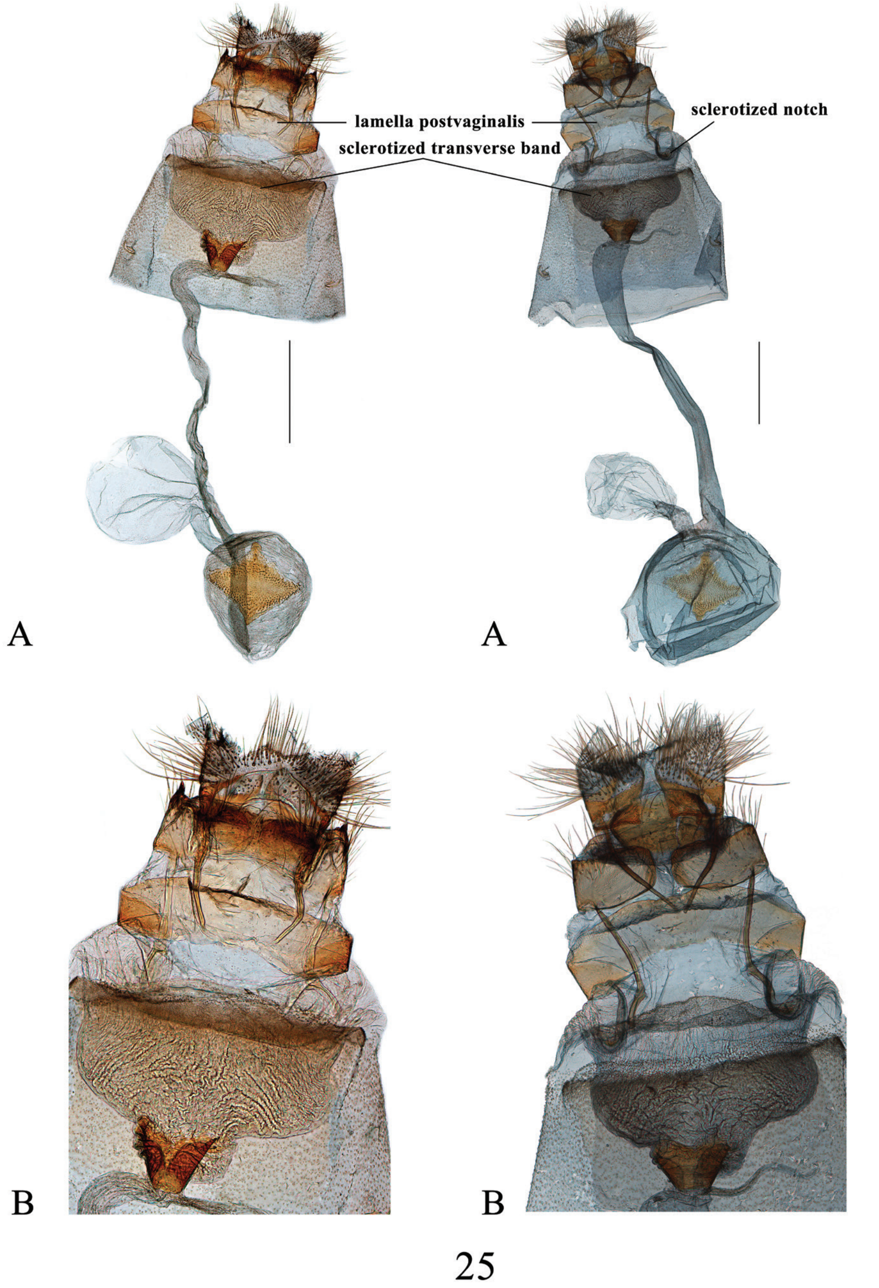
Figures 19–21. Female genitalia of *Spinosuncus* spp. **19** *S. contractalis*, Hainan (genitalia slide no. SYSU0185) **20** *S. rectacutus*, Guangxi (genitalia slide no. SYSU0979) **21** *S. brevacutus*, Guizhou (genitalia slide no. SYSU0978). A–B: Ventral views. B: Posterad of colliculum. Scale bars: 1.0 mm.

from base to middle; laterally membranous and set with several setae ventrally; otherwise strongly sclerotized; with two caniniform teeth medioventrally; distally with four sharp and slender spines, the lateral two longer, about two times as long as the median two. Valva narrow, as in *S. aureolalis*; transtilla extended ventrally into a long and narrow projection, dorsal margin with sparse setae; costal sclerotized band rather narrow, extended to near distal end of valva; sacculus with central caniniform projection and distal cheliform projection, distal half set with dense setae ventrally, distal projection strongly sclerotized, set with dense and slightly raised spines and one moderately downcurved spine pointing towards juxta; sella short and broad, distally inflated, set



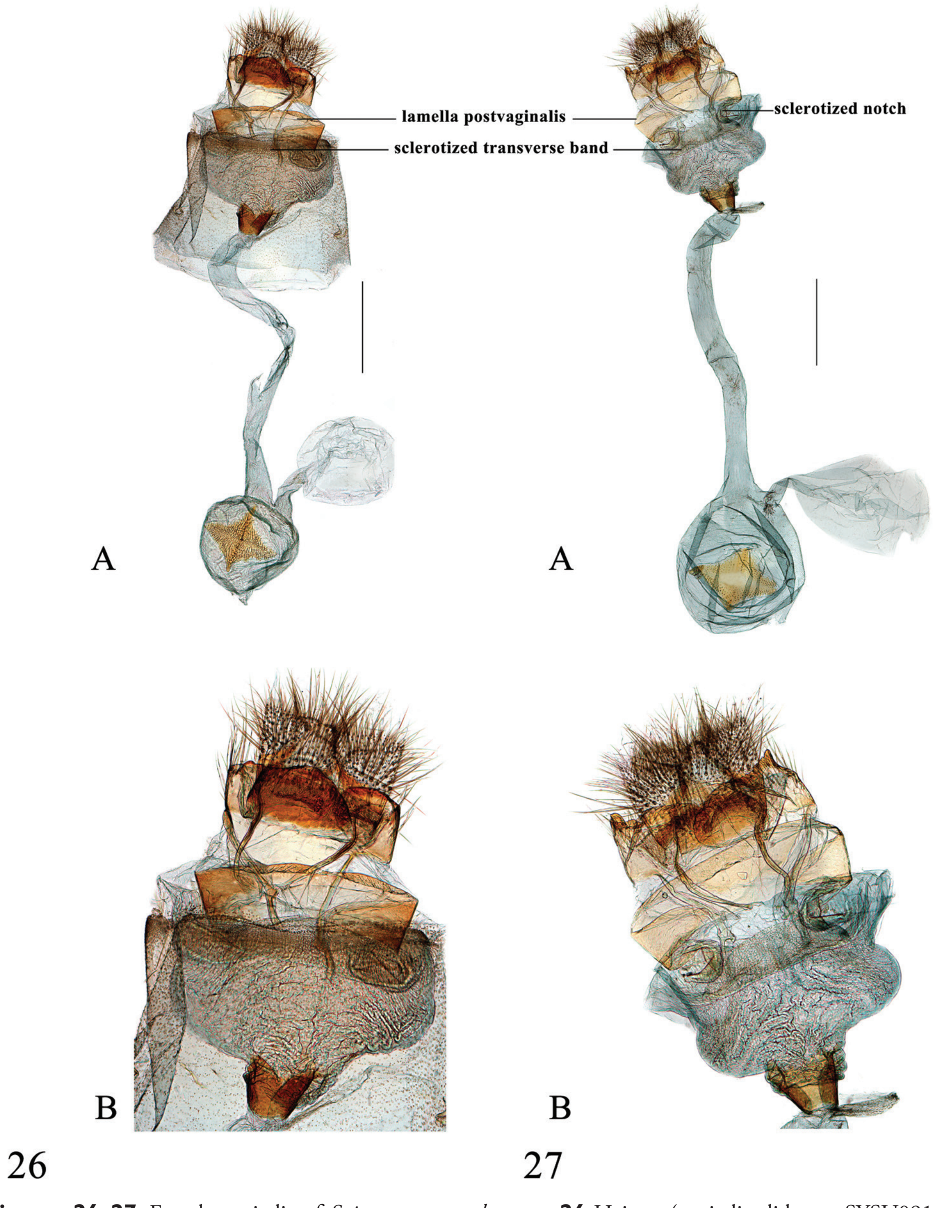
Figures 22–23. Female genitalia of *Spinosuncus* spp. **22** *S. praepandalis*, Yunnan (genitalia slide no. SYSU0980) **23** *S. curvisetaceus*, Jiangxi (genitalia slide no. SYSU0061). **A–B**: Ventral views. **B**: Posterad of colliculum. Scale bars: 1.0 mm.

with modified setae forming editum, varying form fin-shaped to thick needle-shaped, ventral margin upcurved, thickened and sclerotized, distally spinose, ending in long, curved spine. Juxta shield-shaped, pentagonal, distal margin slightly bifid. Phallus as in *S. aureolalis*. *Female genitalia* (Figs 26, 27). Anterior apophysis sclerotized, slightly sin-



Figures 24–25. Female genitalia of *Spinosuncus aureolalis*. **24** Yunnan (genitalia slide no. ZDD12052) **25** Yunnan (genitalia slide no. FCEL0002) **A–B**: Ventral views. **B**: Posterad of colliculum. Scale bars: 1.0 mm.

uate in distal third; posterior apophysis oblong, slender, and strongly sclerotized. Sinus vaginalis with two large, thick, hook-like notches anterolaterally; lamella postvaginalis sclerotized, band-shaped, extended dorsolaterally to approximately 1/3 width of sinus



Figures 26–27. Female genitalia of *Spinosuncus quadracutus*. **26** Hainan (genitalia slide no. SYSU0912) **27** Hainan (genitalia slide no. SYSU0035). A–B: Ventral views. B: Posterad of colliculum. Scale bars: 1.0 mm.

vaginalis. Antrum granulated and broad. Ductus bursae long and moderately wide, about two times as long as diameter of corpus bursae; colliculum well-developed, with anterior end narrower. Corpus bursae globular; accessory bursa arising from posterior end of corpus bursae; rhombic signum with carinae well-developed and connected (Figure 26A) or weak and wide separated (Figure 27A), other two angles densely bearing spines, sometimes smooth medially (Figure 27A); second signum absent.

Etymology. The specific name is derived from the Latin *quadri-* (four) and *acutus* (pointed), referring to the distal uncus with four pointed spines.

Distribution.(Figure 28). China (Fujian, Hainan)

Key to species of *Spinosuncus*

1	Wingspan large, usually more than 24 mm. Uncus with setae. Ductus bursae at least twice as long as length or diameter of corpus bursae........................**2**
–	Wingspan small, usually less than 24 mm. Uncus without setae. Ductus bursae approximately as long as length or diameter of corpus bursae **5**
2	Forewing with postmedial line thickened near costa. Uncus without teeth ventrally; transtilla with two to three thick needle-shaped setae; sella distally only with fin-shaped setae. Antrum membranous; sinus vaginalis without notch.... **3**
–	Forewing with postmedial line not thickened near costa. Uncus with two caniniform teeth ventrally; transtilla with few normal setae; sella distally with fin-shaped and thick needle-shaped setae. Antrum granulated; sinus vaginalis with two large, hook-like notches **4**
3	Wings with lines somewhat dentate; ground color dark yellow (Fig. 6). Transtilla with two to three straight setae, the longer one about twice as long as the shorter one (Fig. 13B); distal half of sacculus expanded, semicircular, with margin sparsely set with teeth (Fig. 13A)............. ***S. praepandalis* (Snellen, 1890), comb. n.**
–	Wings with lines not dentate, background color pale yellow (Fig. 7). Transtilla with two curved setae, the longer one less than twice as long as the shorter one (Fig. 14B); distal half of sacculus expanded, rectangular, with margin densely set with teeth (Fig. 14A) ....***S. curvisetaceus* sp. n.**
4	Uncus distally with two thick teeth, with two very minute spines, often indistinct (Figs 15A, 16A); sacculus with distal projection relatively pointed, often bearing two long spines pointing towards juxta (Figs 15C, 16C) .... ***S. aureolalis* (Lederer, 1863), comb. n.**
–	Uncus distally with four slender spines, the lateral two about two times as long as the median two (Figs 17A, 18A); sacculus with distal projection blunt, bearing one long spine pointing towards juxta (Figs 17C, 18C).......... ....***S. quadracutus* sp. n.**
5	Uncus distally blunt, with two minute spines (Fig. 12A); transtilla dorsally with a row of sparse setae (Fig. 12B) ....***S. brevacutus* sp. n.**
–	Uncus distally with two distinct spines laterally; transtilla dorsally densely setose **6**
6	Distal spines of uncus excurved, lateral margins below spines strongly bulging; distal half of sacculus with acinaciform process (Fig. 10A). Notches of sinus vaginalis curved (Fig. 19B) .... ***S. contractalis* (Warren, 1896), comb. n.**
–	Distal spines of uncus straight, lateral margins below spines slightly bulging; distal half of sacculus without acinaciform process (Fig. 11A). Notches of sinus vaginalis straight (Fig. 20B)...................................***S. rectacutus* sp. n.**

Discussion

The results of the molecular analysis robustly support the monophyly of *Spinosuncus*. The monophyly of the genus is further supported morphologically by the following potential synapomorphies: the sclerotized uncus distally with two spines or teeth, the lamellate, distally inflated sella with fin-shaped setae forming editum, the dorsally expanded sacculus with the dorsal margin sclerotized, the distally expanded, spinulose phallus, the funnel-shaped bunch of cornuti, the sclerotized lamella postvaginalis always extended dorsolaterally and the sclerotized transverse band at the posterior end of the antrum.

According to the tree topology (Figure 1), *Paratalanta* is not so closely related to *Spinosuncus*, and as already discussed by Zhang et al. (2014), species of *Spinosuncus* share no synapomorphy with *Paratalanta*. The relationship between *Pseudopagyda* + *Aglaops* and *Spinosuncus* is well supported (PP = 1.00, BS = 77), but the clade *Pseudopagyda* + *Aglaops* is only weakly supported (PP = 0.81, BS = 50). Morphologically, *Aglaops* species are similar to *Pseudopagyda* in the campanulate uncus and the distally inflated sella (which is also similar in *Spinosuncus*), but other genitalia traits differ. The wing pattern of *Aglaops* species lacks a subterminal line, whereas *Pseudopagyda* and *Spinosuncus* species have such a line. *Pseudopagyda* species resemble *Spinosuncus* species in the wing pattern. In the male genitalia, the distally inflated sella is similar to that of *Spinosuncus*; the needle-shaped setae forming editum and the presence of several large spines in the phallus distally are also found in *S. aureolalis* and *S. quadracutus*; the heart-shaped juxta is similar in *S. contractalis*, *S. rectacutus*, *S. brevacutus*, *S. praepandalis* and *S. curvisetaceus*. Based on the molecular phylogenetic results and morphological characters, *Pseudopagyda* could be the most closely related genus to *Spinosuncus*.

Other genera included in the molecular analysis, represented by *Ostrinia furnacalis* (Guenée, 1854), *Placosaris rubellalis* (Caradja, 1925), *Thliptoceras sinense* (Caradja, 1925) and *Aglaops youboialis* (Munroe & Mutuura, 1968), all lack a forewing subterminal line. *Placosaris rubellalis* and *Thliptoceras sinense* have a rod-like sella similar to that of *Spinosuncus* in the male genitalia, but the editum are different. *Ostrinia furnacalis* has a weakly sclerotized uncus, distally divided into three small, laterally setose processes, which is somewhat similar in some *Spinosuncus* species. However, other traits of the male genitalia of *O. furnacalis* are quite different from those of *Spinosuncus* species. At present, it is impossible to confirm the generic position of *Spinosuncus* within the subfamily since only few genera of Pyraustinae were included in this study.

Taxonomically, *Spinosuncus* can be divided into three species groups: the *contractalis* group, the *praepandalis* group and the *aureolalis* group. The monophyly of these three species groups is well supported by the phylogenetic analysis (Figure 1). The *aureolalis* group, comprising *S. aureolalis* and *S. quadracutus*, is well characterized by the laterally setose uncus, distally with two or four spines, ventrally with two large teeth; the lamellate, distally inflated sella with fin- and needle-shaped setae forming editum; the cheliform sacculus with a long spine pointing towards juxta; and the two thick, hook-like notches anterolaterally on the sinus vaginalis. The *contractalis* group comprises *S. contractalis*, *S. rectacutus* and *S. brevacutus*. This species group is well defined by several characters: the glabrous, sclerotized uncus distally with two spines; a row of setae on the transtilla dorsally; and two streak-like sclerotized notches anterolaterally on the sinus vaginalis. Within the *contractalis* group, *S. contractalis* is closer to *S. rectacutus* than to *S. brevacutus* based on the relatively long spines on the uncus distally and the densely setose transtilla dorsally. The *praepandalis* group, comprising *S. praepandalis* and *S. curvisetaceus*, can be recognized by the following characters: the bifid uncus with two basally setose teeth; the two needle-shaped setae on the transtilla dorsally; a long, narrowly triangular lobe projecting from the transtilla ventrally; and the long and slender ductus bursae which is about twice as long as the diameter of the corpus bursae. Within the genus, the *praepandalis* group is closer to the *contractalis* group than to the *aureolalis* group.

In this study, four new species are described based on morphological and genetic differences from related species. The morphological differences are given above in the diagnoses of the new species. The genetic distance between species in Lepidoptera are ordinarily greater than 3% (Hebert et al. 2003) in the COI barcode. Among the new species, *S. quadracutus*, *S. curvisetaceus* and *S. brevacutus* are well recognized by distance values greater than 3% from their most closely related species (Table 2). Another new species, *S. rectacutus* showed relatively low genetic distance (2.5%–2.7%) to its most closely related species *S. contractalis*. However, *S. rectacutus* can be distinguished from *S. contractalis* as mentioned above under the diagnosis of *S. rectacutus* and by the key. Moreover, such cases of low genetic divergence are also observed in some other studies in Lepidoptera (Hebert et al. 2003, 2010, Yang et al. 2016). The low interspecific divergence of congeneric species pairs may indicate their recent origin or introgression (Hebert et al. 2003, Zahiri et al. 2014). Based on the covariation between barcodes and morphological traits, *S. rectacutus* is treated as a distinct species.

A relatively high intraspecific divergence was observed in *S. aureolalis* (2.7%). The two specimens concerned, a male and a female, were collected in two localities in Yunnan that are distant by approximately 550 km (Figure 28A). According to the genitalia (Figure 24), the female specimen belongs to the *aureolalis* species group and it can be distinguished from *S. quadracutus* by the two hook-like notches more widely separated from each other. Moreover, no obvious genital variation could be found in the males found in these two localities. Consequently, they are here treated as conspecific. Genital variation is observed in two male specimens collected in Daxichang, Yunnan and Nonggang, Guangxi (genitalia slides no. SYSU0173, SYSU 0909, respectively), both places which are near the north of Vietnam. The distal projection of the sacculus has only one large spine, as in those of *S. quadracutus*, whereas those specimens collected in other places of Yunnan, Thailand and India have two spines. However, other genital traits, as given in the redescription, are all uniform, suggesting their recognition as the same species, *S. aureolalis*.

In the present study, four new species are discovered which are superficially similar to the three described species. Considering the lack of sufficient generic revisions, especially in Oriental region, there is little doubt that many described species have been misplaced and more cryptic species will be revealed within the subfamily. As Munroe (1976a) pointed out, inclusion of genitalia structures and careful analyses of the interspecific and intraspecific differences will certainly help to move ahead to natural classifications as opposed to artificial arrangements. However, the understanding of the

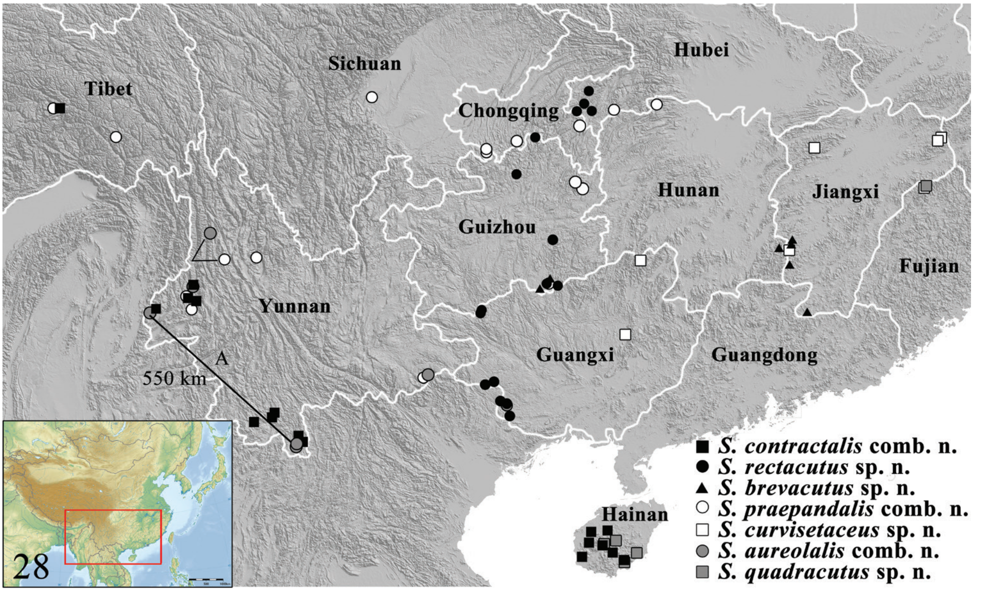


Figure 28. Distribution of *Spinosuncus* species in China. **A** Distance between Bubang and Nabang.

phylogenetic relationships between most genera of Pyraustinae is still very imperfect. Phylogenetic systematics based on morphology helps little as pyraustine genera are separated in most cases only by minute morphological differences which are difficult to interpret as apo- or plesiomorphic. The use of genetic data will facilitate species identification and help to understand the interspecific and intergeneric relationships. It calls for more comprehensive investigations on Pyraustinae in the future in order to understand this species-rich subfamily better.

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