Zootaxa 4084 (2): 233–257
http://www.mapress.com/j/zt/
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Article

ISSN 1175-5326 (print edition)
ZOOTAXA
ISSN 1175-5334 (online edition)

http://doi.org/10.11646/zootaxa.4084.2.4
http://zoobank.org/urn:lsid:zoobank.org:pub:700FBA46-8B5B-4053-9884-282DE3CFBD68

The earwig fauna (Insecta: Dermaptera) of Penang Island, Malaysia, with descriptions of two new species

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Abstract

The earwig (Dermaptera) fauna of Penang Island, Malaysia, was evaluated by means of an extensive field survey together with revision of the few published data. Based on the results of the field survey, 31 species are recognized (2 Diplatyidae, 3 Pygidicranidae, 5 Anisolabididae, 2 Labiduridae, 14 Spongiphoridae, 4 Chelisochidae, 1 Forficulidae). Fifteen of these taxa are new to Peninsular Malaysia (=West Malaysia): *Diplatys annandalei* Burr, 1911, *Diplatys mutiara* **n. sp.**, *Euborellia philippinensis* Srivastava, 1979, *Metisolabis punctata* (Dubrony, 1879), *Pseudovostox brindlei* Srivastava, 2003, *Chaetospania anderssoni* Brindle, 1971, *Chaetospania javana* Borelli, 1926, *Chaetospania huisiangi* **n. sp.**, *Paralabellula boettcheri* (Borelli, 1923), *Paralabellula rotundifrons* (Hincks, 1954), *Nesogaster amoenus* (Stål, 1855), *Hamaxas crassus* Borelli, 1926, *Proreus coalescens* (Borelli, 1927), *Hypurgus humeralis* (Kirby, 1891), and an unidentified *Echinosoma* sp. Species composition of the island are compared with the dermapteran fauna of Thailand. Descriptions of females (or female genitalia) are given for some species for the first time.

Key words: *Chaetospania huisiangi*, *Diplatys mutiara*, semi-urban environments, Southeast Asia, species catalog, species diversity

Introduction

Dermaptera (earwigs) is a polyneopteran insect order with ~2200 described species from mainly tropical and warm temperate regions (Popham 2000; Grimaldi & Engel 2005, Haas *et al.* 2012). Although several species are considered pests in gardens and in agriculture, or act as pest control agents, most earwig species inhabit natural and semi-natural environments with no direct relationship to human activities (Costa 2006). Although many dermapteran families show circumtropical distributions (Popham 2000), faunal, taxonomic, and ecological studies are especially scarce for tropical earwigs. For the Malaysian earwig fauna, no comprehensive review or checklist has been reported for Peninsular Malaysia (=West Malaysia) or Borneo (Sabah and Sarawak) in recent years. To begin filling this gap, we conducted an intensive faunal study of the earwigs of Penang Island, Peninsular Malaysia. Penang Island (Pulau Pinang) is a 299-km^2 island of Penang state, located in the Straits of Malacca, approximately 5 km from the western coast of the mainland of Peninsular Malaysia (Fig. 1). It has a typical tropical climate with average temperatures throughout the year of 27–30°C and 22–24°C during the day and night, respectively, and with a mean annual rainfall of 2,670 mm (Gardner *et al.* 2011). Although Penang Island has become increasingly urbanized, there are still large natural forests and plantation areas in the central and northeastern parts of the island (Gardner *et al*. 2011). Furthermore, recent studies on other insect groups have found many insect species new to Malaysia or new to science on this small island (e.g., Lee *et al.* 2004, Disney *et al.* 2009, Smith *et al.* 2011).

The aim of this study was to examine the contemporary dermapteran fauna of the island, which was almost unknown, by means of an extensive field survey. In total, 31 species are listed and discussed, and 2 new species are described. Including the new species and an undescribed species, 15 species are recorded for the first time in

Accepted by E. Bernard: 24 Dec. 2015; published: 25 Feb. 2016

Peninsular Malaysia. Taxonomists rarely include the morphology of female genitalia in descriptions of earwig species. However, female genital characteristics are being increasingly recognized to contain important information for phylogenetic studies of earwigs (Klass 2001, 2003, Schneider & Klass 2013, Kamimura & Lee 2014b). For some species with sufficient materials, female genital structures, especially the structure of the spermatheca, are described for the first time.

Material and methods

Earwigs were collected from various places on Penang Island during March 2012 to March 2013, for a total of 67 days. At each field survey (usually 1–5 hours during daytime), insect samples were collected by hand-sorting of decaying logs, fallen fruits, leaf litter, and loose tree bark, or by sweeping shrubs with an insect net. Nymphs were reared to adulthood in the laboratory for identification. The type material of new species and some representative samples collected in this study will be deposited in the Lee Kong Chian Natural History Museum (LKCNHM), Singapore, and the Osaka Museum of Natural History (OMNH) and the Ehime University Museum (EUMJ), Japan. A few additional records are reported from collections made in 2014.

The following five areas were selected as intensive study sites, with more than 10 days of surveys at each site (Table 1, Fig. 1): Telok Bahang-Batu Ferringi, Ayer Itam-Kebun Bunga, Bukit Jambul-Bukit Kukus, Bayan Mutiara, and Sungai Burung-Sungai Nipah areas. Collectively, these sites included almost all environmental and vegetation types on the island (coastal environments, grasslands, park gardens, fruit plantations, rubber plantations, rice fields, secondary forests, and natural forests), from the coastline to mountainous regions with elevations of up to 700 m (Table 1). We also reviewed critically the literature records of Dermaptera from Penang Island and the distribution of species found in the field survey. Monographs or compilations by Sakai (1985, 1987, 1990, 1991, 1992, 1993, 1994, 1995a, 1995b, 1995c, 1995d, 1996) and Steinmann (1986, 1989a, 1989b, 1990, 1993) were used extensively as primary references.

TABLE 1. Penang Island environments of the five intensive study sites plotted in Fig. 1.

Study sites, GPS coordinates	Environment
Telok Bahang-Batu Ferringi area 5.464946N,100.222778E	Sandy beaches, coastal forests, and natural forest areas including dipterocarp forests in Penang National Park (or Pantai Ache Forest Reserve), elevation to about 400 m.
Ayer Itam-Kebun Bunga area 5.433503N,100.280113E	Plantations of durian and other fruits, natural forests at high elevation on Bukit Bendera (= Penang Hill), recreational parks and gardens including Kebun Bunga (= Penang Botanical Garden), elevation to 730 m.
Bukit Jambul-Bukit Kukus area 5.348821N,100.285692E	Plantations of rubber, durian, banana and other fruit trees, surrounded by secondary forests, elevation up to about 400 m.
Sungai Burung-Sungai Nipah area 5.332071N,100.199776E	Paddy fields and banana plantations in a coastal wetland, elevation less than 10 m.
Bayan Mutiara 5.342241N,100.310497E	Sandy beach with grasslands, elevation less than 10 m.

The suprageneric classification followed in the present work follows Srivastava (2003b), excepting the family Pygidicranidae. Srivastava (2003b) placed the subfamily Diplatyinae in the family Pygidicranidae. In the present work, Diplatyidae at the level of family and Diplatyinae were used according to the classification proposed by Sakai (1982). The generic classification of Diplatyidae + Pygidicranidae, Anisolabididae and Spongiphoridae basically follows Srivastava (1992, 1999, 1995), respectively, unless otherwise noted. For several species, the reproductive biology and morphology have already been reported elsewhere based on samples collected during the field survey (Kamimura & Lee 2014a, b; Kamimura *et al*. in press).

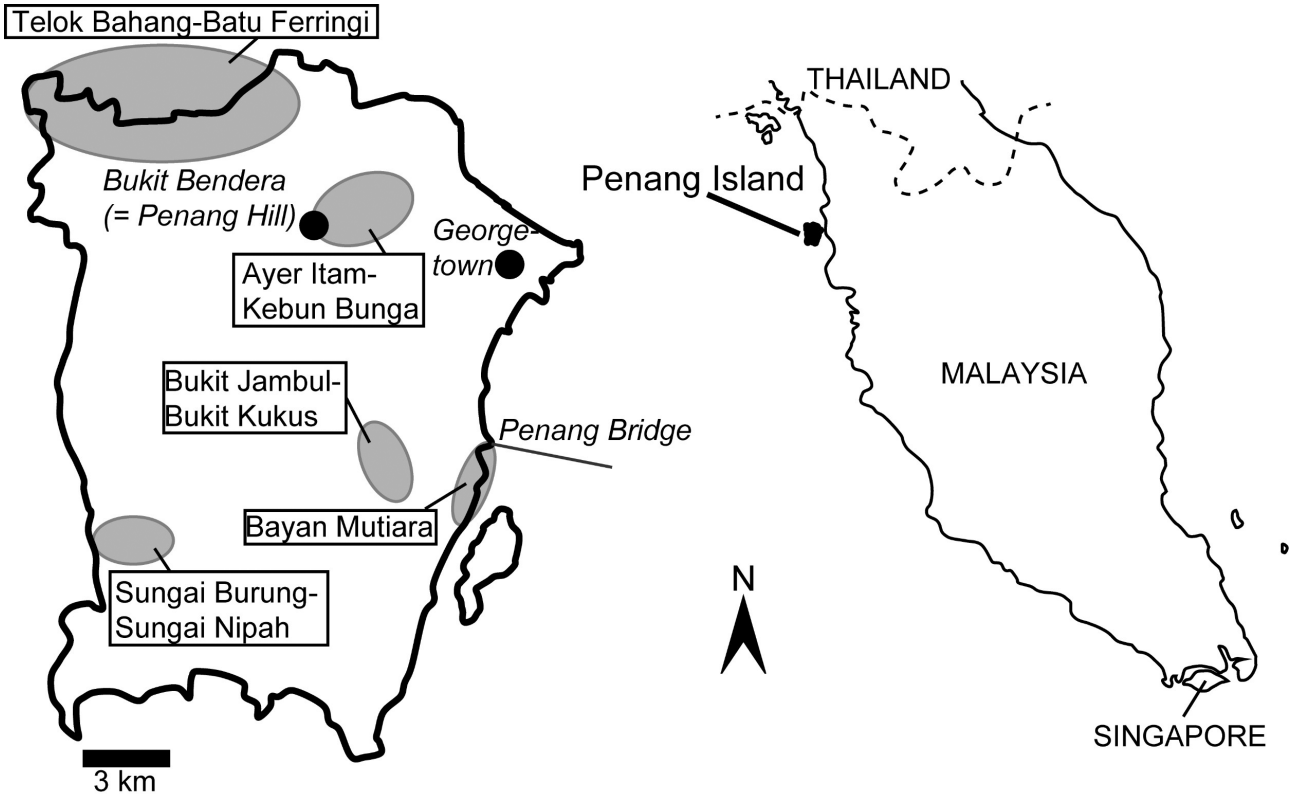


FIGURE 1. Location of Penang Island and the five intensive study sites on the island, indicated by grey ellipses.

Results

The following 31 species from seven families, of which two species could be determined only to family or genus level, were recorded in the field survey. All species, including the two new species described herein, are shown in Figs. 2–57 as male and female adults, or males only.

Order Dermaptera

Family Diplatyidae

Subfamily Diplatyinae

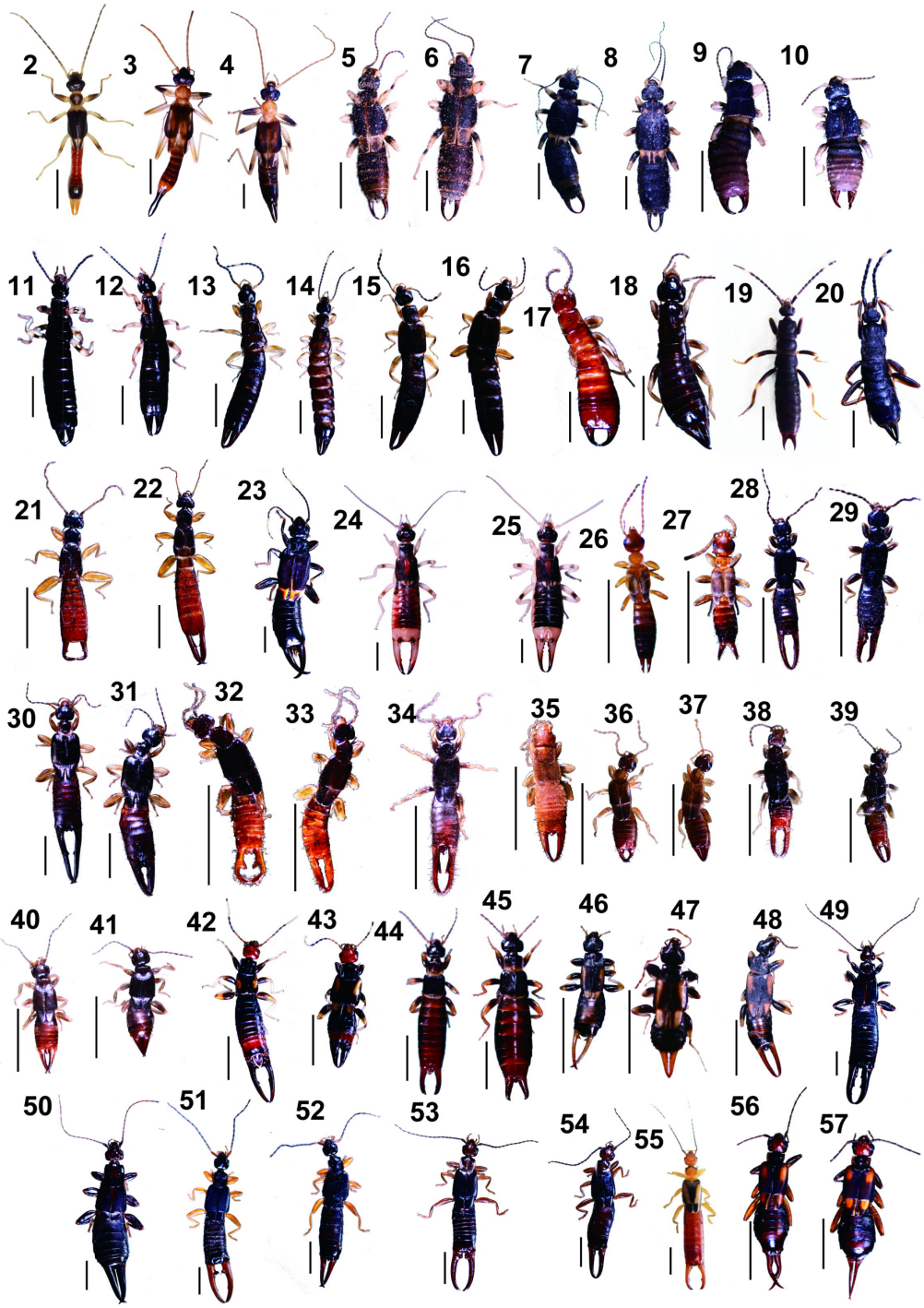
***Diplatys annandalei* Burr, 1911**
(Fig. 2)

Diplatys annandalei Burr, 1911: 42.

Material examined: 1 male reared from nymph collected from a dead log. From Ayer Itam-Kebun Bunga.
Distribution. Thailand and Peninsular Malaysia (Penang Island, new record).

***Diplatys mutiara* Kamimura & Nishikawa n. sp.**
(Figs. 3, 4, 58–65)

Description. Length of body without forceps: males 11.0–12.4 mm, females 11.0–13.5 mm. Length of forceps: males 2.4–2.5 mm, females 2.0–2.5 mm.



FIGURES 2–57. Thirty earwig species from Penang Island. Scale bars = 3 mm. 2) *Diplatys annandalei* male. 3, 4) *Diplatys mutiara* **n. sp**., male, female. 5, 6) *Echinosoma denticulatum* male, female. 7, 8) *Echinosoma sumatranum* male, female. 9, 10) *Echinosoma* sp. males. 11, 12) *Euborellia annulata* male, female. 13–16) *Euborellia philippinensis* male, female, fully winged form male, fully winged form female. 17, 18) *Gonolabis electa* male, female. 19, 20) *Metisolabis punctata* male, female. 21, 22) *Platylabia major* male, female. 23) *Allostethus indicum* male. 24, 25) *Labidura riparia* male, female. 26, 27) *Pseudovostox brindlei* male, female. 28, 29) *Chaetospania anderssoni* male, female. 30, 31) *Chaetospania javana* male, female. 32, 33) *Chaetospania huisiangi* **n. sp.**, male, female. 34) *Chaetospania thoracica* male. 35) *Paralabellula boettcheri* male. 36, 37) *Paralabellula curvicauda* male, female. 38, 39) *Paralabellula rotundifrons* male, female. 40, 41) *Spirolabia pilicornis* male, female. 42, 43) *Nesogaster amoenus* male, female. 44, 45) *Marava arachidis* male, female. 46, 47) *Spongovostox mucronatus* male, female. 48) *Spongovostox semiflavus* male. 49, 50) *Chelisoches morio* male, female. 51, 52) *Hamaxas crassus* male, female. 53, 54) *Proreus coalescens* male, female. 55) *Proreus ludekingi* male. 56, 57) *Hypurgus humeralis* male, female.

Male (Fig. 3) generally dark brown; mouth parts, antennae, pronotum, tegmina at base, scutellum and legs light yellowish brown, except foreleg with tarsus, tibia and apical two thirds of femur dark brown. Head (Fig. 58) sparsely pubescent, about as long as broad, widest in the region of eyes; frons tumid and occiput depressed; transverse suture obsolete, median suture distinct; hind margin weakly emarginated in middle; post-ocular carina sharp, curved, running from middle of the internal margin of eyes to the hind margin of the head. Antennae (Fig. 59) partly broken in holotype; first segment stout, slightly expanded apically, length about half of the distance between the antennal bases; second segment short, transverse; third segment long and slender, fourth only slightly longer than broad, shorter and stouter than third; fifth segment nearly equal to third, remaining segments gradually lengthening and narrowing distally. Eyes prominent, longer than post-ocular length. Pronotum (Fig. 58) smooth, about as long as broad, octagonal; anterior and posterior margins almost straight; sides rounded; fore and hind angles weakly rounded; median sulcus distinct; prozona weakly raised and metazona depressed. Tegmina and wings (Fig. 58) well-developed, smooth, pubescent; small triangular scutellum visible. Legs long, slender; hind tarsi with first segment 2.5–3.0 times longer than third, second segment about half as long as third, claw with arolium. Abdomen long, cylindrical, smooth, sparsely pubescent, segments eight and nine slightly enlarged. Penultimate sternite (Fig. 60) caudal margin deeply trisinuate; horseshoe-shaped depression present on posterior half originating from the lateral sides of the median sinuation, the sides of the median sinuation taking the form of two long, prominent projections that curve inward with several strong setae only at the apices. Ultimate tergite (Fig. 61) smooth, about as long as broad, gradually sloping backwards; lateral margins oblique; hind margin with a pair of swellings at the bases of forceps. Forceps (Fig. 61) pubescent, slender, tapering apically, undulate; apices pointed and gently hooked (apex of right branch broken in holotype); inner margin covered with row of small black denticles. Genitalia (Fig. 62) with virga dividing in apical third of lobe, with tips protruding from penis lobes; parameres (= external parameres) comparatively short, base wide, inner margin with large rounded tooth proximally.

Female (Fig. 4) coloration similar to males but with dark brownish markings on middle and hind femora from apical one-third to slightly before apex. Third segment of hind tarsi minute. Eyes smaller, about as long as postocular length. Penultimate sternite (Fig. 63), simple, almost triangular in posterior half. Forceps (Fig. 64) straight, tapering, with inner margin crenulate. Genitalia (Fig. 65) with well-developed ovipositor components, with pair of spermathecae each with brownish capsule at the distal end.

Specimens examined. All specimens listed below were collected by Y. Kamimura. Holotype male, Jalan Kebun Bunga, Penang Island, Peninsular Malaysia, collected as nymph 4.XI.2012, adult 20.XI.2012 (OMNH). Allotype female, same locality as holotype, collected as nymph 18.X.2012, adult 30.X.2012 (OMNH).

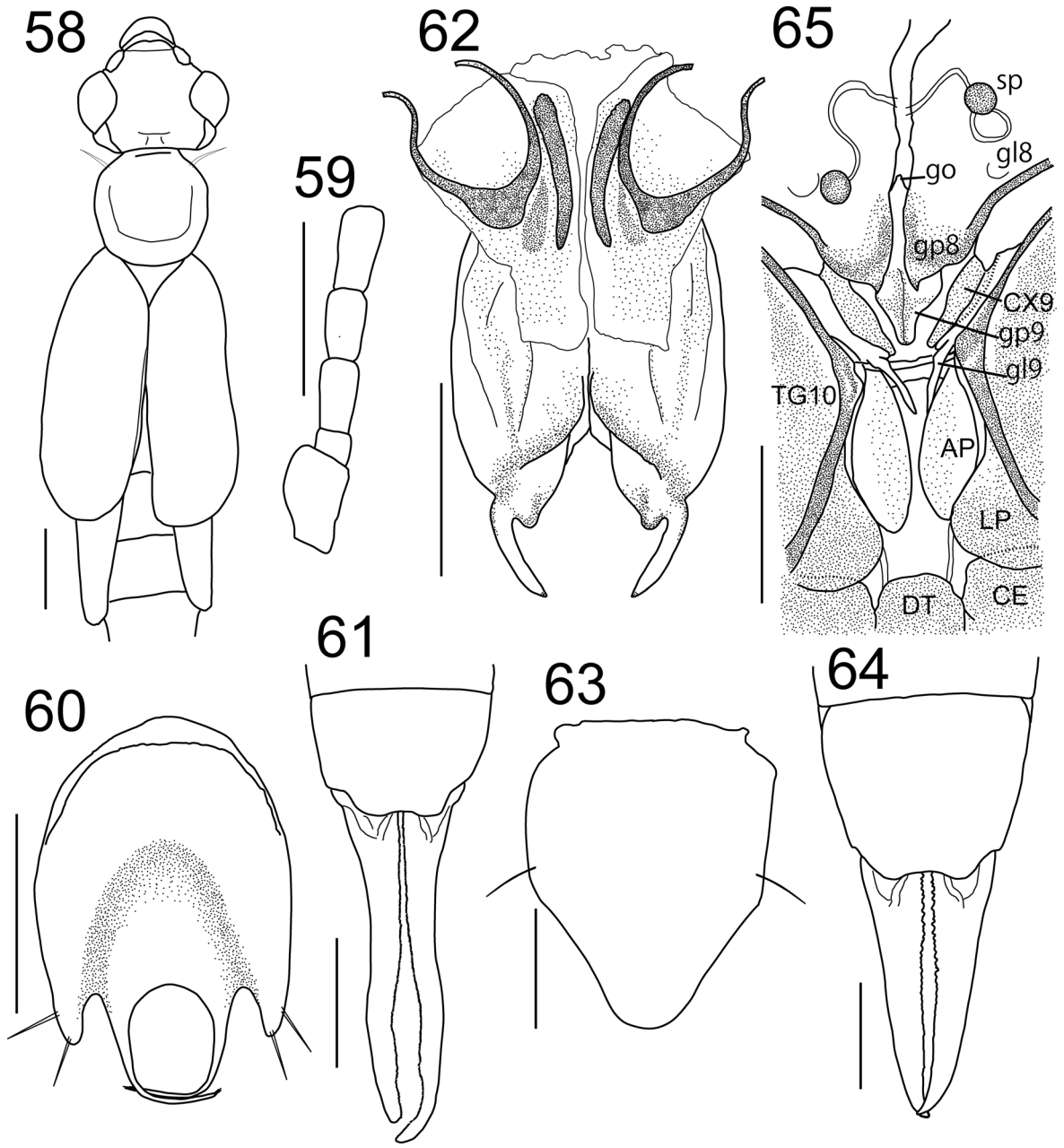
Paratypes from same locality as holotype: 1 male (genitalia mounted between two cover slips and attached to pin of specimen) collected as nymph 18.X.2012, adult 30.X.2012 (OMNH); 1 female (genitalia, ultimate tergite, and forceps mounted between two cover slips and attached to pin of specimen), collected as nymph 15.X.2012, adult 5.XI.2012 (OMNH); 1 male collected as nymph 18.X.2012, adult 11.XI.2012 (LKCNHM); 1 female, collected as nymph 4.XI.2012, adult 17.XI.2012 (LKCNHM); 1 male collected as nymph 18.X.2012, adult 2.XI.2012 (EUMJ); 1 female collected as nymph 18.X.2012, adult 30.X.2012 (EUMJ); 1 female collected as nymph 1.XII.2012, adult 17.XII.2012 (EUMJ); 1 male collected as nymph 6.III.2014, adult 5.V.2014 (EUMJ); 1 female, collected as nymph 6.III.2014, adult 5.IV.2014(EUMJ); Paratypes from Ayer Itam, Penang Island, Peninsular Malaysia: 1 female collected as nymph 6.XII.2012, adult 23.XII.2012 (LKCNHM); 1 male collected as nymph 6.XII.2012, adult 23.XII.2012 (EUMJ).

Additional material examined, same locality as holotype: 1 female collected as nymph 4.XI.2012, adult 20.XI.2012; 1 female collected as nymph 18.X.2012, adult 30.X.2012.

Etymology. The specific epithet refers to the type locality, Penang Island, which is often called the "Pearl of the Orient." "Mutiara" means pearl in the Malay language.

Distribution. Penang Island, Malaysia.

Remarks. Nymphs are common under fallen leaves near small mountain streams and also found from Telok Bahang-Batu Ferringi and Bukit Jambul-Bukit Kukus areas. Adult males can be distinguished readily from all other species of the family by the combination of the characteristic penultimate sternite that bears a horseshoe-shaped depression and a pair of prominent projections that curve inward with several strong setae only at the apices (Fig. 60), and parameres with a wide base and a large rounded tooth proximally at the inner margin (Fig. 62).



FIGURES 58–65. *Diplatys mutiara* **n. sp.** 58) Head and thorax (holotype male). 59) Basal part of right antenna (holotype male). 60) Penultimate sternite (paratype male). 61) Ultimate tergite and forceps (holotype male). 62) Male genitalia (paratype male). 63) Penultimate sternite (paratype female). 64) Ultimate tergite and forceps (allotype female). 65) Female genitalia (paratype female). Abbreviations: AP, anal plate; CE, cercus; CX9, coxa IX; DT, dorsal sclerite of telson; gl8, gonoplac (=coxal lobe) VIII ; gl9, gonoplac (=coxal lobe) IX; go, anterior border of definitive genital opening; gp8, gonapophysis VIII; gp9, gonapophysis IX; LP, lateral plate; sp, spermatheca; TG10, tergum X. Scale bars: 1 mm for Figs. 58–61, 63–64; 0.5 mm for Figs. 62, 65.

Family Pygidicranidae

Subfamily Echinosomatinae

***Echinosoma denticulatum* Hincks, 1959**
(Figs. 5, 6, 66)

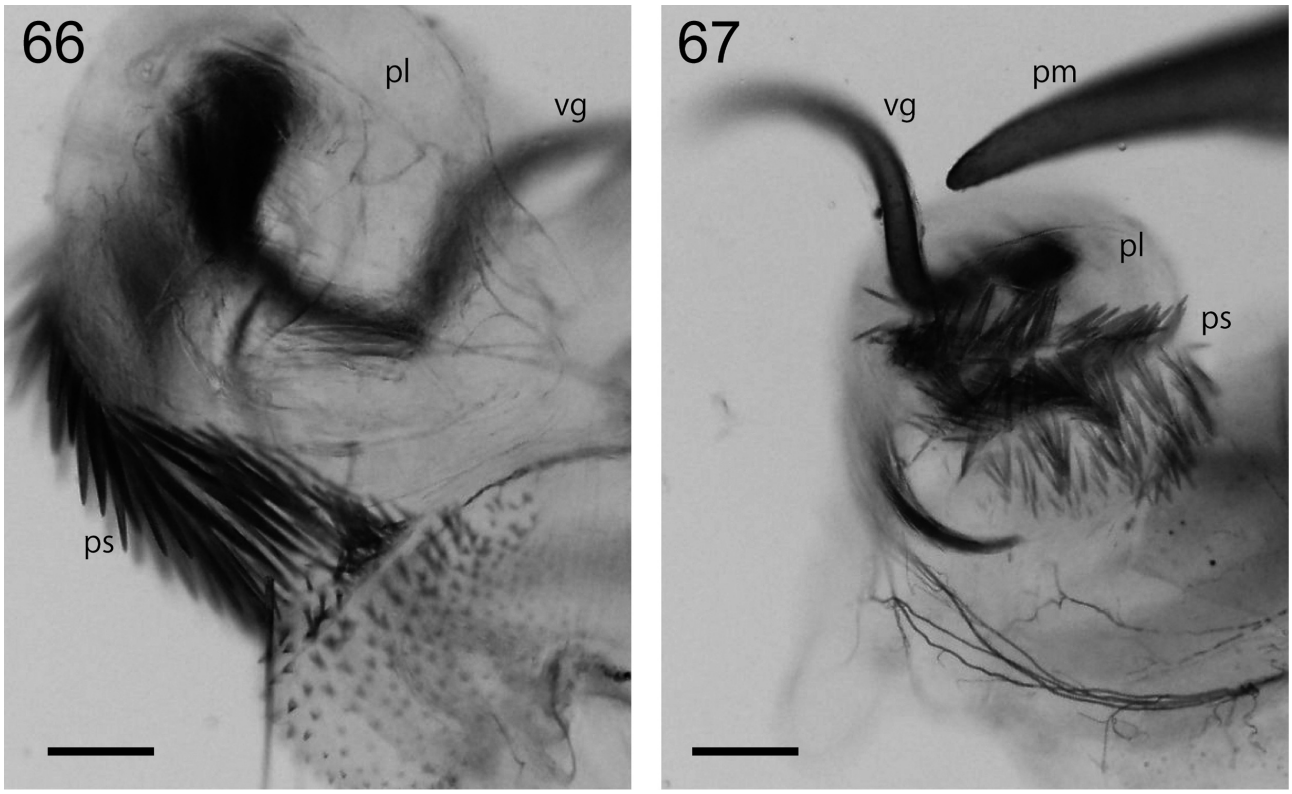
Echinosoma denticulatum Hincks, 1959: 150.

Material examined: 1 male, 4 females from Ayer Itam-Kebun Bunga, Bukit Jambul-Bukit Kukus.

Distribution. Indonesia (Sumatra, Borneo) and Peninsular Malaysia.

Records in Peninsular Malaysia: Penang Island (Kamimura & Lee 2014a)

Remarks. Kamimura & Lee (2014a) described the genital morphology and reproductive behavior of this species based on other specimens collected during the survey.



FIGURES 66-67. Distal part of penis lobe, penial spines, and virga (in part) of *Echinosoma sumatranum* (see Fig. 67) and *E. denticulatum* (see Fig. 66). Abbreviations: pl, penis lobe; pm, paramere; ps, penial spines; vg, virga. Scale bars = 0.1 mm.

***Echinosoma sumatranum* (de Haan, 1842)**
(Figs. 7, 8, 67)

Forficula (*Echinosoma*) *sumatrana* de Haan, 1842: 241.

Material examined: 1 male, 1 female from Bukit Jambul-Bukit Kukus.

Distribution. Widely distributed in Indo-Malayan Region, South China and Taiwan.

Records in Peninsular Malaysia: Penang Island (Dohrn 1863a as *E. westermanni* n. sp.); Pahang (Hebard 1929; Borelli 1932a).

Remarks. Dohrn (1863a) described *Echinosoma westermanni* based on samples collected from Penang Island. However, Burr (1910) and Hincks (1959) synonymized this species with *E. sumatranum*. This species resembles *E.*

denticulatum, but can be distinguished by the darker coloration of the body (especially the basal part of femora), the different shape of the female pygidium (see Hincks 1959), and less-developed penial spines in the male genitalia (Figs. 66, 67).

***Echinosoma* sp.**
(Figs. 9, 10)

Material examined: 2 males from Bukit Jambul-Bukit Kukus.

Remarks. These specimens possibly represent an undescribed species.

Family Anisolabididae

Subfamily Anisolabidinae

***Euborellia annulata* (Fabricius, 1793)**
(Figs. 11, 12, 68A)

Forficula annulata Fabricius, 1793: 4.

Material examined: 5 males, 10 females from Telok Bahang-Batu Ferringi, Ayer Itam-Kebun Bunga, Bayan Mutiara, Sungai Burung-Sungai Nipah.

Distribution. Almost worldwide in distribution, especially in warmer parts.

Record in Peninsular Malaysia: Pahang (Borelli 1932a as *Euborellia stali*).

Remarks. The identification of the samples is only tentative, because of the many similar species in the genus that are inadequately described. As in other examined *Euborella* spp, (Hudson 1973; Kamimura 2000), the spermatheca is a very long, thin, blind duct without a capsule at the distal end (Fig. 68A). In one laboratory-raised male the tegmina were well-developed but hindwings were totally lacking.

***Euborellia philippinensis* Srivastava, 1979**
(Figs. 13−16, 68B)

Euborellia philippinensis Srivastava, 1979: 49.

Material examined: 10 males, 11 females from Sungai Burung-Sungai Nipah.

Distribution. Philippines (Luzon), and Peninsular Malaysia (Penang Island, new record).

Remarks. The brachypterous specimens possessed tegmina as narrow ovate flaps. The external morphology and male genitalia of this species agree with previous descriptions of *E. philippinensis*, and thus we assign our specimens to this species. Field-collected adults were all brachypterous, but laboratory-reared adults showed remarkable wing dimorphism. In the fully winged form adults, both tegmina and hindwings are fully developed (Figs. 15, 16). This form is reported here for the first time for *E. philippinensis*. The fully winged form of our specimens cannot be distinguished from those of *Euborellia plebeja* (Dohrn, 1863) (Dohrn 1863b; Srivastava 2003a), warranting further studies of this group. Similar to its close relatives (Hudson 1973; Kamimura 2000), the spermatheca is a very long, thin, blind duct without a capsule at the distal end (Fig. 68B).

***Gonolabis electa* Burr, 1910**
(Figs. 17, 18)

Gonolabis electa Burr, 1910: 79.

Material examined: 2 males, 1 female from Ayer Itam-Kebun Bunga, Bukit Jambul-Bukit Kukus.

Distribution. Oriental Region, adventive in Africa (São Tomé and west African coast).

Records in Peninsular Malaysia: Negeri Sembilan (Nishikawa 1973); Ulu Gombak, Selangor (Steghaus-Kovac & Maschwitz 1993).

Remarks. The male shown in Fig. 17 was bleached by long-term preservation in alcohol, but in life the color of males is similar to that of females (Fig. 18).

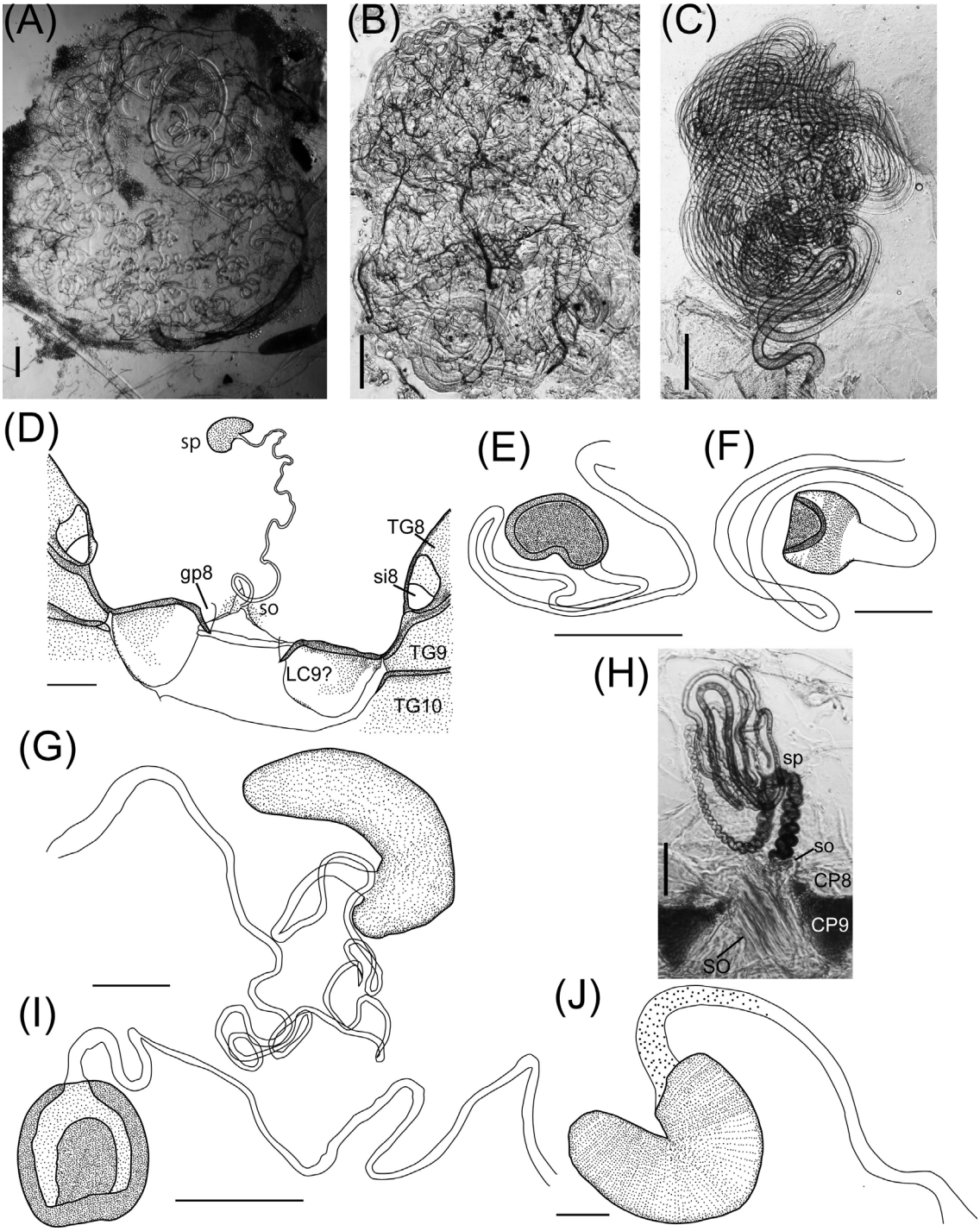


FIGURE 68. Spermatheca of several species of earwigs from Penang Island. A) *Euborellia annulata*. B) *Euborellia philippinensis*. C) *Metisolabis punctata*. D) *Platylabia major*. E) *Chaetospania anderssoni*. F) *Spirolabia pilicornis*. G) *Nesogaster amoenus*. H) *Spongovostox mucronatus*. I) *Proreus coalescens*. J) *Hypurgus humeralis*. For *P. major* (D) and *S. mucronatus* (H), structures near the spermatheca are also shown. Abbreviations: CP8, coxopodite VIII; CP9, coxopodite IX; gp8, gonapophysis VIII; LC9?, laterocoxa IX?; si8, spiracle VIII; so, spermathecal opening; SO, sclerotization around spermathecal opening; sp, spermatheca; TG8-10, tergum VIII-X. Scale bars = 0.1 mm.

Subfamily Brachylabidinae

***Metisolabis punctata* (Dubrony, 1879)**
(Figs. 19, 20, 68C)

Brachylabis punctata Dubrony, 1879: 357.

Material examined: 1 male, 3 females from Telok Bahang-Batu Ferringi, Ayer Itam-Kebun Bunga, Bukit Jambul-Bukit Kukus.

Distribution. Oriental Region, New Guinea, North Australia. Peninsular Malaysia (Penang Island, new record).

Remarks. The spermatheca is a very long, thin, blind duct without a capsule at the distal end (Fig. 68C).

Subfamily Platylabinae (= Palicinae Engel & Haas 2007, = Palexinae Kočárek 2010)

***Platylabia major* Dohrn, 1867**
(Figs. 21, 22, 68D)

Platylabia major Dohrn, 1867: 347.

Material examined: 12 males, 16 females from Ayer Itam-Kebun Bunga, Bukit Jambul-Bukit Kukus, Bukit Gedung.

Distribution. Widely distributed in the Oriental Region: South India (?), Sri Lanka, Peninsular Malaysia, Myanmar, China (Guangxi, Hainan), Thailand, Laos, Vietnam, Indonesia (Java, Sumatra, Celebes), and Philippines.

Records in Peninsular Malaysia: Pulo Penang (= Penang Island, Bormans 1900, as *Platylabia sparattoides*); Selangor (Srivastava & Kovac 1993).

Remarks. The spermatheca of this species consists of a weakly pigmented capsule at the end of an elongated duct (Fig. 68D). The opening region of the spermatheca is located between a pair of triangular lobes (Fig. 68D), which are apparently homologous to the eighth-segment gonapophyses (gp8) of some labidurids (Kamimura & Lee 2014b). The outer margins of gp8 are heavily sclerotized and well-pigmented, and continue to a laterally adjoining sclerite with many muscles (Fig. 68D). This sclerite likely represents the ninth-segment laterocoxa (LC9; see Kamimura & Lee 2014b). These remarks constitute the first report of gp8 and LC9 for a member of Anisolabididae.

Family Labiduridae

Subfamily Allostethinae

***Allostethus indicum* (Burmeister, 1838)**
(Figs. 23)

Forficula indica Burmeister, 1838: 751.

Material examined: 3 males, 2 females from Ayer Itam-Kebun Bunga, Bukit Jambul-Bukit Kukus.

Distribution. Indonesia (Java, Sumatra, Borneo, Sulawesi, Batu Island), Malaysia (Malay Peninsula), Thailand (Trang), Philippine Islands.

Records in Peninsular Malaysia: Selangor and Pahang (Hebard 1929); Perak (Burr 1912; Borelli 1932a); Pahang (Borelli 1932a); Penang Island (Dubrony 1879; Kamimura & Lee 2014b); Malacca (Burr 1912).

Remarks. Kamimura & Lee (2014b) described the genital morphology and reproductive behavior of this species based on other specimens collected during the survey.

Subfamily Labidurinae

***Labidura riparia* (Pallas, 1773)**
(Figs. 24, 25)

Forficula riparia Pallas, 1773: 727.

Material examined: 4 males, 2 females from Bayan Mutiara

Distribution. Cosmopolitan.

Record in Peninsular Malaysia: Negri Sembilan and Selangor (Borelli 1932a); Penang Island (Kamimura & Lee 2014b).

Remarks. Kamimura & Lee (2014b) described the female genital morphology of this species based on other specimens collected during the survey.

Family Spongiphoridae

Subfamily Geracinae

***Pseudovostox brindlei* Srivastava, 2003**
(Figs. 26, 27, 69, 70)

Pseudovostox brindlei Srivastava, 2003b: 45.

Material examined: 10 males, 10 females from Ayer Itam-Kebun Bunga, Bukit Jambul-Bukit Kukus.

Distribution. Vietnam and Peninsular Malaysia (Penang Island, new record).

Remarks. Previously known from Vietnam. The body coloration of the samples collected from Penang Island differed slightly from those of the original description: Srivastava (2003b) described the head, pronotum, tegmina, and hindwings of this species as blackish brown, except for yellow makings on the pronotum, tegmina and hindwings. Specimens from Penang Island have the head reddish-brown, pronotum and tegmina bases mostly yellowish-brown, and distal parts of tegmina and hindwings purplish brown with white markings (Figs. 26, 27). Except for the body coloration, our material agrees well with previous descriptions of the morphology of the species, including male genital morphology (Fig. 69), and thus the Penang Island specimens are considered to be *P. brindlei*. The female genitalia of this genus are described here for the first time. A pair of well-developed lobes were found posterior to the spermatheca, which is a long, thin duct (Fig. 70). The morphological identity of the lobes is presently unknown, but they represent the first report of ovipositor-like structures for females of the Eudermaptera (Schneider & Klass 2013).

This species may be myrmecophilous, and is frequently found together with ants of the genus *Crematogaster*, which show similar body coloration.

Subfamily Labiinae

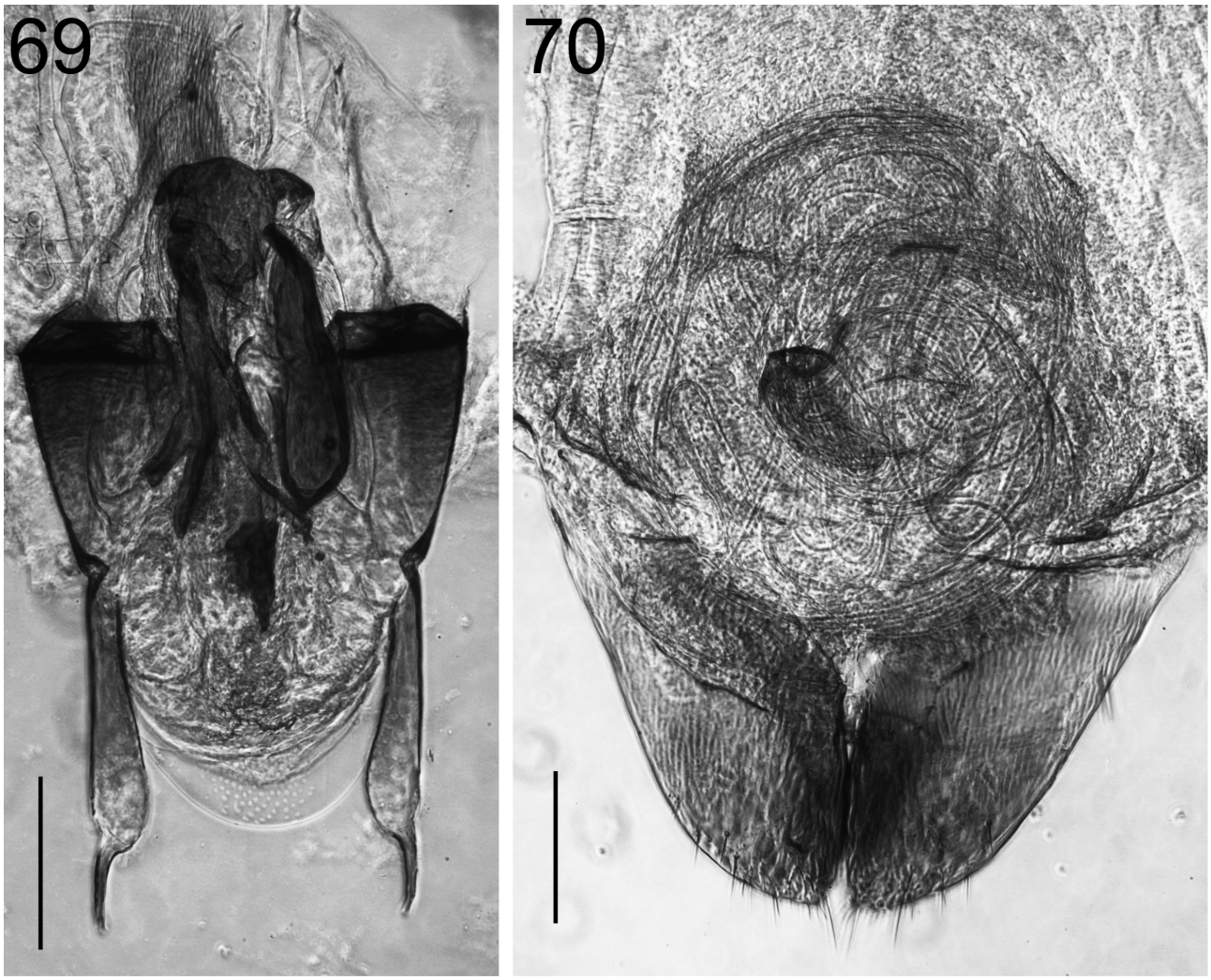
***Chaetospania anderssoni* Brindle, 1971**
(Figs. 28, 29, 68E)

Chaetospania anderssoni Brindle, 1971: 227.

Material examined: 6 males, 4 females from Sungai Burung-Sungai Nipah.

Distribution. Sri Lanka and Peninsular Malaysia (Penang Island, new record).

Remarks. The spermatheca of this species consists of an elongated thin tube with a well-pigmented sclerotized capsule at the distal end (Fig. 68E). Kočárek (2009) reported ovoviviparity for *Chaetospania borneensis* (Dubrony, 1879), but we observed that female *C. anderssoni* deposits eggs as is usual in forficuline earwigs.



FIGURES 69, 70. *Pseudovostox bridlei*. 69) Male genitalia. 70) Female genital region including spermatheca. Scale bars = 0.1 mm.

***Chaetospania javana* Borelli, 1926**
(Figs. 30, 31, 71−73)

Chaetospania javana Borelli, 1926b: 261.

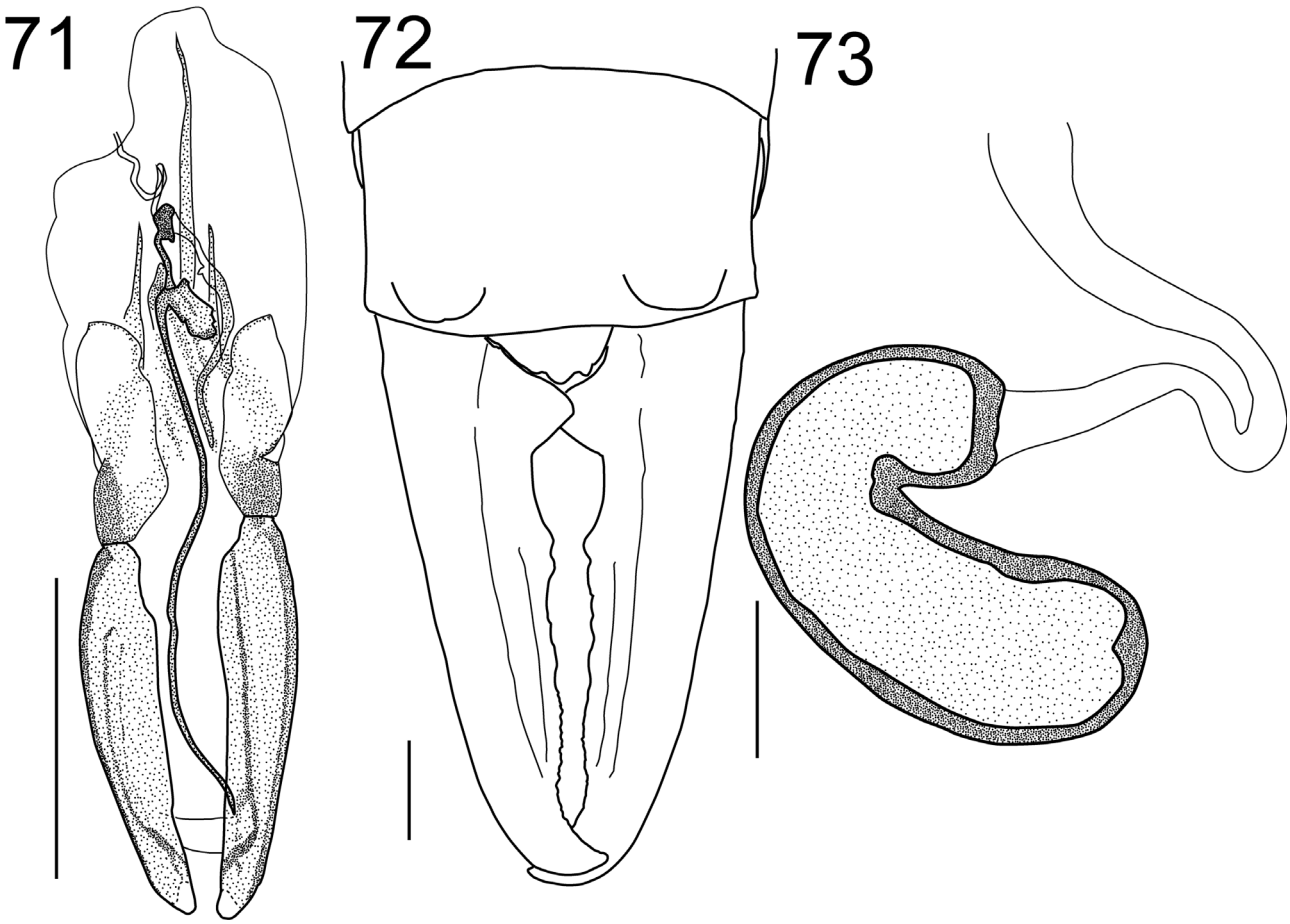
Material examined: 13 males, 4 females from Ayer Itam-Kebun Bunga, Bukit Jambul-Bukit Kukus.

Distribution. Java and Peninsular Malaysia (Penang Island, new record).

Remarks. The number and positions of the inner teeth of male forceps are variable. Some of the material examined fit well with previous descriptions of this species (Borelli 1926b, Steinmann 1990). According to Steinmann (1990), the holotype lacks the genitalia, and females have not been described. Male genitalia of a Penang Island specimen are illustrated in Fig. 71: parameres robust, well pigmented, apically rounded; penis lobe broad; virga with a conspicuous process at base.

Description of females. Head, pronotum, tegmina, and wings brownish black; antennae and mouth parts brown; legs testaceous; abdomen and forceps reddish brown. Head rounded, weakly depressed; postfrontal and coronal sutures very finely visible. Eyes typical of the genus, small, length about half the post-ocular length. First segment of antenna long, but shorter than distance between antennal bases; second segment almost quadrate, segments 3–5 about half the length of the first. Pronotum longer than wide; lateral margins straight, more or less parallel; posterior margin convex; median sulcus present on anterior half. Tegmina well developed, about twice as

long as pronotum. Hindwings fully developed; cuticle of tegmina and wings punctuate, pubescent. Abdomen long; lateral margins parallel-sided; segments with long yellowish setae. Ultimate tergite (Fig. 72) broad, with a pair of swellings at the bases of forceps. Pygidium (Fig. 72) hemispherical, posterior margin with one medial and two lateral tubercles. Forceps (Fig. 72) robust, straight except at apices; branches with well-marked dorsal edge; inner margins with a larger tooth near the pygidium, afterwards with irregular crenulation ventrally. Spermatheca consisting of an elongated thin tube with a well-pigmented sclerotized capsule at the distal end (Fig. 73).

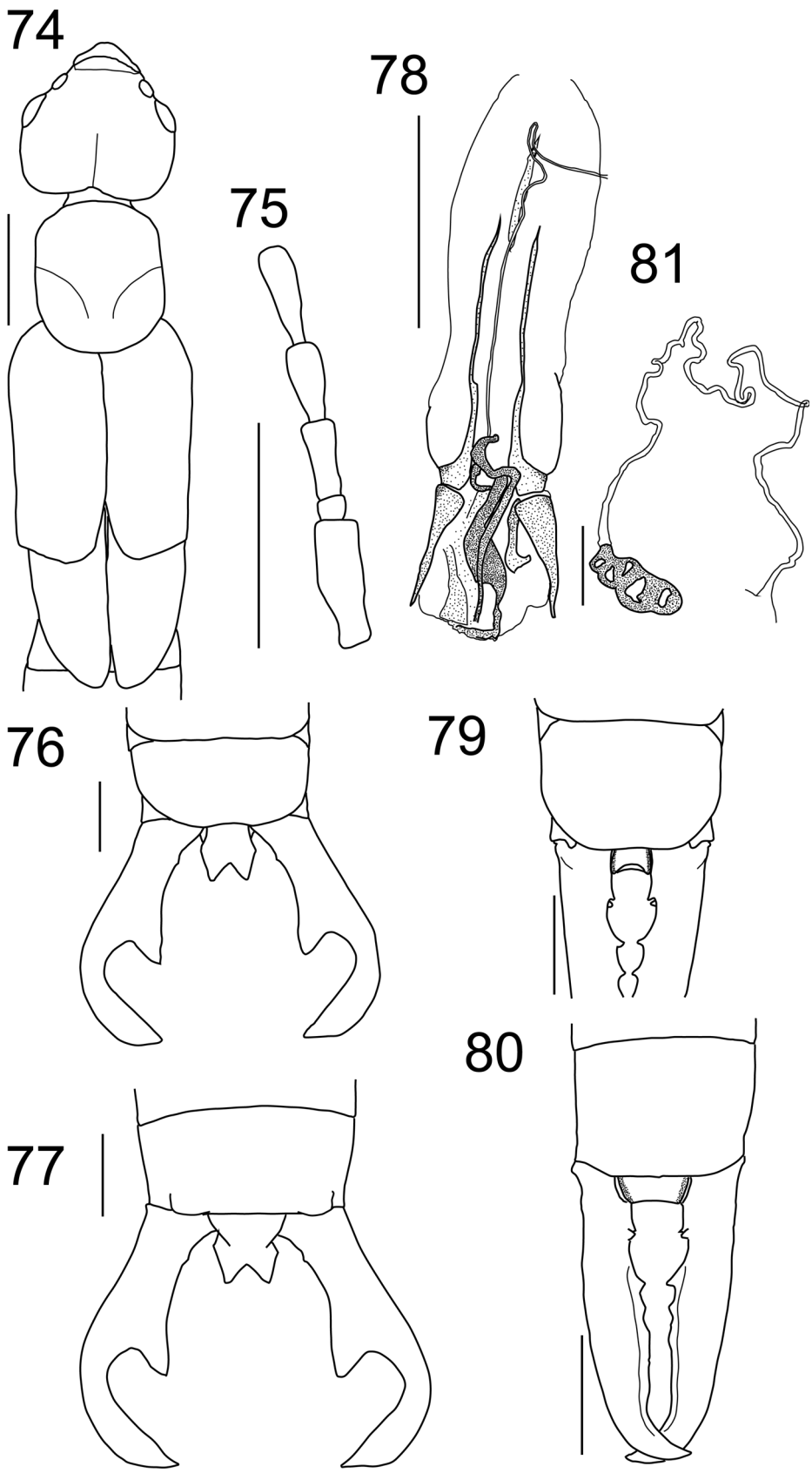


FIGURES 71–73. *Chaetospania javana*. 71) Male genitalia. 72) Female ultimate tergite and forceps. 73) Spermatheca. Scale bars: 0.5 mm for Figs. 71, 72; 0.1 mm for Fig. 73.

Chaetospania huisiangi **Kamimura & Nishikawa n. sp.**
(Figs. 32, 33, 74–81)

Description. Length of body excluding forceps: males 4-6 mm, females 4-5 mm.Length of forceps: males 0.9–1.0 mm, females, 1.0–1.5 mm.

Male (Fig. 32) color generally blackish-brown; more posterior abdominal tergites and forceps reddish; legs and mouthparts yellowish. Head (Fig. 74) slightly longer than broad, smooth; frons convex; transverse suture obsolete, median suture distinct; hind margin feebly emarginated in middle. Segments of antennae mostly stout (Fig. 75; partly broken in holotype); first segment gradually expanded apically, about as long as the distance between antennal bases; second segment short, about as long as broad; third long and slender, about twice as long as broad; fourth stouter, but shorter than third; fifth segment longer than third, narrowed basally; more distal segments slightly thinner. Eyes not prominent, length about half the post-ocular length. Pronotum (Fig. 74) slightly longer than broad, sides almost straight and depressed, hind margin convex; prozona weakly raised at humeral angles and differentiated from depressed metazona; median sulcus fairly distinct. Tegmina 1.5 times longer than the pronotum, covered with fine pubescence, punctulate; humeral angle weak, anal angle rounded off to show a small, triangular



FIGURES 74–81. *Chaetospania huisiangi* **n. sp.** 74) Head and thorax (holotype male). 75) Basal part of left antenna (holotype male). 76) Penultimate sternite and forceps (paratype male). 77) Ultimate tergite and forceps (holotype male). 78) Male genitalia (paratype male). 79) Penultimate sternite and forceps (paratype female). 80) Ultimate tergite and forceps (allotype female). 81) Female genitalia (paratype female). Scale bars: 0.5 mm for Figs. 74–80, 0.1 mm for Fig. 81.

scutellum; hind margin oblique. Wings well developed, punctate, pubescent. Femora swollen; first tarsal segment of hind leg almost equal to third; second segment short, about as long as broad. Abdomen strongly depressed, long, more or less parallel-sided, except first two segments narrowed; segments with long yellowish setae on sides; lateral tubercules on third and fourth tergites inconspicuous; sides of segments broadly convex. Penultimate sternite (Fig. 76) transverse, obscurely punctulate, with fine and long pubescence; hind margin rounded with slight emargination in middle. Ultimate tergite (Fig. 77) smooth, rectangular, transverse, moderately depressed; hind margin nearly truncate with small rounded swellings above the base of forceps. Pygidium large, with dorsal and ventral part; dorsal part rounded, tumid; ventral part flattened, armed with one pair of large lateral tubercles separated by deep emargination. Forceps (Figs. 76, 77) strongly setose, strongly curving in posterior half, depressed, tapering apically; internal margin with a large triangular tooth at middle directed inwards. Genitalia (Fig. 78) with parameres broader in basal two-thirds, apically narrowed with acute tip; penis lobe provided with several sclerotized plates and rows of fine chitinous teeth; virga short, tubular, with vesicle at base.

Female (Fig. 33) similar to male, but hind margin of penultimate sternite (Fig. 79) without emargination in middle. Pygidium (Fig. 80) transverse, broad basally, narrowed apically; lateral margins weakly raised; posterior margin weakly emarginated in middle. Forceps (Figs. 79-80) stout and straight; at base with large ventral tooth, otherwise irregularly dentate dorsally as well as ventrally. Spermatheca consists of an elongated thin tube with a characteristic pea pod-shaped sclerotized capsule at the distal end (Fig. 81).

Specimens examined. All specimens listed below were collected by Y. Kamimura at Bukit Jambul. Penang Island, Peninsular Malaysia. Holotype male, offspring of a female collected 22.XI.2012 (OMNH). Allotype female, same data as for holotype (OMNH).

Paratypes, same locality data as holotype: 1 male (genitalia mounted between two cover slips and attached to pin of specimen), same data as for holotype (OMNH); 1 female (spermatheca mounted between two cover slips and attached to pin of specimen), 7.XII.2012 (OMNH); 2 males, 7.XII.2012 (LKCNHM); 1 male, 2.III.2013 (LKCNHM); 1 female, same data as for holotype (LKCNHM); 2 males, 30.XI.2012 (EUMJ); 1 female, same data as for holotype (EUMJ).

Additional material, same locality data as holotype: 1 male, 26.X.2012; 2 males, 22.XI.2012; 1 male, 2.III.2013; 8 males, 5 females, 22.XI.2012; 1 female, 30.XI.2012.

Etymology. Named in honor of Hui-Siang Tee, Universiti Sains Malaysia, who assisted in our collection and rearing of insects during the survey on Penang Island.

Distribution. Penang Island, Malaysia.

Remarks. Adults and nymphs of this species were found under bark of dead logs in rubber plantations. The general appearance of this species closely resembles that of *C. minuta* Borelli, 1921, which has been recorded from Borneo (the type locality), Langkawi Island, and the Philippines (Mindanao) (Borelli 1921, 1926a, 1932a, 1932b). However, the shape of male pygidium is distinctively different; the posterior margin is convex in *C. minuta* (Srivastava 1983) but deeply incised in *C. huisiangi* **n. sp.** (Fig. 77). Females of the two species cannot be distinguished. The record of *C. minuta* from Langkawi Island, located about 90 km north of Penang Island, is based on a female sample (Borelli 1932a: 86), and thus it might be belong to *C. huisiangi* **n. sp.**. This new species also resembles *C. brunneri* (Bormans, 1883) in many external features, but the shapes of the male genitalia and female spermatheca are markedly different (Hincks 1949, Hudson 1973, Steinmann 1990 (as *Paraspania brunneri*)).

Chaetospania thoracica (Dohrn, 1867)

(Fig. 34)

Platylabia thoracica Dohrn, 1867: 348.

Material examined: 4 males, 1 female from Ayer Itam-Kebun Bunga, Bukit Jambul-Bukit Kukus.

Distribution. Oriental Region, New Guinea, Seychelles.

Records in Peninsular Malaysia: Selangor (Borelli 1932a; Srivastava & Kovac 1993); Perak (Borelli 1932a); Malacca (Brindle 1968); Penang (Dohrn 1867 as *Platylabia thoracica*).

Remarks. Penang Island is the type locality of this species (Dohrn 1867).

***Paralabellula boettcheri* (Borelli, 1923)**
(Fig. 35)

Labia boettcheri Borelli, 1923: 7.

Material examined: 1 male from Bukit Jambul-Bukit Kukus.

Distribution. Philippines and Peninsular Malaysia (Penang Island, new record).

***Paralabellula curvicauda* (Motschulsky, 1863)**
(Figs. 36, 37)

Forfiscelia curvicauda Motschulsky, 1863: 2.

Material examined: 13 males, 7 females from Telok Bahang-Batu Ferringi, Ayer Itam-Kebun Bunga, Bukit Jambul-Bukit Kukus, Sungai Burung-Sungai Nipah, Bukit Gedung.

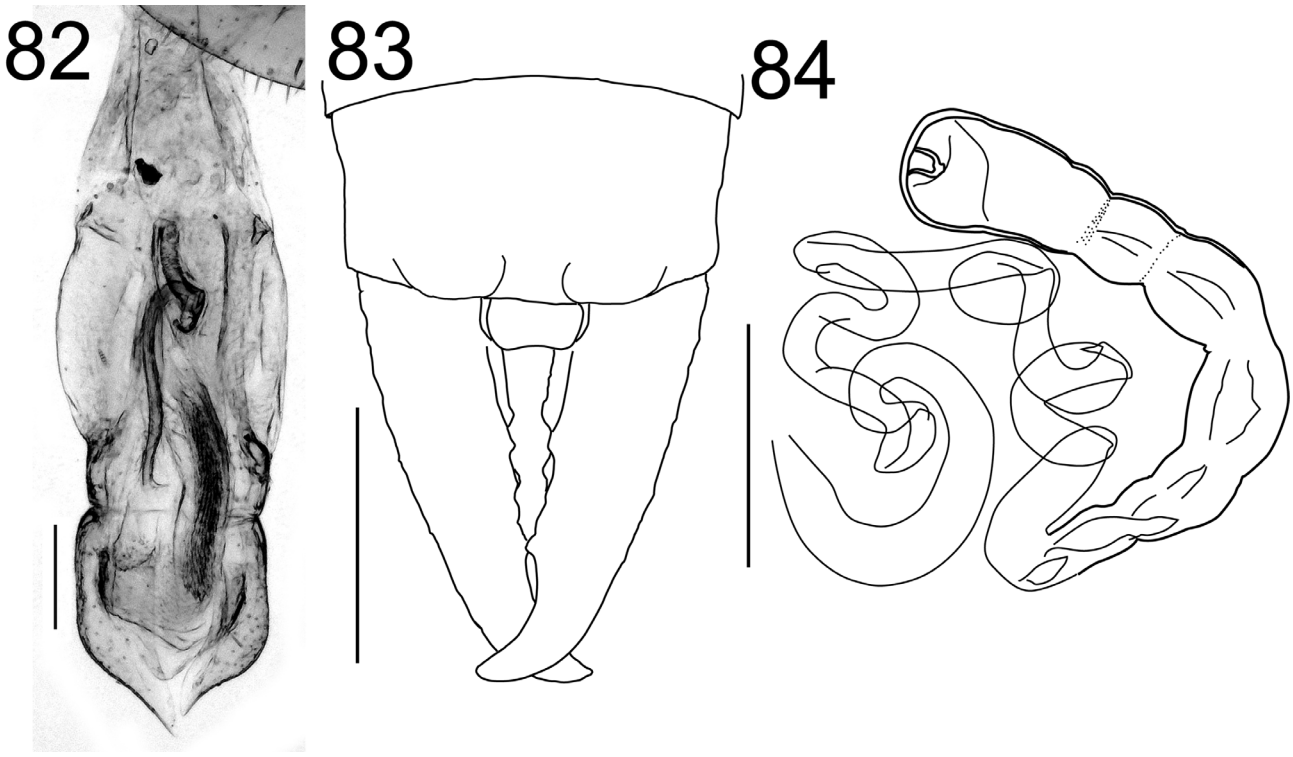
Distribution. Cosmopolitan.

Records in Peninsular Malaysia: Penang Island (Dubrony 1879 as *Labia curvicauda*); Pahang (Borelli 1932a as *Labia curvicauda*); Selangor (Borelli 1932a as *Labia curvicauda*; Srivastava & Kovac 1993 as *Paralabella curvicauda*).

Remarks. Dubrony (1879) reported this species (as *Labia curvicauda*) from "Pulo Penang" (= Pulau Pinang, Penang Island) based on one male. The spermathecal morphology has been described by Hudson (1973).

***Paralabellula rotundifrons* (Hincks, 1954)**
(Figs. 38, 39, 82−84)

Labia rotundifrons Hincks, 1954: 20.



FIGURES 82–84. *Paralabellula rotundifrons*. 82) Male genitalia. 83) Female ultimate tergite and forceps. 84) Spermatheca. Scale bars: 0.1 mm for Figs. 82, 84; 0.5 mm for Fig. 83.

Material examined: 5 males, 6 females from Telok Bahang-Batu Ferringi, Bukit Jambul-Bukit Kukus.

Distribution. Sri Lanka, and Peninsular Malaysia (Penang Island, new record).

Remarks. The male genitalia have a well-sclerotized plate in the penis lobe (Fig. 82). Females are described here for the first time.

Description of female. Body colour fuscous, antennae and legs lighter; abdominal segments of distal part and forceps dark reddish-brown. Cuticle finely punctate and pubescent. Head broad, tumid; postfrontal and coronal sutures indistinct; lateral margins behind eyes with postero-lateral angles rounded; posterior margin concave. Eyes small, length about half of post-ocular length. First antennal segment shorter than distance between antennal bases; second segment wider than long, third longer than fourth. Pronotum longer than wide; lateral margins straight; posterior margin convex. Tegmina and hindwings normally developed. Abdomen fusiform, slightly widened medially. Ultimate tergite (Fig. 83) transverse, smooth, simple; posterior margin with a pair of swellings at the base of forceps. Pygidium (Fig. 83) transverse. Forceps trigonal; inner margins serrated both ventrally and dorsally. Spermatheca (Fig. 84) resembles that of *P. curvicauda*, but capsule less pigmented.

***Spirolabia pilicornis* (Motschulsky, 1863)**
(Figs. 40, 41, 68F)

Forfiscelia pilicornis Motschulsky, 1863: 2.

Material examined: 6 males, 12 females from Bukit Jambul-Bukit Kukus, Sungai Burung-Sungai Nipah.

Distribution. Widely distributed in circumtropical regions.

Records in Peninsular Malaysia: Selangor (Borelli 1932a as *Labia pilicornis*); Malacca (Burr 1912 as *Labia pilicornis*).

Remarks. The spermatheca of this species consists of an elongated thin tube with a sclerotized capsule at the distal end (Fig. 68F).

Subfamily Nesogastrinae

***Nesogaster amoenus* (Stål, 1855)**
(Figs. 42, 43, 68G)

Forficula amoena Stål, 1855: 350.

Material examined: 12 males, 20 females from Telok Bahang-Batu Ferringi, Ayer Itam-Kebun Bunga, Bukit Jambul-Bukit Kukus, Bukit Gedung.

Distribution. Philippines (Mindanao, Luzon), Peninsular Malaysia (Penang Island, new record), Indonesia (Sumatra, Mentawei, Java, Borneo, Celebes), New Guinea, and Australia.

Remarks. The spermatheca of this species consists of an elongated thin tube with a weakly pigmented capsule at the distal end (Fig. 68G).

Subfamily Spongiphorinae

***Marava arachidis* (Yersin, 1860)**
(Figs. 44, 45)

Forficula arachidis Yersin, 1860: 509.

Material examined: 203 males, 432 females from Minden (Universiti Sains Malaysia)

Distribution. Almost all faunal Regions.

Record in Peninsular Malaysia: Malacca (Brindle 1968); Penang Island (Kamimura *et al.* in press).

Remarks. A detailed description of the female genital structures is given in Schneider & Klass (2013). Kamimura *et al.* (in press) described the reproductive biology of this ovoviviparous species based on other specimens collected during the survey.

Spongovostox mucronatus (Stål, 1860)

(Figs. 46, 47, 68H)

Forficula mucronata Stål, 1860: 303.

Material examined: 3 males, 2 females from Bukit Jambul-Bukit Kukus.

Distribution. Widely distributed in the Oriental Region: India, Sri Lanka, Myanmar, Peninsular Malaysia, Indonesia (Sumatra, Java, East Sumba, West Flores), and Philippines; also recorded from Mauritius, New Guinea and Ambon Island.

Records in Peninsular Malaysia: Selangor (Borelli 1932a, as *Labia mucronata*; Srivastava & Kovac 1993).

Remarks. Srivastava (2013) transferred this species to the genus *Paratages* (of the subfamily Homotaginae) on the basis of tarsal morphology. However, well-developed sclerotization around the spermathecal opening of this species (Fig. 68H) suggests a close affinity to *S. semiflavus* and *M. arachidis*, for which the female genitalia were described by Schneider & Klass (2013).

Spongovostox semiflavus (Bormans, 1894)

(Fig. 48)

Spongophora semi-flava de Bormans, 1894: 385.

Material examined: 2 males from Bukit Jambul-Bukit Kukus.

Distribution. Widely distributed in the Oriental Region: India, Sri Lanka, Bhutan, Myanmar, China (Yunnan), Laos, Thailand, Vietnam, Malaysia (Sarawak; Peninsular Malaysia), Indonesia (Sumatra, Java, Simalur, Borneo, Sumba), Philippines (Palawan, Mindanao, Luzon), and Taiwan; also recorded from Bismarck Island.

Record in Peninsular Malaysia: Kedah (Borelli 1932a).

Remarks. Detailed description of the female genital structures is given in Schneider & Klass (2013).

Spongiphoridae gen. et sp. indet.

Material examined: 1 female from Bukit Jambul-Bukit Kukus.

Remarks. Possibly a female *Irdex* sp. (Irdexinae), but the identity is uncertain because of the poor condition of the sample.

Family Chelisochidae

Subfamily Chelisochinae

Chelisoches morio (Fabricius, 1775)

(Figs. 49, 50)

Forficula morio Fabricius, 1775: 270.

Material examined: 1 male, 2 females from Bukit Jambul-Bukit Kukus, Sungai Burung-Sungai Nipah.

Distribution. Widely distributed in Oriental, Australian and Afrotropic Regions, and USA.

Records in Peninsular Malaysia: Malay Peninsula (Burr 1910); Selangor (Borelli 1932a; Hoshiba et al.

1988); Kuala Lumpur (McClure et al. 1967); Penang Island (Dohrn 1865, as *Lobophora morio*; Dubrony 1879, as *Labophora morio*; Burr 1901).

Remarks. Detailed descriptions of the female genital structures are given in Hudson (1973) and Schneider & Klass (2013).

Hamaxas crassus Borelli, 1926

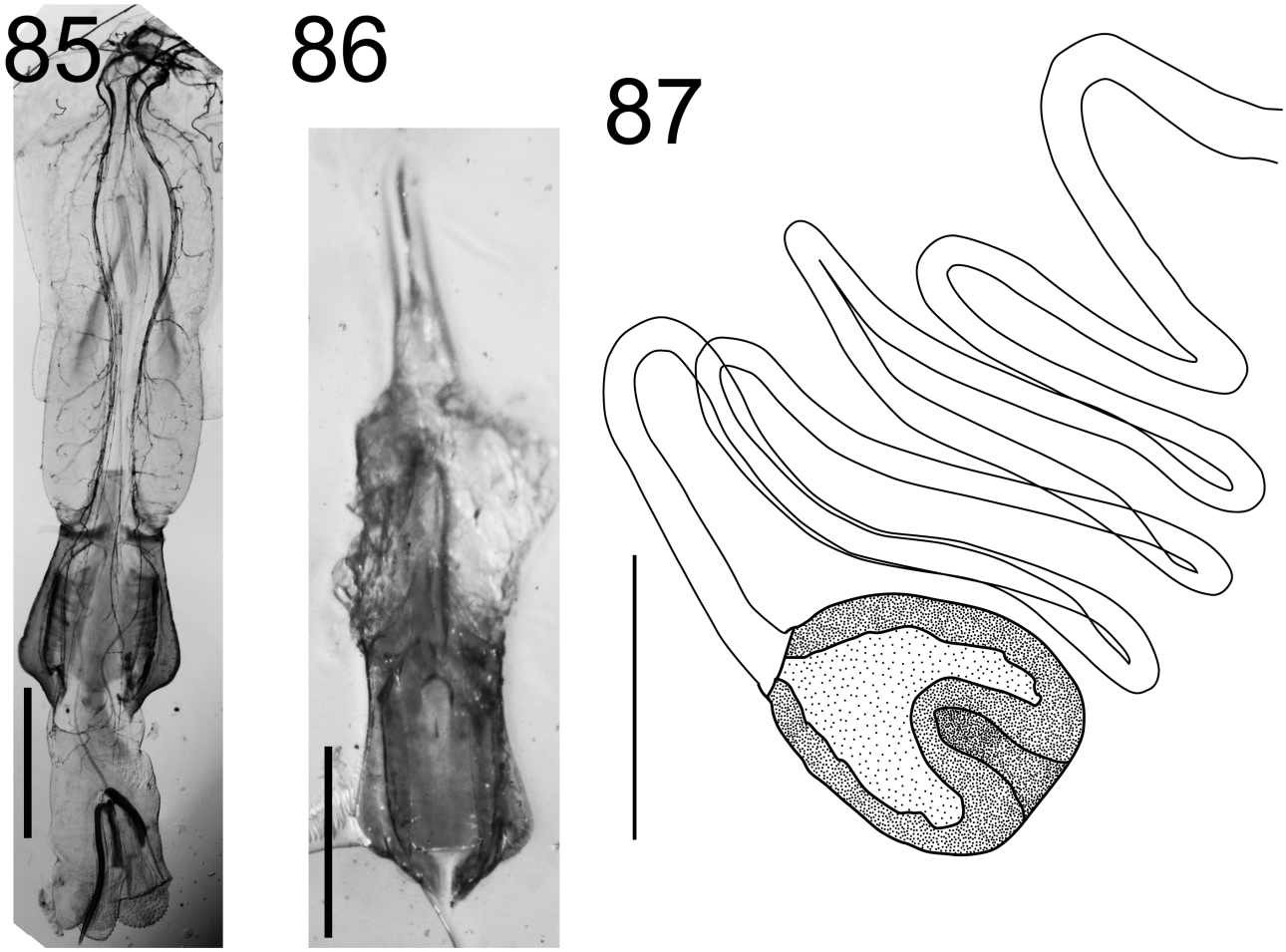
(Figs. 51, 52, 85−87)

Hamaxas crassus Borelli, 1926a: 77.

Material examined: 9 males, 12 females from Ayer Itam-Kebun Bunga.

Distribution. Philippines (Mindoro), Indonesia (Sulawesi), Peninsular Malaysia (Penang Island, new record).

Remarks. We examined two specimens (one male, one female) in Manchester Museum that had been collected at the type locality (Mindoro Island) and had been determined as *H. crassus* (Brindle 1968). For both sexes the samples from Penang and Mindoro corresponded well with each other, including the male genital structures (Figs. 85, 86). The spermatheca of this species consists of an elongated thin tube with a well-pigmented sclerotized capsule at the distal end (Fig. 87).



FIGURES 85–87. *Hamaxas crassus*. 85) Male genitalia of a specimen from Penang Island. 86) Male genitalia of a specimen from Mindoro Island (Philippines) preserved in Manchester Museum. 87) Spermatheca. Scale bars: 0.5 mm for Figs. 85, 86; 0.1 mm for Fig. 87.

***Proreus coalescens* (Borelli, 1927)**
(Figs. 53, 54, 68I)

Chelisoches coalescens Borelli, 1927: 75.

Material examined: 7 males, 3 females from Bukit Jambul-Bukit Kukus.

Distribution. Philippines (Luzon), Indonesia (Sumatra) and Peninsular Malaysia (Penang Island, new record).

Remarks. The spermatheca of this species consists of an elongated thin tube with a well pigmented sclerotized capsule at the distal end (Fig. 68I).

***Proreus ludekingi* (Dohrn, 1865)**
(Fig. 55)

Lobophora ludekingi Dohrn, 1865: 73.

Material examined: 1 male from Bukit Jambul-Bukit Kukus.

Distribution. Oriental Region.

Records in Peninsular Malaysia: Kedah, Pahang and Selangor (Borelli 1932a); Langkawi Island (Tworzydło *et al.* 2010, as "Malaysia").

Family Forficulidae

Subfamily Opisthocosminae

***Hypurgus humeralis* (Kirby, 1891)**
(Fig. 56, 57, 68J)

Opisthocosmia humeralis Kirby, 1891: 523.

Material examined: 8 males, 15 females from Ayer Itam-Kebun Bunga

Distribution. India, Nepal, Sri Lanka, Myanmar, China (Yunnan), Thailand, Vietnam, Borneo, and Peninsular Malaysia (Penang Island, new record).

Remarks. The spermatheca of this species consists of an elongated thin tube with a weakly pigmented capsule at the distal end (Fig. 68J). Srivastava (2013) provided a synonym list for this species.

Discussion

We collected 31 species of Dermaptera during these field surveys, of which two species were new to science. Including the new species and an undescribed species, fifteen of the 31 are new records for Peninsular Malaysia. *Echinosoma denticulatum*, for which the reproductive biology has already been reported elsewhere (Kamimura and Lee 2014a), was also recorded for the first time from Peninsular Malaysia during the field survey. Some of these have been recorded previously from an adjacent country: Thailand (1 species), Indonesia (2), and Vietnam (1). Two other species (*Chaetospania anderssoni*, *Paralabellula rotundifrons*) were previously known only from Sri Lanka. Penang Island is located at almost the same latitude as Sri Lanka at the opposite side of the Bay of Bengal, suggesting spreading by ocean currents via rafting. Similarly, *Euborellia philippinensis* and *Paralabellula boettcheri* were known only from the Philippines. On Penang Island, both species occur in semi-disturbed habitats (banana and rubber plantations, respectively), suggesting possible human-assisted migration.

The female genital morphologies described herein provide insights into the phylogenetic relationships of earwigs. The finding of the eighth-segment gonapophyses (gp8) and the ninth-segment laterocoxa (LC9) in female *Platylabia major* (Fig. 68D) suggests its possible affinity to the family Labiduridae (Kamimura & Lee 2014b).

Srivastava (1995) treated the genera *Paralabella* Steinmann, 1990 (later synonymized with *Paralabellula* Kevan, 1997; Kevan & Vickery 1997) and *Spirolabia* Steinmann, 1987 as a synonym of *Circolabia* Steinmann, 1987. Steinmann (1987, 1990) distinguished these three genera by the shape and arrangement of the virga, while Srivastava (1995) considered these characters unstable for generic classification. Considering the differences in the shapes of the spermathecae of *Paralabellula* and *Spirolabia* spp. (Figs. 68F, 84) revealed in this study, we have followed Steinmann's (1990) view in this paper.

Among the five intensive-study sites, the highest diversity was recorded at two central island sites: Bukit Jambul-Bukit Kukus (23 of 31 species), followed by Ayer Itam-Kebun Bunga (15 species) (Fig. 88). These two sites commonly include large fruit or rubber plantations in addition to natural and secondary forests around durian plantations (Table 1). In contrast to these sites located in the central part of the island, only a few species of earwigs were recorded from the other three sites (Fig. 88). However, many species recorded from these sites are unique to these coastal environments, indicating that the observed diversity of earwig fauna is also due to the environmental heterogeneity within the island.

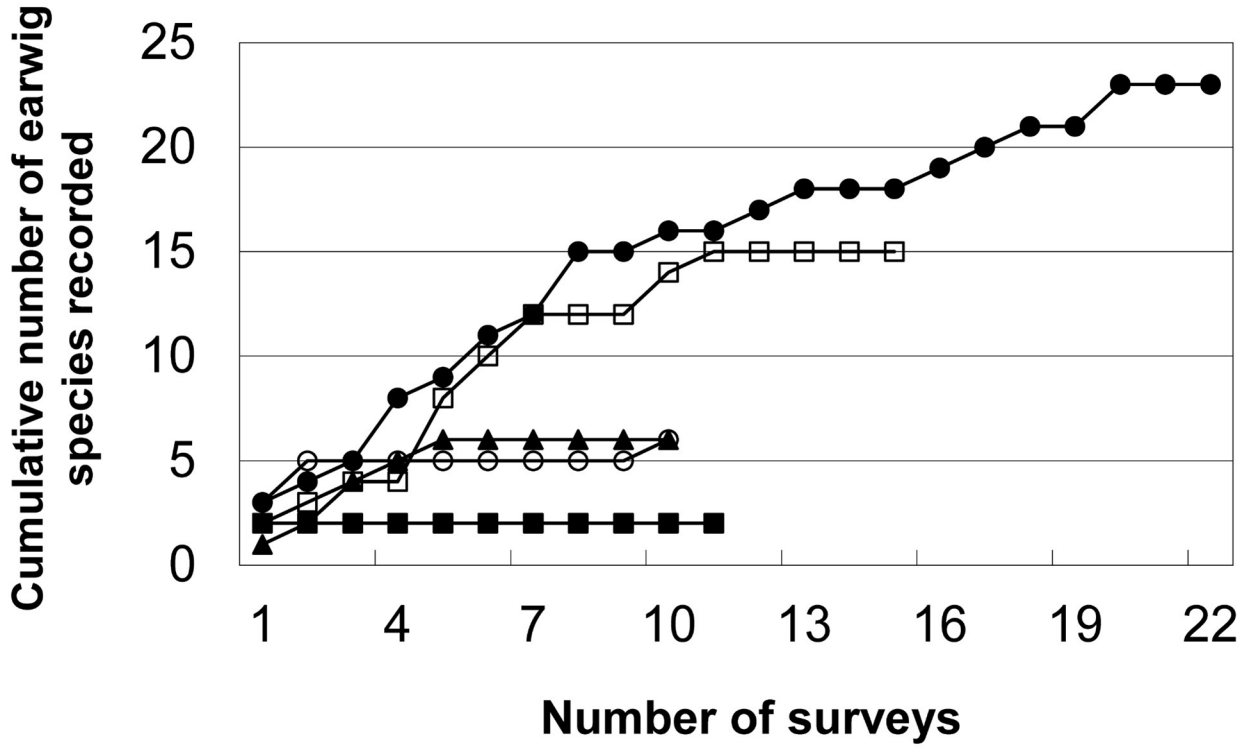


FIGURE 88. Cumulative number of Dermaptera species collected from the five intensive study sites in relation to the number of surveys conducted. Closed circles, Bukit Jambul-Bukit Kukus; open squares, Ayer Itam-Kebun Bunga; closed triangles, Telok Bahang-Batu Ferringi; open circles, Sungai Burung-Sungai Nipah; closed squares, Bayan Mutiara.

Although no comparable study has been reported for the dermapteran fauna of other places in Malaysia, Nishikawa (2005) published a comprehensive checklist for the earwigs of Thailand, based on a bibliographic survey. Penang Island is approximately 100 km south of the southern border of Thailand. Nishikawa (2005) listed 72 species (including two unidentified species) recorded from all of Thailand up to 2004. Due to the difference in the research method, it is difficult to compare the species richness between the two regions. However, it is worthwhile to compare the species composition (Fig. 89). Forficulidae and Pygidicranidae are poorly represented on Penang Island compared with the Thai fauna: only one species of Forficulidae (*Hypurgus humeralis*) was collected in the present study, while 12 forficulids have been recorded from Thailand. In general, Forficulidae is more adapted to cooler environments than other dermapteran families, and many forficulid genera are distributed in the temperate zone of the Northern hemisphere (Popham 2000). Thus, the lower latitude and absence of high mountains in Penang Island probably accounts for the poor representation of Forficulidae in the island fauna.

Only 9 species of earwigs were previously reported from the island, of which six (*Echinosoma sumatranum*, *Platylabia major*, *Allostethus indicum*, *Chaetospania thoracica*, *Paralabellula curvicauda*, and *Chelisoches morio*)

were confirmed in our field survey (see Results). *Proreus simulans* (Stål, 1860), *Chelisochella superba* (Dohrn, 1865) (Chelisochidae) and *Apachyus chartaceus* (De Haan, 1842) (Apachyidae) have also been recorded from the island (Dohrn 1865; Bormans & Krauss 1900) but were not found in our field survey. These three species, especially *P. simulans*, which is commonly found in suburban environments in warmer parts of the Oriental Region, are possibly still present on the island. In addition, *Cranopygia similis* (Zacher, 1911) has been recorded from "Penang" (Burr 1910; Hincks 1959), but a question remains of whether the specimens were collected from Penang Island or from the mainland state of Penang. Further detailed field surveys, especially in natural forest areas, are required to confirm their present status on Penang Island.

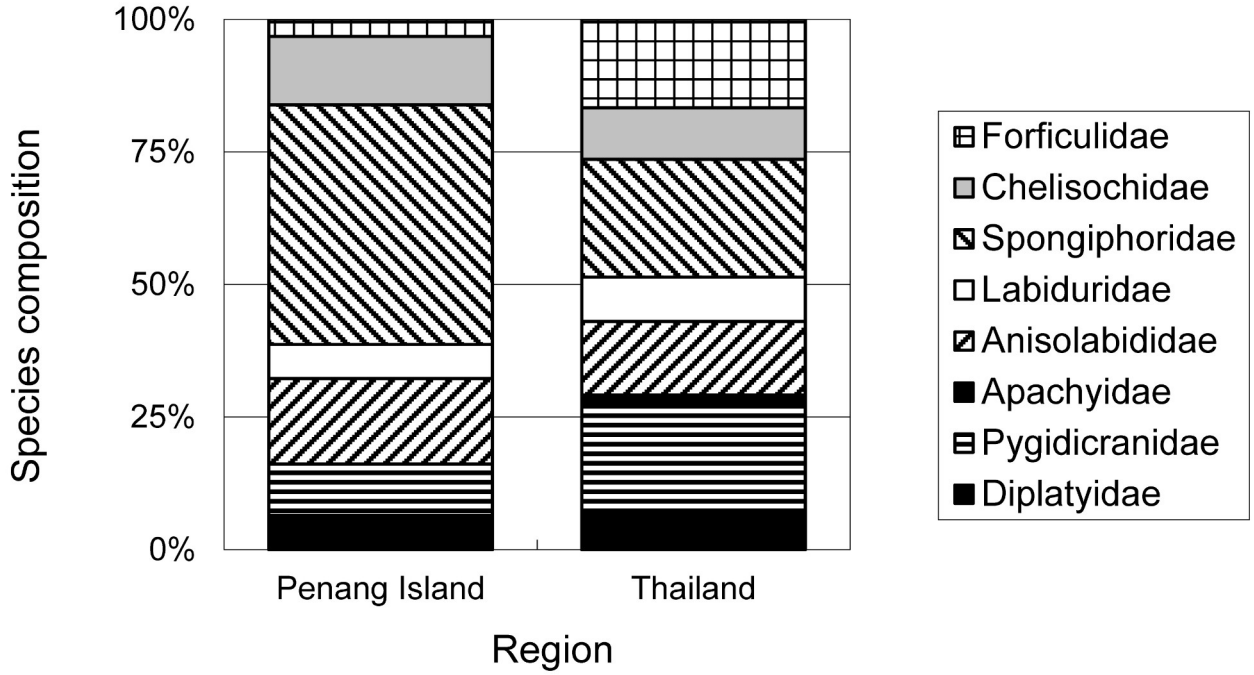


FIGURE 89. Comparison of the family-level species composition of Dermaptera of Penang Island (this study) and Thailand (Nishikawa 2005).

Acknowledgements

This study was conducted with the approval of the Economic Planning Unit, Malaysia (Reference No. UPE: 40/200/19/2844). We thank the Department of Wildlife and National Parks, Malaysia (PERHILITAN) for permission for sampling in the Penang National Park (Pantai Acheh Forest Reserve) and Highlands Forest Reserve. We also thank H.-S. Tee, L.-H. Ang, C.-C. Lee, and X.-Y. Goh of Universiti Sains Malaysia for their assistance in insect collection, D.V. Logunov for allowing us to examine specimens preserved in Manchester Museum, Y. Matsumura for providing us with useful references, and an anonymous reviewer for their helpful comments on previous versions of the manuscript. This study was partly supported by a grant for overseas research and a Keio Gijuku Academic Development Fund from Keio University, and a Grant-in-Aid for Scientific Research (Kakenhi, Nos. 22770058 and 15K07133) from the Japan Society for the Promotion of Science to Y.K.

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