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A JOURNAL ON ZOOLOGY OF THE INDO-AUSTRALIAN ARCHIPELAGO

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A JOURNAL ON ZOOLOGY OF THE INDO-AUSTRALIAN ARCHIPELAGO
Vol. 48, no. 2, pp. 81–170, December 2021

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CONTENT

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UDC: 595.76:611.6(594.53)

Yaheita Yokoi

CALLIDIOPINI BEETLES (COLEOPTERA, CERAMBYCIDAE) IN THE COLLECTION OF MUSEUM ZOOLOGICUM BOGORIENSE, INDONESIA. PART II. GENITALIA AND TAXONOMY OF THE GENUS *TETHIONEA* PASCOE

TREUBIA, December 2021, Vol. 48, No. 2, pp. 81–102.

Species of *Tethionea* Pascoe, 1869, Callidiopini, in the collection of Museum of Zoologicum Bogoriense are reviewed. Two new species of the genus are described, *T. peggieae* sp. nov. and *T. oculata* sp. nov., both from Papua Province, Indonesia. In addition, *T. unicolor* Pascoe, *T. strumosa* Pascoe and *T. tridentata* Pascoe are redescribed. Their male genitalia are documented and illustrated in detail. In particular, the ejaculatory duct complexes of endophalli are carefully observed, as well as 8th sternites and tergites. For *T. oculata* sp. nov., the female genitalia are described. Morphological and taxonomical aspects of these species are discussed.

(Yaheita Yokoi, Hiroshi Makihara, and Woro A. Noerdjito)

Key words: Callidiopini, ejaculatory duct complex, endophallus, genitalia, *Tethionea*

UDC: 598.112.8:597.6

Ahmad Nauval Arroyyan

FIRST REPORT ON THE FEEDING BEHAVIOR OF EARLESS MONITOR, *LANTHANOTUS BORNEENSIS* AND ITS PREDATION ON RICE FIELD FROG, *FEJERVARYA LIMNOCHARIS* IN A CAPTIVE ENVIRONMENT

TREUBIA, December 2021, Vol. 48, No. 2, pp. 103–116.

Being endemic to Borneo, the Earless monitor, *Lanthanotus borneensis* (Steindacner, 1878) is rarely found in its habitats due to its cryptic behavior. We provide care for confiscated animals in the Reptile House of Museum Zoologicum Bogoriense (MZB) in Cibinong, West Java, Indonesia since 2014. Little is known on its natural prey but from scattered descriptive reports. This study is aimed at documenting the feeding behavior of ten captive Earless monitors and events of predation on frogs. We set up two experiments, one with meat of Rice Field Frog, *Fejervarya limnocharis*, and the other with live frog of the same species. Our recorded observations ran for four weeks for the frog meat feeding experiment and followed by the frog predation experiment. Our results showed that lizards constantly accepted frog meat. Lizards tended to feed before sunset for a short period of time on the muddy soil surface, although a few individuals inconsistently fed under water. The average body mass for these lizards increased by 4.29 g and average SVL by 0.45 cm. We recorded predation on frogs in three out of ten individuals observed during this study. If *F. limnocharis* is confirmed to occur in the natural habitats of *L. borneensis*, it is possible that this frog species is among the natural prey for Earless monitors. Further studies on its natural diets should be conducted to gain in-depth knowledge essential for generating effective captive husbandry for this nationally protected species in Indonesia.

(Ahmad Nauval Arroyyan, Evy Arida, and Nirmala Fitria Firdhausi)

Key words: crepuscular, frog meat, prey, reptile house, survival

UDC: 595.771.001.3

Sidiq Setyo Nugroho

SPECIES DISTRIBUTION UPDATE OF *MANSONIA* BLANCHARD, 1901 MOSQUITOES (DIPTERA: CULICIDAE) IN INDONESIA WITH THE ILLUSTRATED KEY FOR FEMALE MOSQUITO

TREUBIA, December 2021, Vol. 48, No. 2, pp. 117–128.

Mansonia is a genus of mosquitoes of which several species are confirmed vectors of lymphatic filariasis. Many countries including Indonesia are still struggling to eliminate lymphatic filariasis. Report of the *Mansonia* mosquito diversity and its distribution is essential to develop the control strategies. Six of eight *Mansonia* species have been confirmed as lymphatic filariasis vectors in Indonesia. This paper aims to update the distribution of the *Mansonia* mosquito in Indonesia. Species distribution data were summarized from various literature regarding the *Mansonia* mosquito. The data is complemented by the results of the National Research on Disease Vector and Reservoir (Rikhus Vektora) results conducted by the National Institute of Health Research and Development (NIHRD) in 2015-2018. There were new distribution records for four species of *Mansonia* mosquitoes in Indonesia. *Mansonia annulata* Leicester*,* *Ma. annulifera* (Theobald)*,* and *Ma. indiana* Edwards are now recorded distributed throughout the archipelago. Meanwhile, *Ma. bonneae* Edwards has a new distribution record in the Moluccas. The illustrated identification key for female *Mansonia* mosquitoes in Indonesia is provided in this paper.

(Sidiq Setyo Nugroho, Mujiyono, and Fahmay Dwi Ayuningrum)

Key words: distribution, Indonesia, *Mansonia*, mosquito

UDC: 595.78:636.082.4(594.53)

Djunijanti Peggie

CAN *TROIDES HELENA* AND *PACHLIOPTA ADAMAS* CO-EXIST? A PERSPECTIVE FROM THE BUTTERFLY BREEDING FACILITY, CIBINONG SCIENCE CENTER, INDONESIA

TREUBIA, December 2021, Vol. 48, No. 2, pp. 129–140.

Troides helena and *Pachliopta adamas* utilize the same food plant species: *Aristolochia acuminata.* For the purpose of captive breeding and conservation, it is desirable to find out whether they can co-exist in captivity. Captive breeding research was conducted on the butterfly species within the period of October 2016 to September 2019. In total, 1,361 individuals were observed. Data on adult emergence of the species is presented to show the trends. Both species co -existed poorly at the facility when food plants were limited. It took 45.9 days for *T. helena helena* and 32.6 days for *P. adamas adamas* to grow from egg to imago stage. Habitat enrichment can encourage the species to come and establish the population.

(Djunijanti Peggie, Supadi, Guntoro, and Muhammad Rasyidi)

Key words: captive breeding, co-exist, *Pachliopta adamas*, parental stocks, *Troides helena*

UDC: 595.799:638.1

Sih Kahono

DIVERSITY OF THE CLOSED-NESTED HONEY BEES (APIDAE: *APIS* SPP.) AND THE TRADITIONAL HONEY COLLECTING AND BEEKEEPING IN FOUR ISLANDS OF INDONESIA

TREUBIA, December 2021, Vol. 48, No. 2, pp. 141–152.

The closed-nested honey bees are an important group that has been successfully bred traditionally and in a modern way. The traditional honey beekeeping practices are still favorable by local people living near natural habitats. Many rural areas in Indonesia are well known as producers of honey from the traditional honey collecting and traditional honey beekeeping of the closed-nested honey bees. However, there is limited information on the diversity of the honey bees that had supported the honey productions and their traditional honey beekeeping. This research was to provide an overview of the diversity of the honey bee species that are used in the wild honey collecting and their traditional honey beekeeping in four selected study sites in the islands of Java, Bawean, Kalimantan, and Peleng. We recorded three species of closed-nested native honey bees in the traditional honey collecting and traditional honey beekeeping, namely *Apis cerana*, *A. koschevnikovi*, and *A. nigrocincta*. We observed that traditional beekeeping of *A. cerana* was carried out in Tasikmalaya and Bawean Island, and that of *A. cerana* and *A. koschevnikovi* were carried out in Kayan Hilir. On Peleng Island, people do not do beekeeping but collect honey directly from the forest. Honey collecting and beekeeping practices are related to changes in the seasons of the flowering period in their habitats. The knowledge of the flowering period is needed to know the seasonal movement of honey bees from forest to village and vice versa.

(Sih Kahono, Djunijanti Peggie, and Eko Sulistyadi)

Key words: *Apis cerana, A. koschevnikovi*, *A. nigrocincta,* Indonesia, traditional honey collecting and beekeeping

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UDC: 594.3(594)

Ayu Savitri Nurinsiyah

LIST OF LAND SNAILS IN JAVA AND SEVERAL ADJACENT

TREUBIA, December 2021, Vol. 48, No. 2, pp. 153–170.

The malacofauna of Java has been most studied among the Indonesian islands, but the list of land snails in the area remains outdated. This study presents an updated check list of land snails in Java and its adjacent islands. This list is a compilation data from field work in Java conducted in 2013-2016, records from various museums in Europe and Indonesia, collections from private collectors, data from citizen sciences, and literatures. In total, 263 land snail species were recorded in Java and its adjacent islands. The number comprises of 36 families i.e. Subclass Neritimorpha (2 families), Caenogastropoda (6 families), and Heterobranchia (28 families). About 40% are species endemic to Java and among them have restricted distribution to certain areas. In addition, 5% or 13 introduced species were recorded in Java.

(Ayu Savitri Nurinsiyah)

Key words: biodiversity, Gastropoda, Indonesia, Mollusca, terrestrial

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http://zoobank.org/urn:lsid:zoobank.org:act:57EA8276-B691-4274-BF30-11DC1F297DB8;
http://zoobank.org/urn:lsid:zoobank.org:act:D6591DB9-5702-4EEF-9DC9-26DC54937F2

CALLIDIOPINI BEETLES (COLEOPTERA, CERAMBYCIDAE) IN THE COLLECTION OF MUSEUM ZOOLOGICUM BOGORIENSE, INDONESIA. PART II. GENITALIA AND TAXONOMY OF THE GENUS *TETHIONEA* PASCOE

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ABSTRACT

Species of *Tethionea* Pascoe, 1869, Callidiopini, in the collection of Museum of Zoologicum Bogoriense are reviewed. Two new species of the genus are described, *T. peggieae* sp. nov. and *T. oculata* sp. nov., both from Papua Province, Indonesia. In addition, *T. unicolor* Pascoe, *T. strumosa* Pascoe and *T. tridentata* Pascoe are redescribed. Their male genitalia are documented and illustrated in detail. In particular, the ejaculatory duct complexes of endophalli are carefully observed, as well as 8th sternites and tergites. For *T. oculata* sp. nov., the female genitalia are described. Morphological and taxonomical aspects of these species are discussed.

Key words: Callidiopini, ejaculatory duct complex, endophallus, genitalia, *Tethionea*

INTRODUCTION

In our previous publication, some Callidiopini species in the collection of the Museum of Zoologicum Bogoriense (MZB), Cibinong, Indonesia, were reviewed. Four new species of *Ceresium* or *Examnes* were described, and their male genital organs were documented and illustrated in detail (Yokoi et al., 2019).

In this study, we review the species of *Tethionea*. The genus includes hitherto 24 species, mostly recorded from the Australian Region. It was first introduced by Pascoe, who described four species from the "Moluccas" (Pascoe, 1862, 1869; now generally known as Maluku). In the last century, one new species was described from New Caledonia (Fauvel, 1906), and 12 species and one subspecies were described from New Guinea (Gressitt, 1951, 1955, 1959). Gressitt redescribed *Tethionea*, providing a diagnostic key for the species. In recent years, 6 new species have been described; one each from the Malay Peninsula, Java, Lombok and Borneo, and two species from the Philippines (Hayashi, 1979; Yokoi, 2015; Holzschuh, 2015; Vives, 2015, 2016). More recently, the genus was redescribed based on species from Australia (Ślipiński & Escalona, 2016). *Tethionea* was compared to *Ceresium* by Pascoe and Gressitt. For further consideration of the taxonomy, however, a more advanced material basis is required. Additional species should be explored and closely examined. In the following, two new species are described and three known species redescribed.

For the taxonomy of the Callidiopini, it is important to investigate male genitalia because these provide definitive diagnoses for the species and also indicate relationships with other genera. Particularly important are the ejaculatory duct complexes and the 8th sternite. In recent years, male genitalia of *Ceresium* Newman, 1842, *Oxymagis* Pascoe, 1866, *Examnes* Pascoe, 1869, *Stenodryas* Bates, 1873, and *Falsoibidion* Pic, 1923, were described (Yokoi, 2019, 2021a, 2021b; 2021 in press; Yokoi et al., 2016, 2019). In contrast, the knowledge of genitalia of *Tethionea* is still very limited. In recent years, male genitalia of *Tethionea lassehubweberi* Yokoi were partly described (Yokoi, 2015). Moreover, the male genitalia were included in the above noted description of the Australian *Tethionea* species by Ślipiński and Escalona. Nevertheless, altogether only a small number of *Tethionea* species have been examined. Therefore, male genitalia of three known species, *Tethionea unicolor* Pascoe, *Tethionea strumosa* Pascoe and *Tethionea tridentata* Pascoe are described below, together with those of the new species *Tethionea peggieae* sp. nov. In addition, female genitalia of *Tethionea oculata* sp. nov. are described.

Other interesting aspects of *Tethionea* morphology were also observed. As the venters were not included in the original descriptions of the above three known species, they were investigated anew. Regarding the structure of their maxillary palpi, Pascoe discovered interesting variations, and Gressitt later made a comprehensive observation. Maxillary palpi were re-examined for this publication. Finally, future prospect of the research is outlined in DISCUSSION.

MATERIALS AND METHODS

The method remains basically the same as in our previous publication (Yokoi et al., 2019). The material was provided by the collection of MZB. The specimens thereof were mostly collected in various parts of Indonesia under the auspices of the Indonesian Institute of Science (LIPI). Additionally, specimens collected by the second author in Papua New Guinea are included in the collection. The holotypes and a paratype designated herein will be preserved in MZB.

The abbreviations used for the ratio of the measurement in the descriptions are as follows: BLe- body length measured from apical margin of clypeus to elytral apices; HW- head width across eyes, PL- length of pronotum, PW- maximum width of pronotum, PA- apical width of pronotum, PB- basal width of pronotum, EL- length of elytra, EW- humeral width of elytra.

In this publication, the sclerotized complex of apical endophallus is referred to as "ejaculatory duct complex", as in the previous publication. The side or direction to which the ejaculatory duct is attached or pointed is referred to as "dorsal "or "apical".

RESULTS

As a result of the above investigation, we describe two new species of the genus *Tethionea* from Irian Jaya, New Guinea. *Tethionea peggieae* sp. nov. is comparable to a few known species, while *Tethionea oculata* sp. nov. is rather singular in appearance.

In the course of the recent observation, the importance of male genitalia for taxonomy was again underlined. Above all, it was revealed that *Tethionea* essentially shares the similar type of endophallus with *Ceresium, Examnes, Stenodryas and Oxymagis*, four affiliated genera of the same tribe. These results are described below in "Taxonomy". Further, morphological and taxonomical aspects beyond the description of individual species are treated in DISCUSSION. The genitalia, prosternal processes and maxillary palpi of the examined species are discussed there.

Taxonomy

Tethionea peggieae sp. nov.
(Figs 1A-E; 2A-L)

Material examined. Holotype ♂: "**INDONESIA**, Irian Jaya, Freeport Concession Timika. 12 -19.IX. 1997, R. Ubaidillah, Peggie, **97032**"; "Pandans peat swamp, East levee of Minajerwi river. 4. 4099'S. 136.5854'W. 15 m. Malaise trap-1(Site 4)";"7701".

Diagnosis. Pronotum elongated. Pronotal sides uneven; densely, deeply punctate-verrucose. Prosternum densely, deeply punctate-scabrous. Prosternal process narrow, apically feebly expanded. Elytral apices each terminated with an acuminate spine. Legs stout, femora keeled. Upper eye-lobes widely separated from each other.

Etymology. The name of this new species is dedicated to Dr. Djunijanti Peggie, the butterfly curator of Museum Zoologicum Bogoriense, who collected the specimen.

Description.

Measurements. BLe=8.5mm. EL/EW=2.80. HW/PW=0.84. PL/PW=1.15. PA/PW=0.74. PB/PW=0.96.

Color testaceus; antennae and legs paler; setae yellowish.

Head evenly, moderately punctate, nearly hairless. Frons transverse-sub-rectangular, horizontally impressed near apex, with a feeble median groove. The terminal joints of maxillary palpi spatulate, with external sides moderately truncated and opened (Fig. 11F). Vertex broad, widely flattened, hardly concave. Upper eye-lobes narrow, separated from each other by 5/2 the width of lobe or 2/5 the width of occiput. Antennal supports flattened. Antennae reaching the elytral apices with the last articles. Scape stout, clavate, weakly arcuate, coarsely punctured. Antennomeres 3 and 4 a little shorter than scape; 5 and 6 about 6/5 as long as scape; 7-11 gradually attenuated.

Pronotum longer than broad, glossy, almost hairless; apex strongly and base moderately constricted; disc flattened, regularly punctured, with an impunctate median stripe 2/5 the length of pronotum; sides arcuate, uneven with irregular costae, densely and deeply punctate -verrucose. Scutellum sub-circular.

Elytra each weakly tapering toward apex; terminated by an acuminate spine. The external side of the spine emarginated; the sutural side weakly so. Basal 3/4 of elytra evenly, moderately punctured; hairless. Apical 1/4 with smaller, shallower punctures, some of which are setiferous, each bearing a sub-erect setae of medium length.

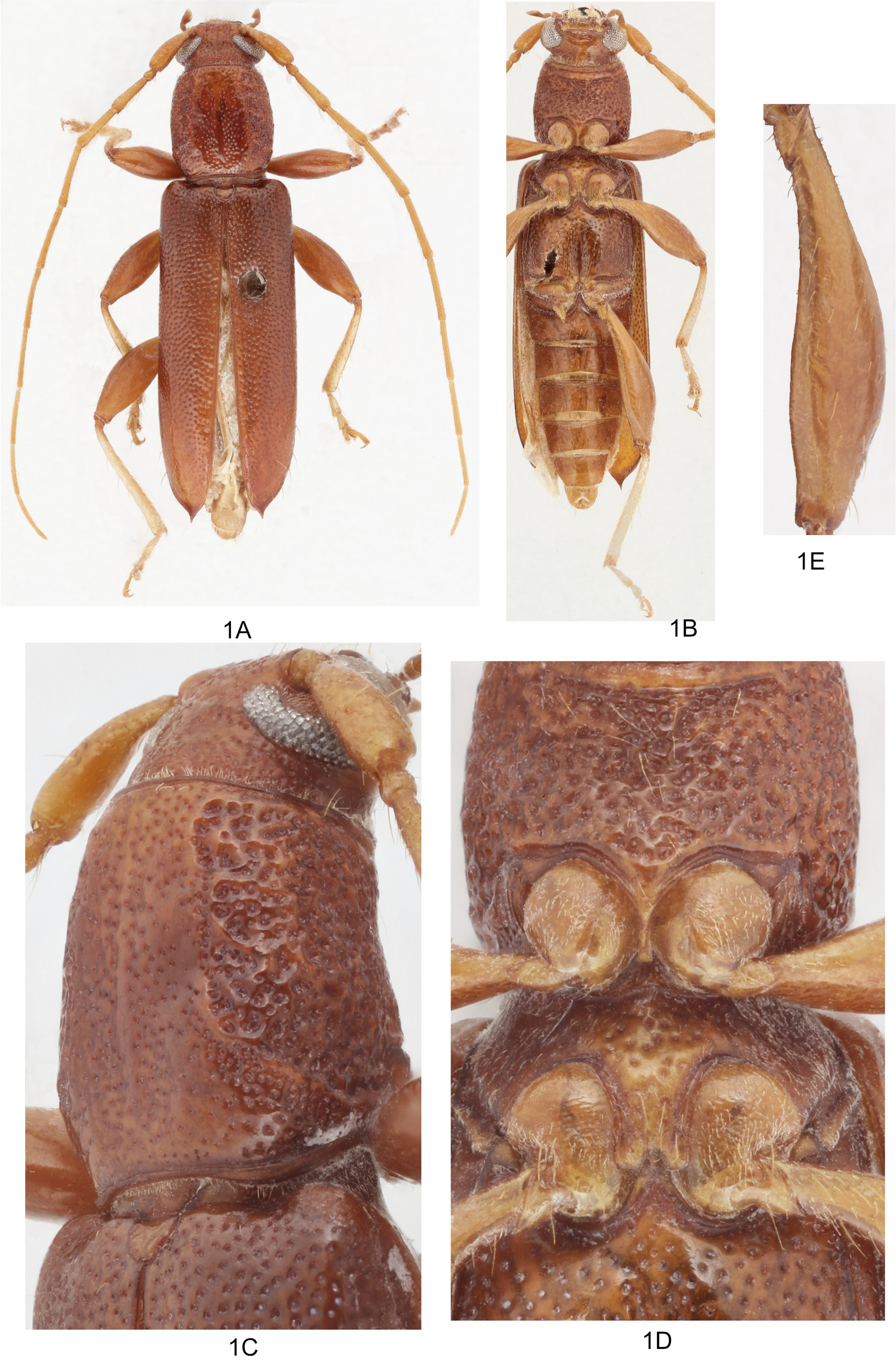
Legs rather short and stout. Femora strongly clavate from base on; ventrally keeled (Fig. 1E).

Venter. Prosternum convex; glossy; deeply, densely punctate-scabrous, with several hairs in the middle. Prosternal process narrow; apex feebly expanded, truncated. Mesoventrite nearly hairless, with sparse though large, deep punctures; moderately elevated toward the process. Mesoventral process with several large setiferous punctures; base broad; apically sub-parallel-sided; apex deeply emarginated in the middle. Metaventrite transverse-sub-rectangular, convex; glossy, regularly provided with sparse though large punctures, which are more or less setiferous in the middle.

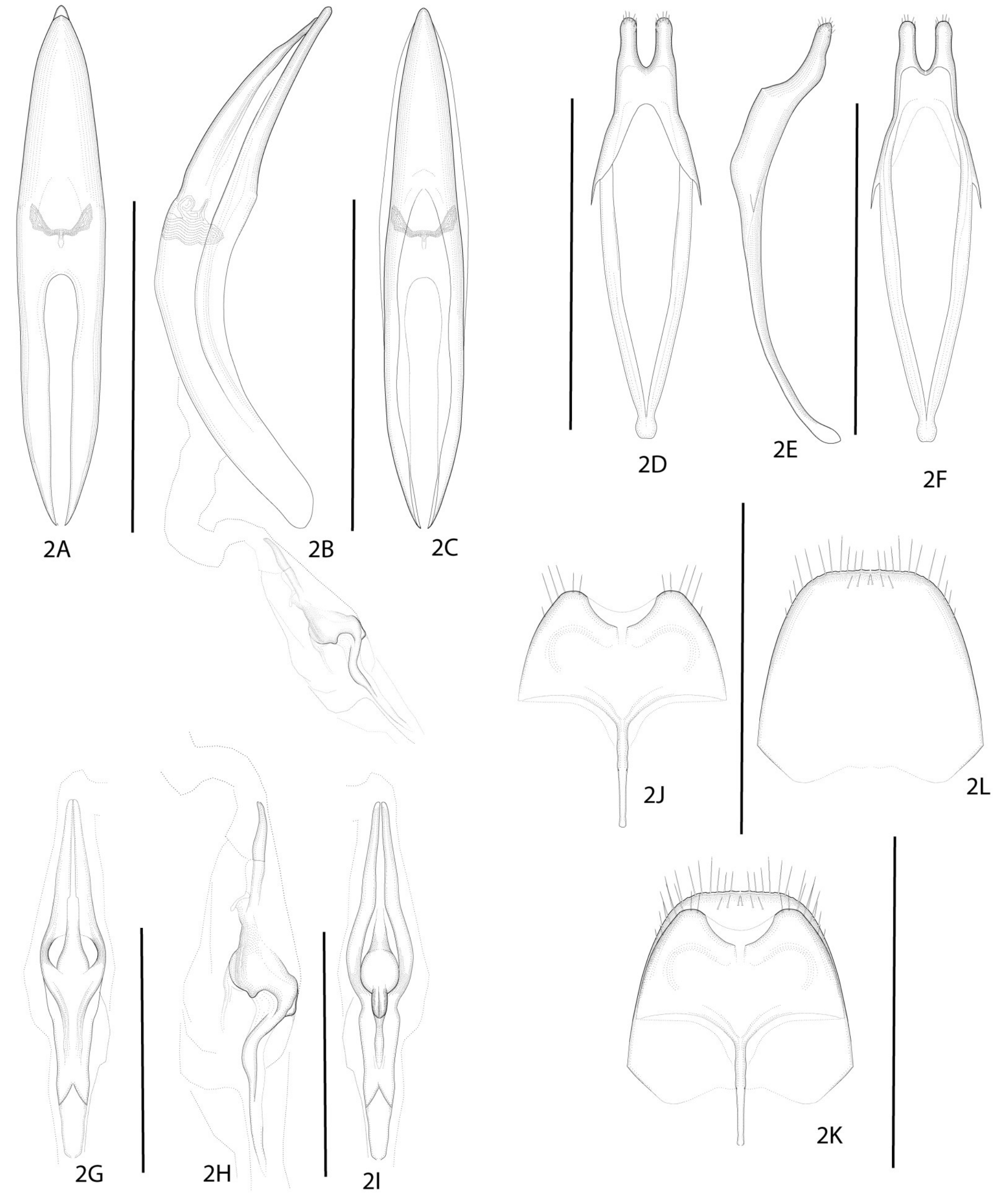
Abdomen gradually narrowed toward apex; sternites 4-7 about 4/5 as long as the third; glossy; with sparse setiferous punctures.

Male genitalia as Figs 2A-L. Median lobe about 2/5 the length of abdomen; fusiform in dorsal view; thick and strongly arcuate in lateral view; dorsal plate dehiscent in the basal half; ventral plate a little longer and narrower than the dorsal, dehiscent in basal 2/3. Tegmen about 4/5 the length of median lobe, arcuate in lateral view. Parameres about 9/20 the length of tegmen; basal half distinctly and apical half feebly tapering toward apex; apical 1/4 bi-lobed; each lobe with several short, stout apical setae. Ejaculatory duct complex as Figs 2G-I; about half as long as median lobe; slender, composed of three inter-connected sclerites; apical sclerite composed of two elongated rod-like structures; median sclerite stout, with a prominent horn-shaped projection; basal sclerite elongated, flattened, apically dehiscent. 8th sternite in gingko-leave-form; blade widely thinned in the middle, with several apical setae; peduncle a little shorter than blade. 8th tergite truncated on apex; apical 2/3 sub-congruent with 8th sternite; apical setae similar to those of the sternite.

Distribution. Papua Province, Indonesia (New Guinea).



Figures 1A-E. *Tethionea peggieae* sp. nov. Holotype male. 1A, habitus, dorsal view; 1B, ditto, ventral view; 1C, head and pronotum, latero-dorsal view; 1D, thorax, ventral view; 1E, hind femur.



Figures 2A-L. *Tethionea peggieae* sp. nov. Holotype male. Genitalia. 2A, median lobe, dorsal view; 2B, ditto, lateral, with endophallus; 2C, ditto, ventral; 2D, tegmen, dorsal view; 2E, ditto, lateral; 2F, ditto, ventral; 2G, endophallus, ejaculatory duct complex, dorsal view; 2H, ditto, lateral; 2I, ditto, ventral; 2J, 8th sternite, ventral view; 2K, ditto, with 8th tergite in the background; 2L, 8th tergite, ventral view. Scale bar: 0.5mm for 2G-I; 1mm for the others.

Comparative notes. The new species can be distinguished externally by the pronotum. It is elongated, with sides uneven, densely, deeply punctate-verrucose. In addition, the upper eye-lobes are more widely separated from each other than usual. *Tethionea waigeona* Gressitt shares uniform body color and singly acuminose elytral apices with the new species. However, its pronotum is less strongly elongated and simply punctate on sides. The genitalia of the new species, including the ejaculatory duct complex, are essentially similar to those of already examined species of genera *Ceresium, Stenodryas, Examnes* and *Oxymagis*.

Tethionea unicolor Pascoe, 1869
(Figs 3A-E; 4A-L)

Tethionea unicolor Pascoe, 1869: 543. Type locality: “Aru”.
Tethionea unicolor: Gemminger & Harold, 1872: 2838.
Tethionea unicolor: Aurivillius, 1912: 126.
Tethionea unicolor: Gressitt, 1951: 20.
Tethionea unicolor: Gressitt, 1959: 120, 121.
Tethionea unicolor: Slipiński & Escalona, 2016: 299

Material examined. ♂: “Gogol River, Madan, PNG, 10-20. iii. 1986, H. Makihara leg.

Additional description.

(Head, pronotum, elytra and legs as in the original description)

Terminal joints of maxillary palpi truncated and opened on both sides (Figs 11C-E).

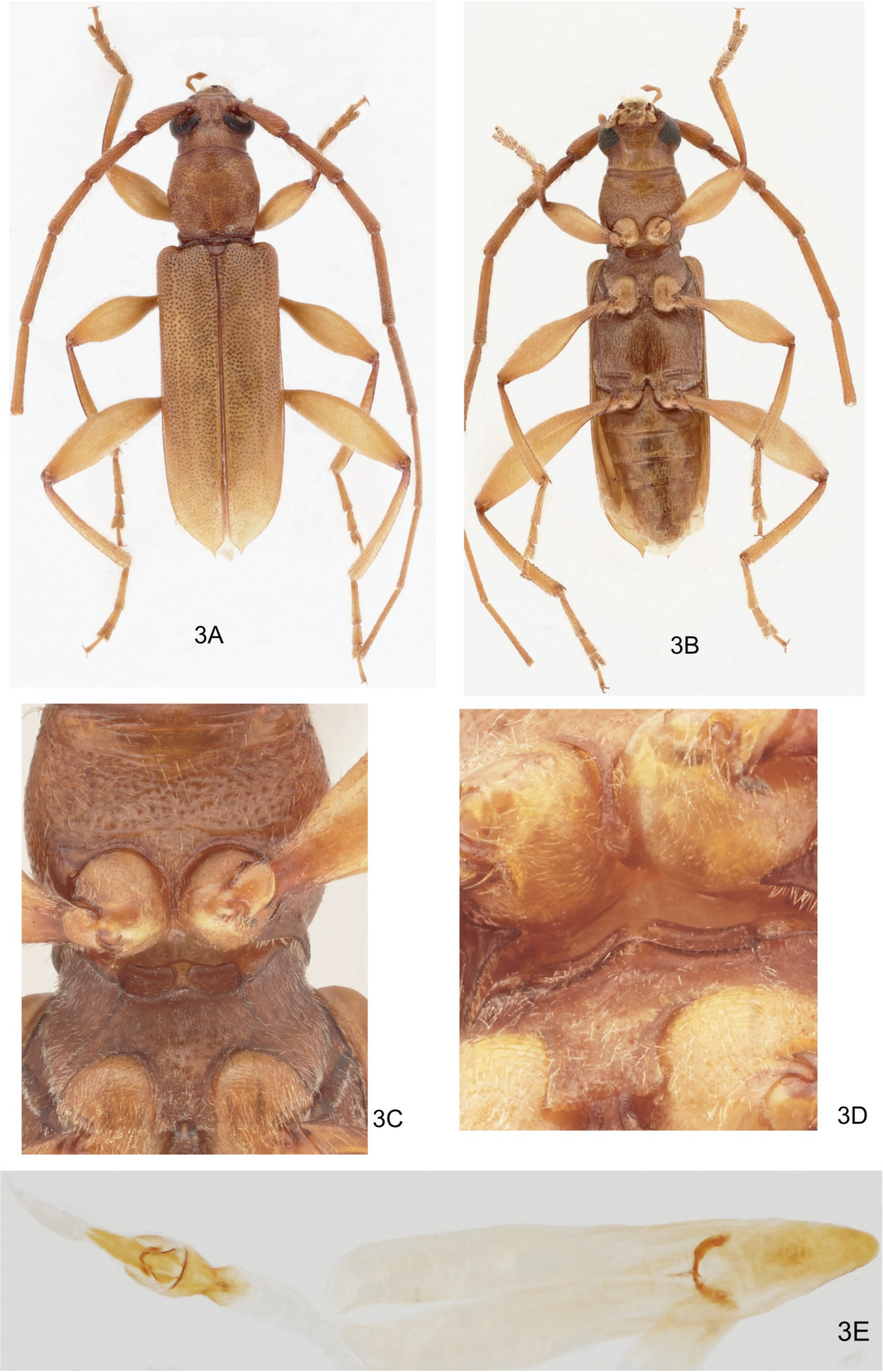
Venter. Prosternum transverse; sides rounded; the middle widely, horizontally impressed; setae sparse, fine, short, recumbent; apical 1/3 nitid, strigate; otherwise deeply punctate, partly rugose. Prosternal process well-bordered, narrow, constricted between the coxae; apex expanded, sub-truncated, impressed in the middle. Mesoventrite with sparse though large, deep punctures; setae short and sparse; moderately elevated toward the process. Mesoventral process sub-parallel-sided; apex moderately emarginated in the middle. Metaventrite transverse-sub-rectangular, convex, glossy, regularly provided with setiferous punctures each bearing a short recumbent hair.

Abdomen glossy, with sparse setiferous punctures; gradually narrowed toward apex; sternites 4-6 about half as long as the third; 7th about 2/3 as long.

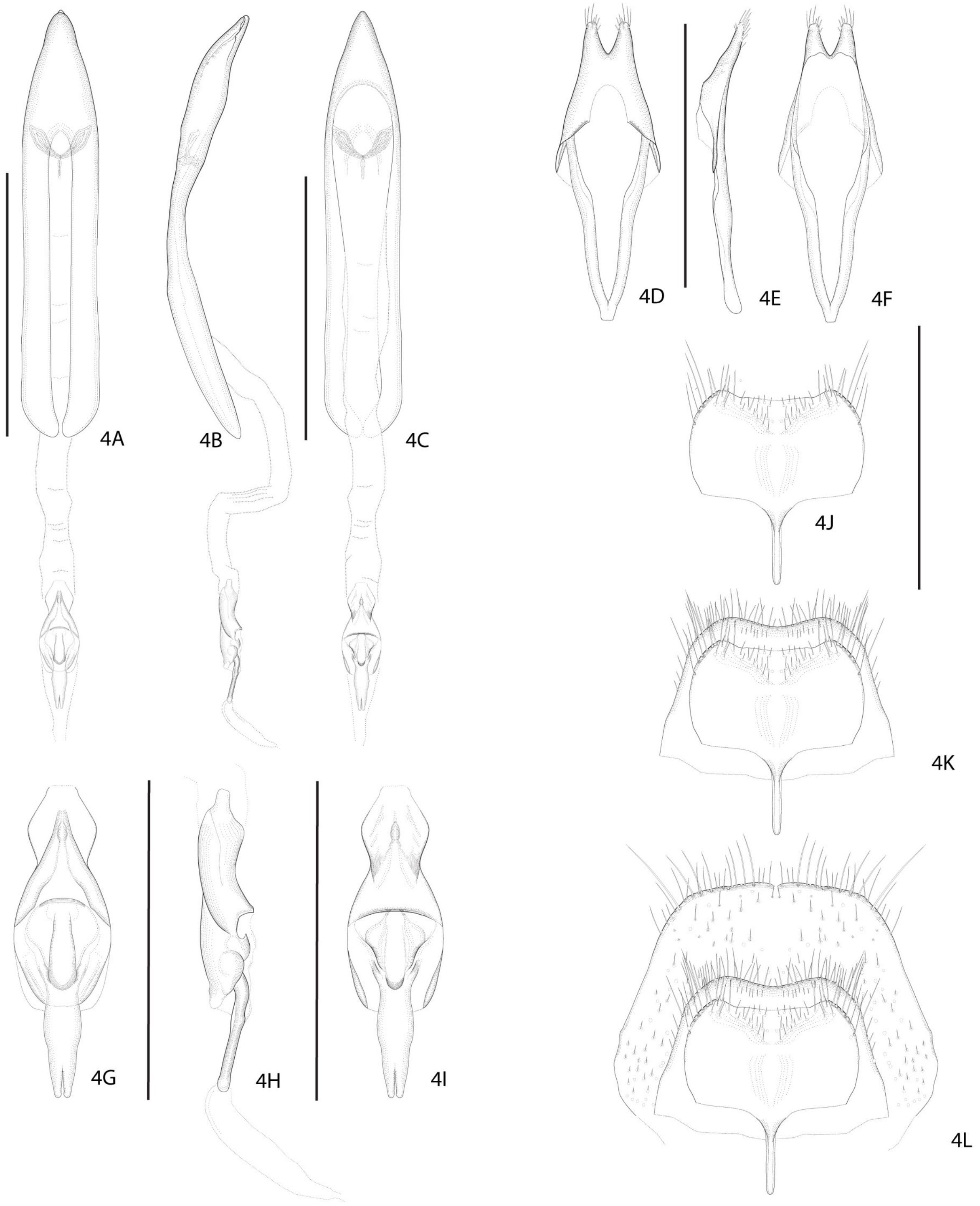
Male genitalia as Figs 3E; 4A-L. Median lobe about 2/5 the length of abdomen, bullet-shaped in dorsal view, narrow and weakly arcuate in lateral view; dorsal plate dehiscent in basal 7/10; ventral plate nearly as long, dehiscent in basal 4/5. Tegmen about 7/10 the length of median lobe, stout, feebly arcuate in lateral view. Parameres about half the length of tegmen, gradually tapering toward apex; apical 1/5 bi-lobed; each lobe with several stout apical setae. Ejaculatory duct complex as Figs 4G-I; about 3/10 as long as median lobe, stout, composed of three inter-connected sclerites; apical sclerite spatulate in dorsal view, thick; median sclerite stout, sub-toroidal in dorsal view, with a horn-shaped projection; basal sclerite elongated-spatulate, apically dehiscent. 8th sternite cotyledonary in outline; blade transverse, sub-emarginated on apex, a little thinned in the middle, fringed with several long apical setae, supplemented by shorter hairs in the apical middle; peduncle 3/4 as long as blade. 8th tergite sub-trapezoidal, broader than the sternite, moderately emarginated on apex; the latero-apical corners rounded; apical setae similar as those of the sternite. 7th tergite trapezoidal, much larger than 8th tergite; apex weakly arcuate.

Distribution. Aru, Northern Queensland, **Papua New Guinea** (**New Distribution**).

Comparative notes. Compared to the holotype from Aru, no obvious difference in morphology was observed. The genitalia, including the ejaculatory duct complex, are essentially analogous to those of *Tethionea peggieae* sp. nov. With the new record of this species from Papua New Guinea, its distribution has become continuous between Aru and Queensland.



Figures 3A-E. *Tethionea unicolor* Pascoe. Male from Papua New Guinea. 3A, habitus, dorsal view; 3B, ditto, ventral; 3C, prosternum and mesoventrite; 3D, prosternal and mesoventral processes, ventral view, angled; 3E, median lobe and endophallus with ejaculatory duct complex, ventral view.



Figures 4A-L. *Tethionea unicolor* Pascoe. Male from Papua New Guinea. Genitalia. 4A, median lobe with endophallus, dorsal view; 4B, ditto, lateral view; 4C, ditto, ventral; 4D, tegmen, dorsal view; 4E, ditto, lateral; 4F, ditto, ventral; 4G, endophallus, ejaculatory duct complex, dorsal view; 4H, ditto, lateral; 4I, ditto, ventral; 4J, 8th sternite, ventral view; 4K, ditto, with 8th tergite in the background; 4L, ditto, with 7th tergite in the background. Scale bar: 0.5mm for 4G-I; 1mm for the others.

Tethionea strumosa Pascoe,1869
(Figs 5A-C; 6A-K)

Tethionea strumosa Pascoe, 1869: 544. Type locality: Ceram, Amboyna.
Tethionea strumosa: Gemminger & Harold, 1872: 2838.
Tethionea strumosa: Macleay, 1886: 202.
Tethionea strumosa: Aurivillius, 1912: 126.
Tethionea strumosa: Gressitt, 1951: 18, 19.
Tethionea strumosa: Gressitt, 1959: 190, 121.

Material examined. ♂: **"INDONESIA**; Irian Jaya, Freeport Concession, Timika. 18-25. VIII. 1997, R. Ubaidillah, Peggie" **97026"**. "Lowland r. forest, Kuala Kencana Light Ind. Park, 4. 2621' S. 136.5259' W. 100 m. Malaise trap 2 (Site 5)". "575".

Additional description.
(Head, pronotum, elytra and legs as in the original description)

The terminal joint of maxillary palp as in the original description (Fig. 11A).

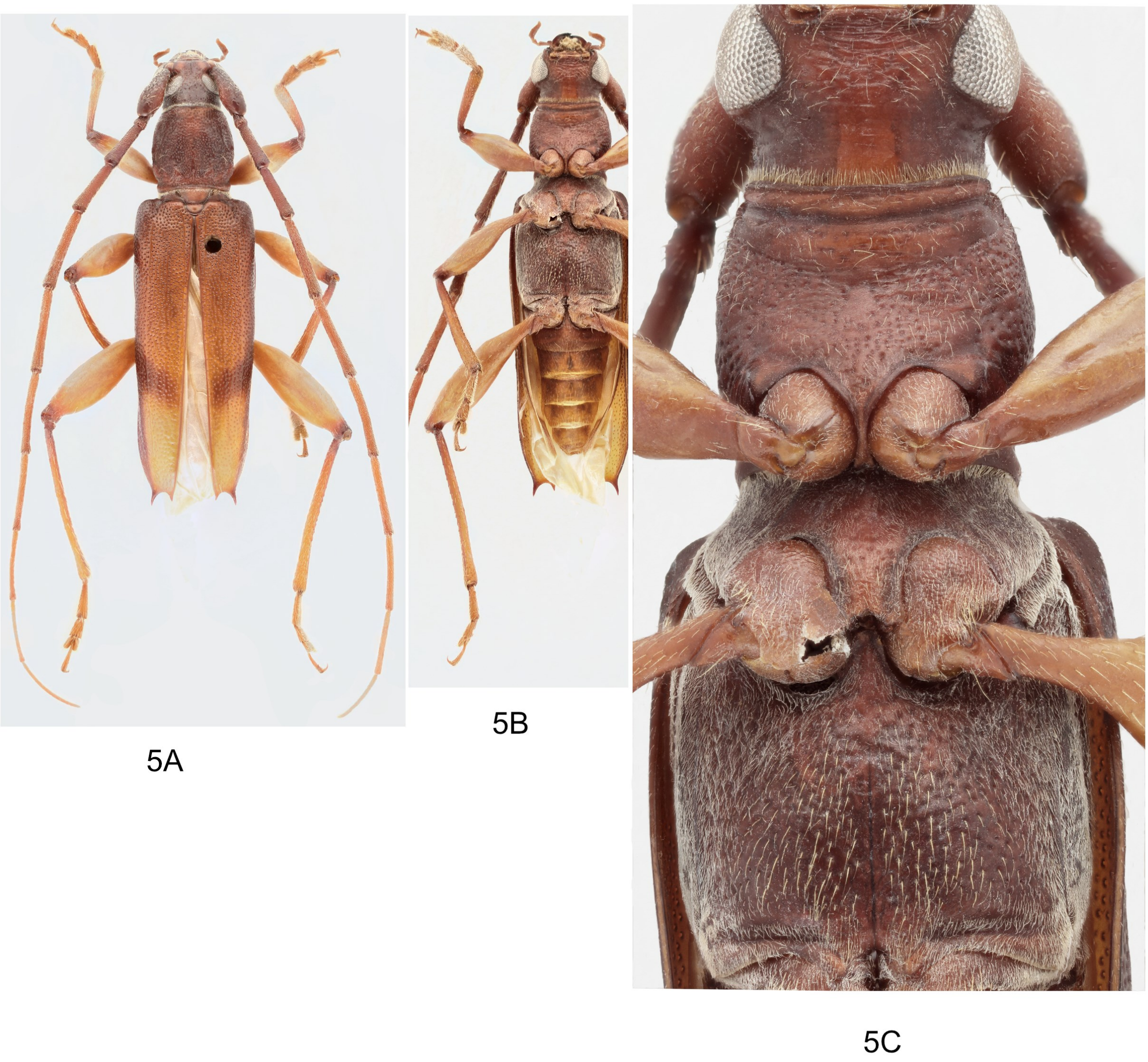
Venter. Prosternum transverse, widely impressed in the middle, concave in profile; surface irregularly punctate, partly rugose-strigate; with an arcuate horizontal furrow stretching from side to side at apical 1/3; setae sparse, short, fine, recumbent. Prosternal process similar as of *T. unicolor*, though less strongly constricted. Mesoventrite sparsely, shallowly punctured; setae finer than on prosternum; the middle moderately elevated toward the process. Mesoventral process broad; the apical part sub-parallel-sided, twice vertically impressed. Metaventrite transverse-sub-rectangular, rounded; with regular, setiferous punctures each bearing a short recumbent hair.

Abdomen glossy; sparsely provided with small, shallow, setiferous punctures; setae short and recumbent; sternites 4-7 gradually reducing in length and width.

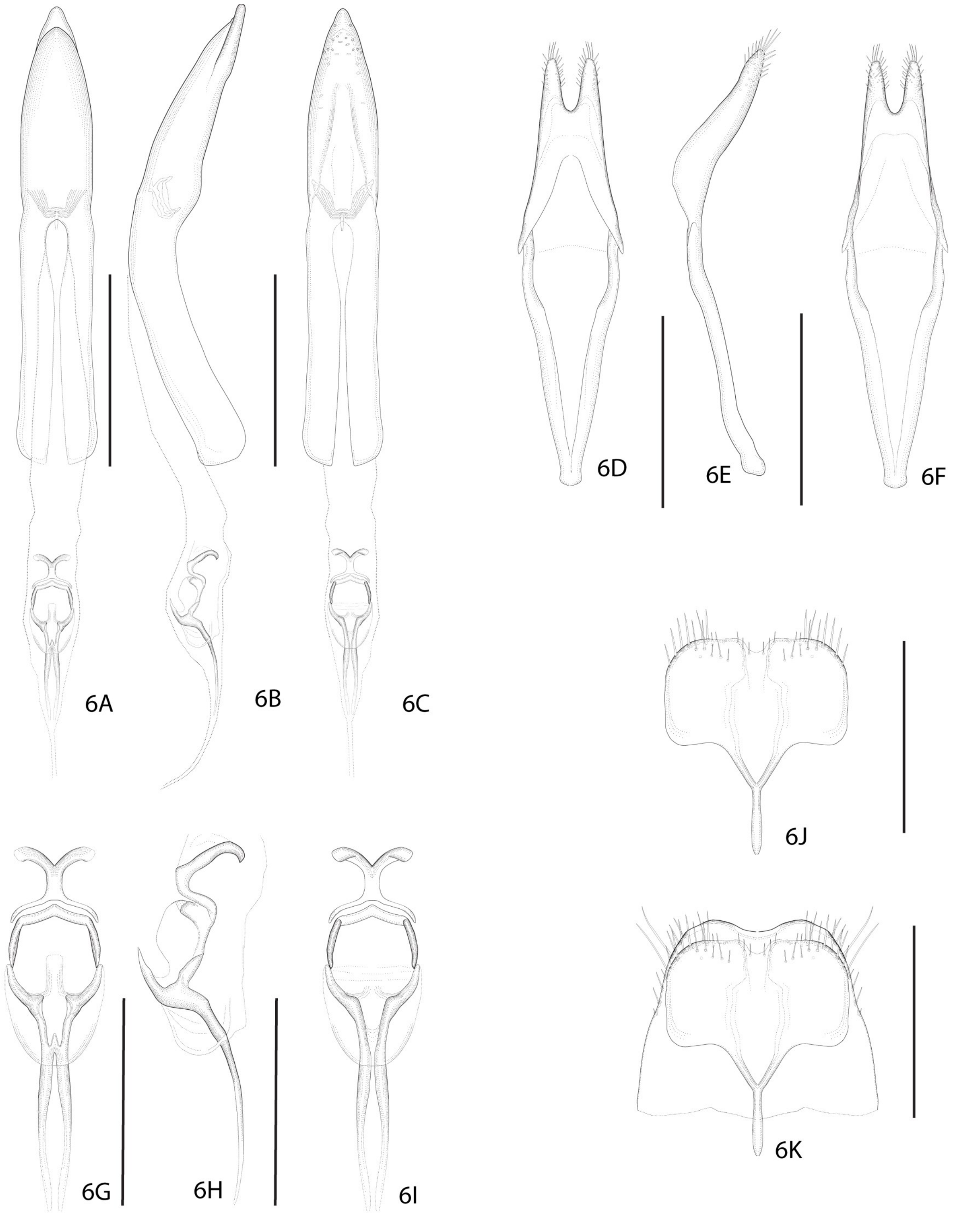
Male genitalia as Figs 6A-K. Median lobe more than 2/5 the length of abdomen, bullet-shaped in dorsal view, arcuate in lateral view; dorsal plate dehiscent in basal 11/20; ventral plate longer, dehiscent in basal 4/5. Tegmen about 9/10 the length of median lobe, rather narrow in dorsal view, weakly arcuate in lateral view. Parameres about 9/20 the length of tegmen, gradually tapering toward apex; apical 1/4 bi-lobed; each lobe with several stout apical setae. Ejaculatory duct complex as Figs 6G-I; more than 1/3 the length of median lobe; composed of four inter-connected sclerites; apical sclerite slender, sub-annular in dorsal view, attached by a sclerotized appendage, which is slender, sharply bent downward and apically bi-lobed; median sclerite bifurcated, with a prominent, horn-shaped dorsal projection; basal sclerite composed of a pair of narrow, elongated flagella. 8th sternite cotyledonary in outline; blade rounded at the corners, strongly thinned in the middle, fringed with several long apical setae, supplemented by shorter ones in the apical middle; peduncle about half the length of the blade. 8th tergite sub-trapezoidal with rounded corners, moderately emarginated on apex; apical half nearly as broad as the sternite; with several long setae along the apical margin.

Distribution. Seram, Ambon, Waigeo, Papua Province (Indonesia); Fly River, New Britain, Goodenough (Papua New Guinea).

Comparative notes. Compared to the holotype from Maluku, no obvious difference in morphology was observed. The genitalia of *T. strumosa* are essentially analogous to those of the above two species. The ejaculatory duct complex is, however, one of the most intricate and delicate among the examined species. 8th tergite of this species resembles that of the above described *Tethionea unicolor*.



Figures 5A-C. *Tethionea strumosa* Pascoe. Male from Papua New Guinea. 5A, habitus, dorsal view; 5B, ditto, ventral view; 5C, head and thorax, ventral view.



Figures 6A-K. *Tethionea strumosa* Pascoe. Male from Papua New Guinea. Genitalia. 6A, median lobe with endophallus, dorsal view; 6B, ditto, lateral view; 6C, ditto, ventral view; 6D, tegmen, dorsal view; 6E, ditto, lateral view; 6F, ditto, ventral view; 6G, endophallus, ejaculatory duct complex, dorsal view; 6H, ditto, lateral view; 6I, ditto, ventral view; 6J, 8th sternite, ventral view; 6K, ditto, with 8th tergite in the background. Scale bar: 0.5mm for 6G-I; 1mm for the others.

Tethionea tridentata Pascoe,1869

(Figs 7A-D; 8A-M)

Tethionea tridentata Pascoe,1869: 545. Type locality: Batchian.
Tethionea tridentata: Gemminger & Harold, 1872: 2838.
Tethionea tridentata: Aurivillius, 1912: 126.
Tethionea tridentata: Mckeown, 1947: 48.
Tethionea tridentata: Gressitt, 1951: 19.
Tethionea tridentata: Gressitt, 1959: 119, 121.
Tethionea tridentata: Vives, Aberlenc & Sudre, 2008: 140 ; fig. 2b.
Tethionea tridentata: Ślipiński & Escalona, 2016: 299.

Material examined. ♂: "Gogol River, Madan, PNG, 10-20.iii.1986, H. Makihara leg.

Additional description.

(Head, pronotum, elytra and legs as in the original description)

The terminal joint of maxillary palp as in the original description. (Fig. 11B).

Venter. Prosternum similar as of *T. unicolor*, though the middle more sparsely punctate-rugose; prosternal process similar. Mesoventrite with the process also similar. Metaventrite transverse, feebly dilated toward apex, well convex, glossy, regularly punctate; punctures setiferous near middle; setae short and recumbent.

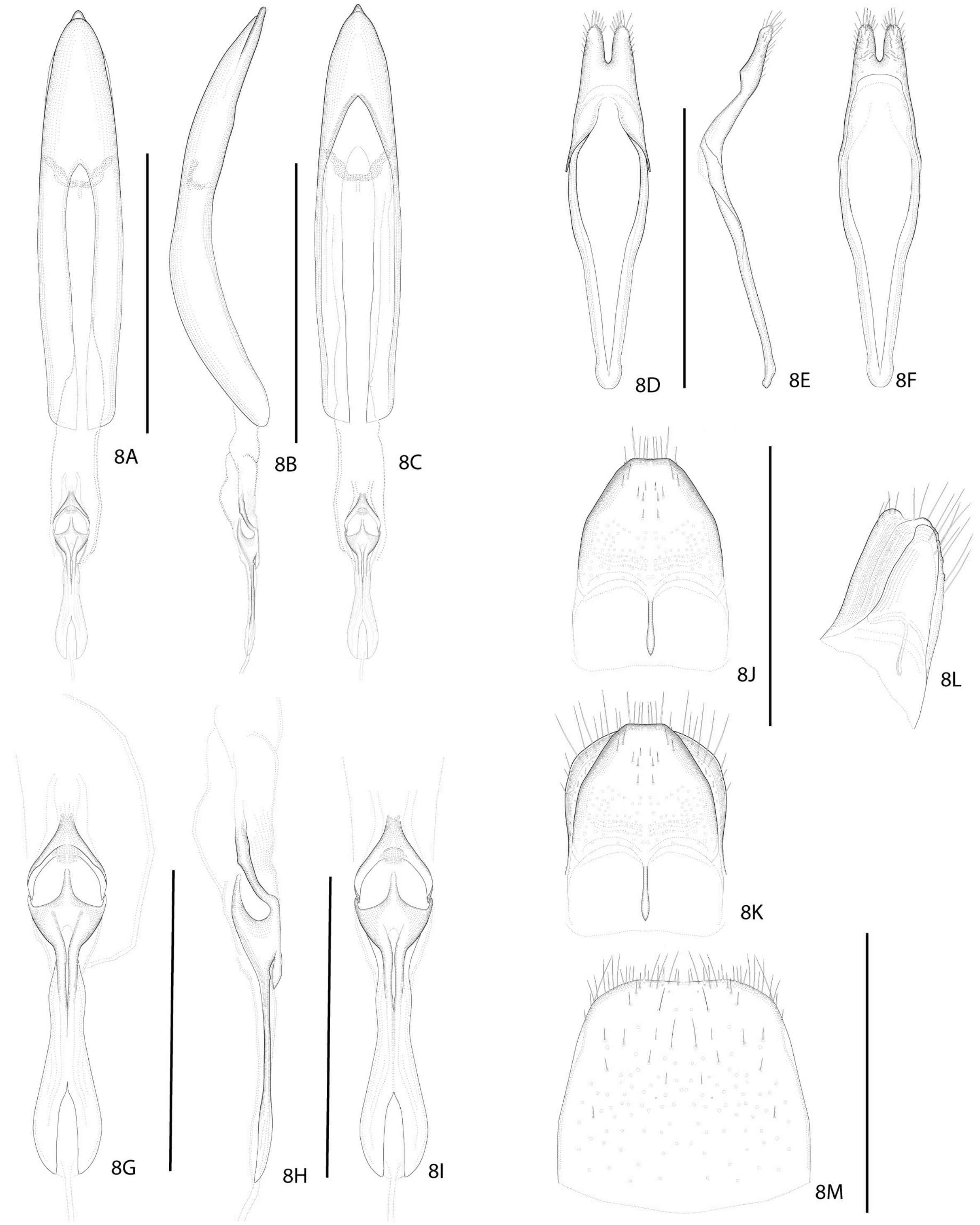
Abdomen glossy; with sparse, small, shallow, setiferous punctures; several setae thereof curved, longer than the others. Sternites 4-7 gradually reducing in length and width.

Male genitalia as Figs 7D; 8A-M. Median lobe nearly 9/20 the length of abdomen, bullet-shaped in dorsal view, arcuate in lateral view; dorsal plate dehiscent in basal 2/3; ventral plate longer, dehiscent in basal 7/9. Tegmen about 8/9 the length of median lobe, rather narrow in dorsal view, arcuate in ventral view. Parameres about 2/5 the length of tegmen, gradually tapering toward apex; apical 1/4 bi-lobed; each lobe with several stout apical setae. Ejaculatory duct complex as Figs 7D; 8G-I; more than 1/3 the length of median lobe; composed of three inter-connected sclerites; apical sclerite in dorsal view spatulate-sub-triangular with base emarginated, arcuate in lateral view; median sclerite stout, with a horn-shaped projection; basal sclerite elongated-spatulate, apically expanded and deeply dehiscent. Blade of 8th sternite hexagonal; apical half trapezoidal; basal half parallel-sided; base thinned; apex fringed with several stout setae; supplemented by several short ones near the middle; peduncle about half the length of blade. 8th tergite sub-circular, as broad as the sternite at base, connected to the sternite with a thick membranous structure (Fig. 8L). 7th tergite trapezoidal, much larger than the 8th tergite, fringed with a line of apical hairs.

Distribution. Bacan, Waigeo, Yapen (Indonesia); Madang, New Britain (Papua New Guinea); Malaita, Vanikoro (Solomon Is.); Queensland (Australia).

Comparative notes. Compared to the holotype from Maluku, no obvious difference in morphology was observed. The genitalia of the new species resemble those of the above observed species. However, its 8th sternite is remarkable. In particular, the blade is projected forward to form an unusual trapezoidal outline. The peduncle is exceptionally short in comparison to the blade. This type of 8th sternite has been so far observed neither in the genus nor in the related genera.

Figures 7A-D. *Tethionea tridentata* Pascoe. Male from Papua New Guinea. 7A, habitus, dorsal view; 7B, ditto, ventral view; 7C, thorax, ventral view; 7D, median lobe and endophallus with ejaculatory duct complex, lateral view.



Figures 8A-M. *Tethionea tridentata* Pascoe. Male from Papua New Guinea. Genitalia. 8A, median lobe with endophallus, dorsal view; 8B, ditto, lateral; 8C, ditto, ventral; 8D, tegmen, dorsal view; 8E, ditto lateral view; 8F, ditto, ventral; 8G, endophallus, ejaculatory duct complex, dorsal view; 8H, ditto, lateral; 8I, ditto, ventral; 8J, 8th sternite, ventral view; 8K, ditto, with 8th tergite in the background; 8L, ditto, latero-dorsal view, angled; 8M, 7th tergite, dorsal view. Scale bar: 0.5mm for 8G-I; 1mm for the others.

Tethionea oculata sp. nov.

(Figs 9A-E; 10A-H)

Material examined. Holotype ♀: **“INDONESIA**, Irian Jaya, Freeport Concession Timika, 12-19. IX. 1997, R. Ubaidillah, Peggie **97032”**; “Lowland r. forest, Kuala Kencana Light Ind. Park, 4. 2621’ S. 136.5259’ W. 100 m. Malaise trap 2 (Site 5)”; “336”. Paratype ♀: “Pandans peat swamp, East levee of Minajerwi River, 4. 4099’S. 136.5854’W. 15 m. Malaise trap-1 (Site 4)”; “7702”.

Diagnosis. Testaceous; glossy. Eyes large; much more approximate to each other than usual. Pronotum elongated, regularly punctate. Prosternal process strongly constricted and terminated between pro-coxae. Elytral apices each terminated with an acuminate spine; the sutural side sub-linear.

Etymology. The name of this new species refers to its large eyes.

Description.

Measurements. Ble=10.0-8.2mm. EL/EW=3.0-2.85. HW/PW=1.0. PL/PW=1.12. PA/PW=0.72-0.7. PB/PW=0.8. (First figure for the holotype, when two figures given).

Color testaceus; antennae and legs a little paler; setae yellowish.

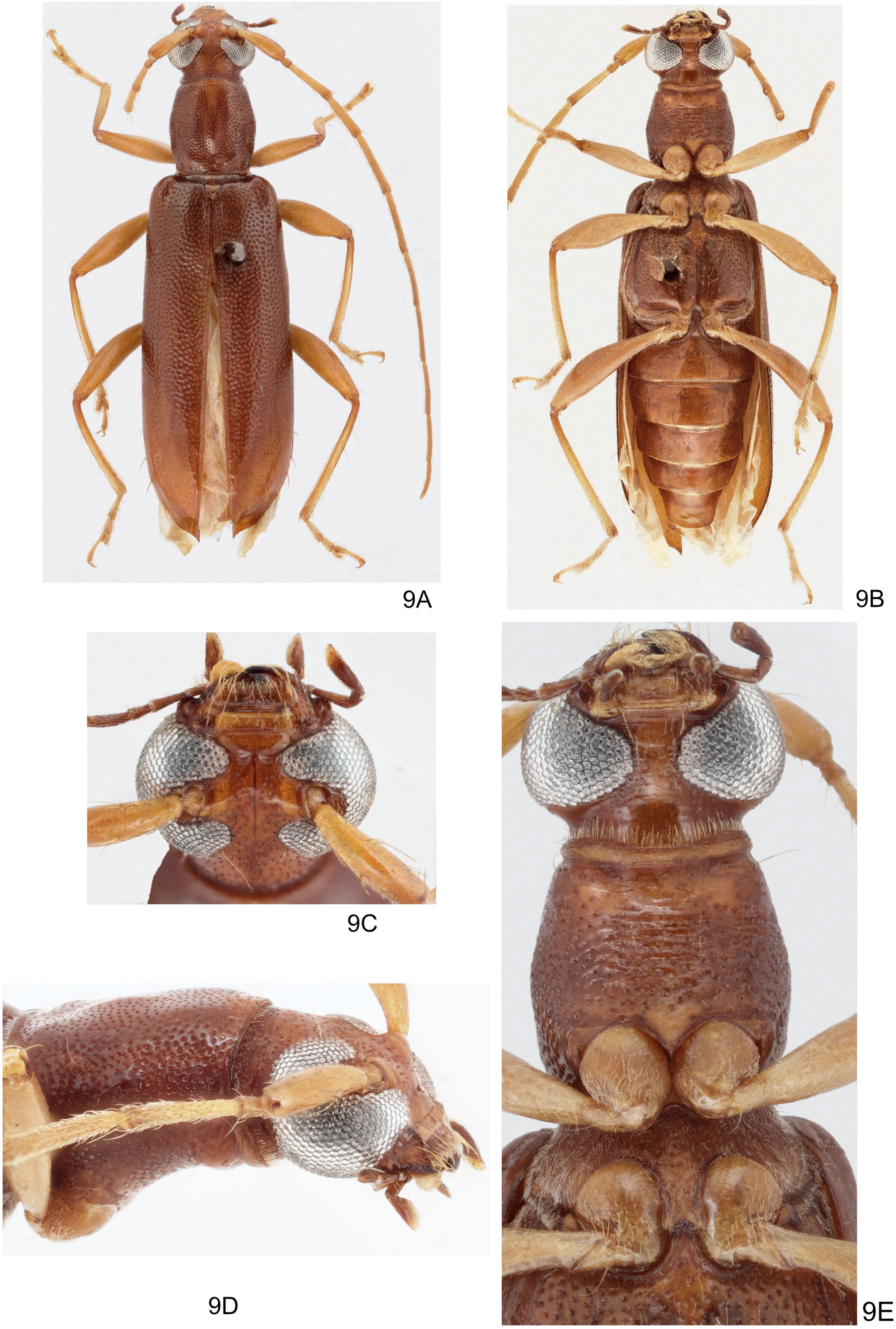
Head as Figs 9C-E. Glossy, glabrous. Occiput, vertex and upper half of frons regularly, deeply, though sparsely punctured. Frons deeply emarginated on sides by lower eye-lobes; with a median groove. The terminal joint of maxillary palp spatulate, with the external side moderately truncated and opened. Vertex broad, widely flattened, feebly concave in the middle. Eyes large; upper eye-lobes separated from each other by 3/2 the width of apical lobe or less than 3/10 the width of occiput. Antennal supports flattened. Antennae nearly reaching the elytral apices. Scapes weakly clavate and arcuate; each with a few large setiferous punctures. Antennomeres 3, 4, 5, 6 each 19/20, 9/10, 12/10, 11/10 as long as scape; 7-11 a little shorter.

Pronotum longer than broad, almost hairless, glossy, regularly and densely punctured; apex and base moderately constricted. Sides evenly arcuate; surface uneven with a few irregular protuberances. Disc with a nitid median stripe half the length of pronotum. Scutellum bell-shaped, strongly bordered.

Elytra moderately long; sides sub-parallel-sided in basal 4/5; apices each terminated with an acuminous spine; the sutural side of the spine sub-linear or feebly emarginated. Each elytron regularly, densely punctured; with several erect, stout hairs toward apex.

Legs rather long and slender. Femora moderately clavate from base on; a little flattened.

Venter. Prosternum glossy; concave in profile, horizontally impressed in the middle; deeply, coarsely punctate-rugose there, with several fine hairs. Prosternal process apically



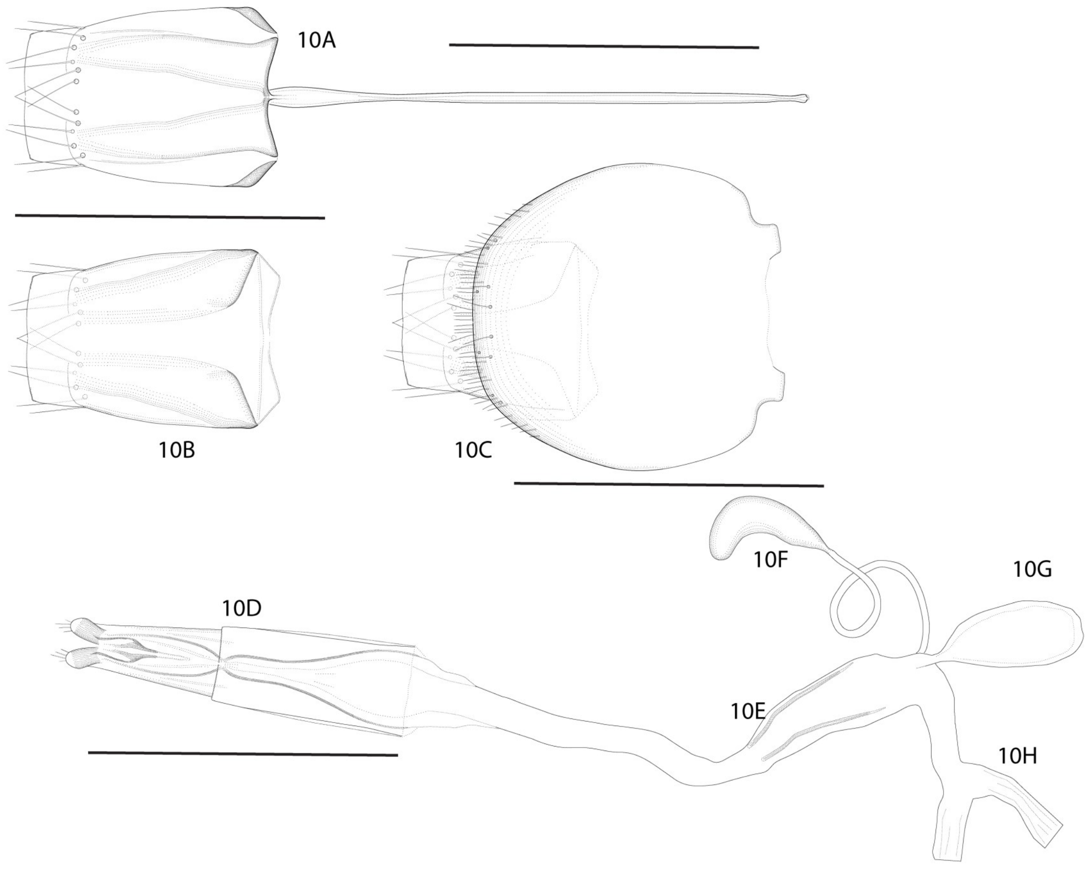
Figures 9A-E. *Tethionea oculata* sp. nov. Holotype female. 9A, habitus, dorsal view; 9B, ditto, ventral view; 9C, head; 9D, head and pronotum, lateral view; 9E, head and thorax, ventral view.

reduced, acutely terminated between procoxae. Mesoventrite similar to that of *T. strumosa*. Mesoventral process also similar, though a little narrower. Metaventrite transverse-sub-rectangular, well rounded; glossy, with large, regular though sparse punctures, which are more or less setiferous in the middle.

Abdomen glossy; with sparse setiferous punctures; sternites 4-6 gradually reducing in length and width. 7th sternite sub-trapezoidal, distinctly longer than the 6th. 7th tergite sub-circular, fringed with short apical setae (Fig. 10C).

Female genitalia as Figs 10A-H. Blade of 8th sternite sub-trapezoidal, longer than broad; apical part prolonged with a membranous structure; clothed with several medium-sized stout hairs on an arcuate horizontal line at apical 1/5; peduncle about 5/2 as long as blade. 8th tergite with latero-basal corners produced and moderately acute. 9th sternite rather short; coxite a little shorter than paraproct; styli stout, each with several short hairs. Vaginal plates elongated, arcuate-flagellar. Bursa copulatrix oval. Spermatheca kidney-shaped, connected to apical vagina with a long duct.

Distribution. Papua Province (Indonesia).



Figures 10A-H. *Tethionea oculata* sp. nov. Holotype female. Genitalia.10A, 8th sternite, ventral view; 10B, 8th tergite, ventral view; 10C, 7th tergite with 8th tergite in the background, dorsal view; 10D, 9th sternite; 10E, vaginal plates; 10F, spermatheca; 10G, bursa copulatrix; 10H, median oviduct. Scale bar: 1mm.

Comparative notes. *Tethionea oculata* sp. nov. can be distinguished by its large eyes, which are much more approximate to each other than usual. In addition, its prosternal process is terminated instead of expanded toward apex. In other respects, it is most comparable to *Tethionea waigeona* Gressitt, 1955, and *Tethionea tenuimembris* Gressitt, 1951.

DISCUSSION

Male genitalia of *Tethionea* species. Endophalli of altogether four species, *T. peggieae* sp. nov., *T. unicolor*, *T. strumosa* and *T. tridentata* were investigated for this publication. In each of these species, the characteristic apical sclerotization, referred to as "ejaculatory duct complex", was identified. *Tethionea* is thus the fifth genus of the tribe observed with this type of endophallus, after *Ceresium*, *Examnes*, *Stenodryas* and *Oxymagis* (Yokoi, 2019; 2021a; 2021b; 2022 in press; Yokoi et al., 2019). The ejaculatory duct complexes of the examined *Tethionea* species are relatively large, 3/10 to 1/2 as long as median lobe, whereas their structures are among the most intricate of the examined genera. Regarding the other genital organs, no essential difference from the above four genera was observed.

The 8th sternites of the examined male species are mostly broad and stout. In three species, *T. peggieae* sp. nov., *T. strumosa* and *T. tridentata*, they are as broad as or nearly as broad as the 8th tergite. 8th sternite of *T. tridentata* differs markedly from these species. The elongated hexagonal outline with extremely short peduncle is unusual even as a species of the Callidiopini.

Maxillary palpi. In the original descriptions of *T. strumosa* and *T. tridentata*, both male, Pascoe observed that the terminal joints of their maxillary palpi are "rather singular", "the truncate slope commencing nearly from base, so that the greater part of the joints appear to be removed" (Pascoe, 1869). This observation is now confirmed for these two species, as described and illustrated above (Figs 11A–B). In this regard, it should be noted that a third species, *Tethionea unicolor*, is also distinct, though in a different way; the terminal joints of its maxillary palpi are truncated on both sides (Figs 11C–E). *Tethionea peggieae* sp. nov. is also distinct. The terminal joints of its palpi are simply and moderately truncated (Fig. 11F), but this type of maxillary palp is rather commonly observed in various genera of the tribe. The type of maxillary palpi observed by Pascoe is not shared by all the members of *Tethionea*. His hypothesis that "it is very probably characteristic of the genus" is not confirmed.

Later, Gressitt (1955) presented a comprehensive illustration of maxillary palpi, and described, in particular, those of *Tethionea bidentata* Gressitt, *Tethionea bicolo*r Gressitt and *Tethionea waigeona* Gressitt, all male, concluding that the genus is characterized, among others, by "last maxillary palpal segment with one or two cavities". This statement is essentially valid for the hitherto examined species, so long as furrows, openings and truncated sections are interpreted as various forms of cavities.

Regarding the female apical palp, Pascoe noted that it is "cylindrical or only slightly triangular". *Tethionea oculata* sp. nov. does not correspond to this observation, as the joint is obviously truncated, though only moderately (Fig. 11G).

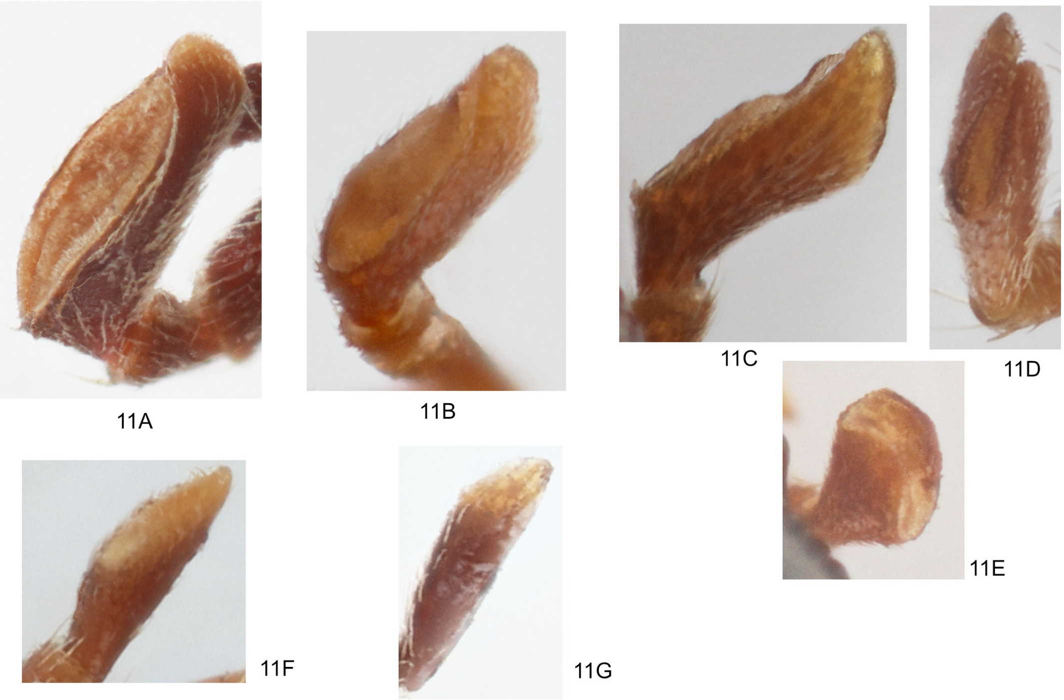
Prosternal processes. The structure of prosternal processes is variable among the five examined species of *Tethionea*. The process is obviously expanded toward apex in *T. unicolor*, *T. tridentata* and *T. strumosa,* while moderately so in *T. peggieae* sp. nov. In contrast, it is terminated between the procoxae in *T. oculata.* This observation does not correspond to the description by Ślipiński and Escalona (2016). Additional species should be observed for a valid general statement.

Tethionea oculata sp. nov. In a few respects, this species is singular among the examined *Tethionea* species. Its eyes are exceptionally large. Their upper lobes are more approximate to each other than usual. The same is valid for the lower eye-lobes. Further, its prosternal process is terminated between pro-coxae, in contrast to those of the other species. The male genitalia of this species should be investigated.

Prospect. Besides the above *T. oculata* sp. nov., several other *Tethionea* species are atypical.

T. pubescens Gressitt, *T. squamata* Gressitt, *T. subcallosa* Gressitt, all three from New Guinea, each with unusual integument, are such examples. *T. brevicollis* Gressitt from New Guinea and *Tethionea minima* Vives from the Philippines differ in the structure of head and pronotum. Further, antennae and legs of *Tehionea bicincta* Fauvel from New Caledonia are distinct. These species should be examined as to their positions in the genus. Moreover, some species of other genera resemble *Tethionea* species in a way or another, particularly of *Semiope* Pascoe,1869, from New Guinea and of *Notoceresium* Blackburn, 1901, from Australia and New Guinea. Of the widely distributed *Ceresium*, its subgenus *Ceresium (Ceresiellum*) Gressitt, 1956, from Micronesia and Fiji, should be examined regarding its affinity to *Tethionea.*

Male genitalia of these species, essential keys for their taxonomy, should be carefully examined. Regrettably, many pivotal species are still not available to the authors. Contributions by colleagues are welcome.



Figures 11A-G. *Tethionea* species. Terminal joint of maxillary palp. 11A, *T. strumosa* (male); 11B, *T. tridentata* (male); 11C, *T. unicolor* (male); 11D, ditto, external side; 11E, ditto, apical view; 11F. *T. peggieae* sp. nov. (male); 11G, *T. oculata* sp. nov. (female).

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FIRST REPORT ON THE FEEDING BEHAVIOR OF EARLESS MONITOR, *LANTHANOTUS BORNEENSIS* AND ITS PREDATION ON RICE FIELD FROG, *FEJERVARYA LIMNOCHARIS* IN A CAPTIVE ENVIRONMENT

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ABSTRACT

Being endemic to Borneo, the Earless monitor, *Lanthanotus borneensis* (Steindachner, 1878) is rarely found in its habitats due to its cryptic behavior. We provide care for confiscated animals in the Reptile House of Museum Zoologicum Bogoriense (MZB) in Cibinong, West Java, Indonesia since 2014. Little is known on its natural prey but from scattered descriptive reports. This study is aimed at documenting the feeding behavior of ten captive Earless monitors and events of predation on frogs. We set up two experiments, one with meat of Rice Field Frog, *Fejervarya limnocharis*, and the other with live frog of the same species. Our recorded observations ran for four weeks for the frog meat feeding experiment and followed by the frog predation experiment. Our results showed that lizards constantly accepted frog meat. Lizards tended to feed before sunset for a short period of time on the muddy soil surface, although a few individuals inconsistently fed under water. The average body mass for these lizards increased by 4.29 g and average SVL by 0.45 cm. We recorded predation on frogs in three out of ten individuals observed during this study. If *F. limnocharis* is confirmed to occur in the natural habitats of *L. borneensis*, it is possible that this frog species is among the natural prey for Earless monitors. Further studies on its natural diets should be conducted to gain in-depth knowledge essential for generating effective captive husbandry for this nationally protected species in Indonesia.

Key words: crepuscular, frog meat, prey, reptile house, survival

INTRODUCTION

Lanthanotus borneensis (Steindachner, 1878) is an endemic lizard to Borneo and rarely found in its habitat due to its cryptic behavior. Little is known about its natural history since its description in the 19th century. The lizard became one of the favorites among reptile hobbyists and breeders because of its rarity and unique appearance. The first record of this rare lizard in West Kalimantan, Indonesia was only in the 21st century (Yaap et al., 2012). Following publication on new record of this enigmatic species in 2012, *L. borneensis* was subjected to illegal international trades. Since then, several attempts have been made to smuggle individual lizards from Kalimantan, Indonesia to destination countries in Europe. Confiscated animals from these illegal trades were sent to the Reptile House of Museum Zoologicum Bogoriense (MZB) in Cibinong, West Java, Indonesia and we have been providing care for these lizards and monitoring their behavioral conditions.

We casually feed these animals with various food items since their arrival in our facility in 2014 based on records from previous observations (Harrisson, 1961; Mertens, 1970;

Sprackland, 1999; Mendyk, 2015; Langner, 2017). Among all the items given to the lizards, there were those not taken, including flesh of squids, one-day old mice, live freshwater fish, as well as tadpoles and froglets of Four-lined Tree Frog, *Polypedates leucomystax*. Interestingly, some of these lizards took the meat of Rice Field Frog, *Fejervarya limnocharis* despite being in a small amount. In December 2019, we re-tried to feed the lizards with meat of this frog species and were surprised to find that all frog meat provided in the tanks disappeared in the next morning (Arida, unpublished data).

This study is the first report of a larger continuing observation on the behavior of *L. borneensis* aimed at supporting the species survival in captive environment. We intend to obtain baseline data on feeding behavior and choice of food items for this protected species in Indonesia. For this reason, we have set a long-term and ongoing series of observations since 2015 to document data for further use in scientific research as well as in the initiation of *ex-situ* conservation programs.

MATERIALS AND METHODS

Animals and Management

We conducted our observation at the Reptile House of Museum Zoologicum Bogoriense (MZB) of Indonesian Institute of Sciences (LIPI) at Cibinong Campus in West Java, Indonesia. Prior to our study, lizards have been maintained at the facility as a result of a series of confiscations in a Jakarta airport since 2014. Since then, we provided care continuously for these lizards and observed their feeding behavior regularly, although in casual manner. Several food items had been given to these lizards one at a time to see their choices for five years before this study. Those include pieces of flesh of fish, prawn, squid, crabs, snails, chicken, and frogs. Occasionally, we provided live animals such as earthworms, tadpoles, froglets, crickets, and one-day-old mice for lizards to prey on. Among the items taken was meat of the Rice Field frog, *Fejervarya limnocharis*. In this study, we extended our previous observation on the lizards' choice for this food item to a verification of this preference. Further, we set an experiment of predation on *F. limnocharis*, with aim to find evidence of intake or non-intake of the frog species as a live prey by these captive lizards.

Body Measurement

All ten Earless monitors in this study were originated from the wild and obtained through confiscation events in 2014, 2016, and 2018. Individual lizards seem to be at different level of maturity but most may have reached adult size in 2020, given their snout-vent length (SVL) and body mass (BM) presented in Table 1. Some of them were difficult to sex; therefore, we set the experiment regardless of sex and maturity level of these lizards.

Table 1. Body measurements of individual *Lanthanotus borneensis* in this study

individual tag	Snout-Vent Length (cm)	Tail Length (cm)	Body Mass (g)
A	18.50	19.50	74.27
B	18.00	20.00	79.13
C	17.00	17.50	57.31
D	18.30	20.20	84.20
E	19.00	22.00	92.47
F	16.00	17.50	40.12
G	17.00	18.50	71.57
H	16.80	19.20	46.95
I	16.50	19.00	54.39
J	17.50	18.00	80.72

Feeding Experiment: Frog Meat

Between January and February 2020, we continued providing meat of *Fejervarya limnocharis* (Fig. 1) for four weeks and recorded our observations using focal animal sampling method. The frog meat was in the form of frozen “frog legs” aimed for exports as food for humans. Each lizard individually kept in a tank was provided with 5 grams of meat of *F. limnocharis* in small chunks once every week to monitor their behavior during three observation phases, i.e. early evening, late night, and early morning. For this purpose, we specifically used a Closed-Circuit Television (CCTV) camera for two hours to monitor each individual lizard placed in a tank measuring 58.0 cm x 58.0 cm x 98.0 cm. Each tank was set with two types of habitat, i.e. a terrestrial area with muddy soil and an aquatic area with tap water of 12-14 cm depth (Fig. 2). A camera was set over each tank and manually switched on and off for data collection. We started recording about one hour before the middle of each phase of observation, i.e. dusk (18:00), midnight (00:00), and dawn (06:00). We continued filming for another hour afterwards; therefore, film duration for each observation phase was approximately two hours. During the course of experiment in January and February 2020, sunset occurred approximately at 18:15 of Jakarta time (https://www.bmkg.go.id/tanda-waktu/terbit-terbenam-matahari.bmkg), which we used as a time-point to determine the two observation sub-phases in the early evening.

The total number of recorded observations was 24 for each lizard, which is calculated as: 3 observation phases x 2 sub-phases (before and after dusk, midnight, or dawn) x 4 weeks. Data on feeding status were tabulated after watching the playbacks, as well as duration of feeding.

Figure 1. **a.** A Rice Field Frog, *Fejervarya limnocharis* and **b.** Pieces of frog meat weighed to the nearest of 5 grams.

There were ten individual lizards being monitored each week for their intake of frog meat. Each lizard was tagged with a labelled elastic cable-tie adjusted to loosely fit around the hind limbs insertion (Fig. 3), in order to identify individuals. Labelling for each individual lizard was done by alphabet “A” to “J” marked on the cable-ties.

Predation Experiment: Live Frog

Six weeks after the end of our feeding experiment, lizards were given one live frog, *F. limnocharis* (Fig. 1b.) in two weekly trial experiments. Nevertheless, we continued providing food items for the lizards at regular schedule and frequency during the interval between the two experiments. We placed each of all ten lizards into a smaller plastic container measuring 31.0 cm x 21.0 cm x 19.5 cm with a firm ventilated lid. A lizard and a live frog were placed in the container filled with shallow water for 20’ before sunset. Following the sunset, we waited in silence in the absence of light for signs of predation such as a squeaking sound of a bitten frog. Predation events were recorded using a camera function of a smartphone. We tabulated data from the playbacks to describe the steps of predation. Additionally, we recorded environmental conditions, i.e. air temperature, humidity of the soil surface, and potential Hydrogen (pH) in water.

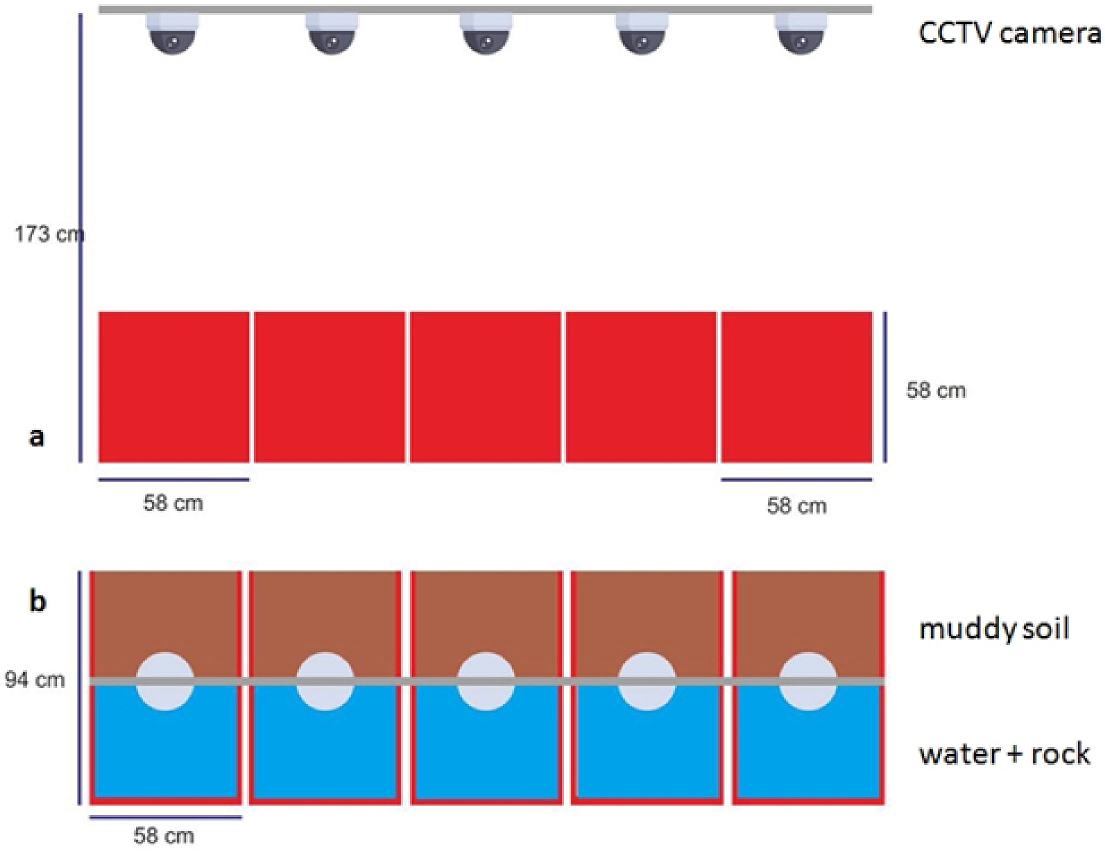

Figure 2. **a.** A front view and **b.** an above view of CCTV cameras positioning relative to the observation tanks. Each tank has a semi-natural terrestrial habitat and an aquatic habitat.

Figure 3. An individual *Lanthanotus borneensis* (“I”) was tagged with a cable-tie around the insertion of hind limbs.

RESULTS

Body Measurements

At the beginning of feeding experiment, mean SVL for all ten lizards was 17.45 cm ± 0.95 and mean body mass was 68.11 g ± 17.38 (Fig. 4). Mean SVL of them was 17.90 cm ± 1.19 and mean body mass was 72.40 g ± 17.40 at the end of this experiment. Air temperature and humidity were stable at 26°C-29°C and 77%-95%, respectively. Water in all containers in this experiment was constantly with pH of 6.

Feeding Behavior

Lizards generally accepted frog meat consistently during the four-week observation. Regardless of body size and sex, most individuals were recorded to consume frog meat in the early evening, i.e. between 17:15 and 19:15 except individual "J". This individual was not observed feeding during the camera recording; however we found evidence that this lizard consumed frog meat during the interval between filming periods. No lizard was observed on camera feeding late at night and in the early morning hours. More specifically, lizards more frequently fed before sunset than after, with 14 *versus* 9 observations, respectively, on camera during the period of one month (Table 2). Each lizard tended to feed less frequently than expected, with the maximum feeding event of five for lizard "B" (Table 2) during the one-month experiment (5 of 24 or about 20.8 %).

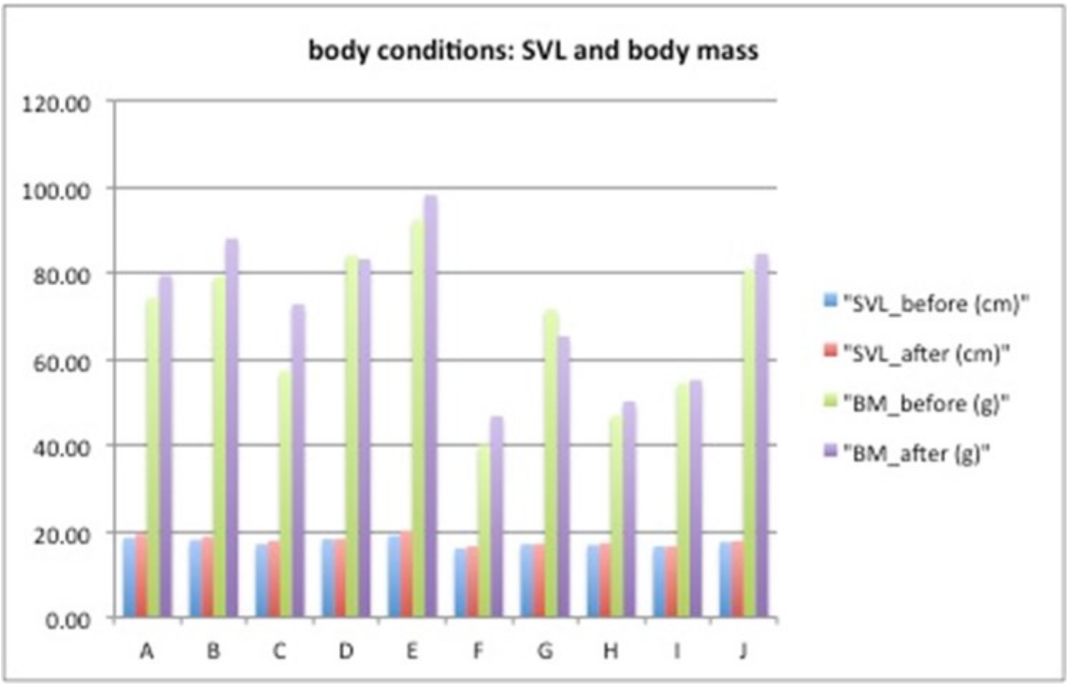

Figure 4. Body measurements of ten individual *Lanthanotus borneensis* before and after feeding experiment.

We noted various frequencies of observed feeding for each lizard, i.e. 1-5 times during the experiment period. Three individuals, i.e. “A”, “B”, and “D” were the most frequently observed feeding, i.e. 3-5 times, whereas the other six lizards were observed to feed less frequently, i.e. 1-2 times during the period of experiment (Table 2). More specifically, lizards “C” and “H” were observed feeding only in Week 3 and Week 1, respectively (Table 3).

Eight lizards were observed feeding in Week 3 with a total of nine observations (Table 3). Among all four weeks of observation, lizard “B” was consistently found feeding and lizards “C” and “H” were found feeding only in one out of the four weeks. Frequencies of observed feeding were increasing over the first three weeks of experiment, with Week 3 as the peak, when most lizards, i.e. eight individuals were observed feeding.

Except for lizards “C” and “F”, all the other six lizards observed in Week 3 (Table 3) were feeding only before sunset, i.e. 6 out of total 14 observations for feeding before sunset (Table 2). Lizard “C” was feeding only in Week 3 (Table 3) but observed twice, i.e. before and after sunset (Table 2). Lizard “F” was observed to be feeding only after sunset (Table 2) in Week 3 and Week 4 (Table 3).

Table 2. Frequency distribution of feeding events across three observation phases for each lizard during four observation weeks

individual tag	total frequency	early evening		late night	early morning
		before sunset	after sunset		
A	4	2	2	0	0
B	5	4	1	0	0
C	2	1	1	0	0
D	3	2	1	0	0
E	2	2	0	0	0
F	2	0	2	0	0
G	2	2	0	0	0
H	1	0	1	0	0
I	2	1	1	0	0
J	0	0	0	0	0
grand total	**23**	**14**	**9**	**0**	**0**

Lizards generally started to feed as early as 17:27 and as late as 18:57. Figure 5 shows container setting and condition after sunset, when lizards were feeding on camera. Lizards tended to feed on spot, where frog was contained in a small plastic tray placed on the muddy soil surface. However, this behavior was inconsistent among individuals and even within an individual. Some lizards brought one piece or more of the frog meat into the aquatic part of the container for consumption under water. Lizards "A", "B", and "D" were observed to bring their feed straight into water after they took hold of it. However, in another feeding event, lizard "B" was observed to be feeding in a spot beside a feeding tray.

Approximately 28800 seconds (4 weeks x 120 minutes x 60) were allocated to record feeding behavior of each lizard. Our study showed that lizards spent time for feeding much less than the time allocated for recorded observations. Only a small proportion of time was spent for feeding, i.e. as much as 0.85% in lizard "B" (244 of 28800 seconds). Whereas other individuals spent a smaller percentage of time for feeding than lizard "B", feeding duration for lizards "F" was the smallest (0.17%).

In general, time for feeding seemed to peak in Week 3, except for lizards "E", "H" and "J" (Table 4). Mean feeding duration for all lizards during the early evening was 29.32 seconds (SD= 37.29, range: 0-115 seconds), i.e.1173: (4 x 10). For each individual lizard, mean time spent for feeding range from 2 to 61 seconds; however lizard "J" did not take any

Table 3. Frequency distribution of feeding events across four observation weeks for each lizard

individual tag	total frequency	Week 1	Week 2	Week 3	Week 4
A	4	0	2	1	1
B	5	1	2	1	1
C	2	0	0	2	0
D	3	1	0	1	1
E	2	0	1	1	0
F	2	0	0	1	1
G	2	0	0	1	1
H	1	1	0	0	0
I	2	1	0	1	0
J	0	0	0	0	0
grand total	**23**	**4**	**5**	**9**	**5**

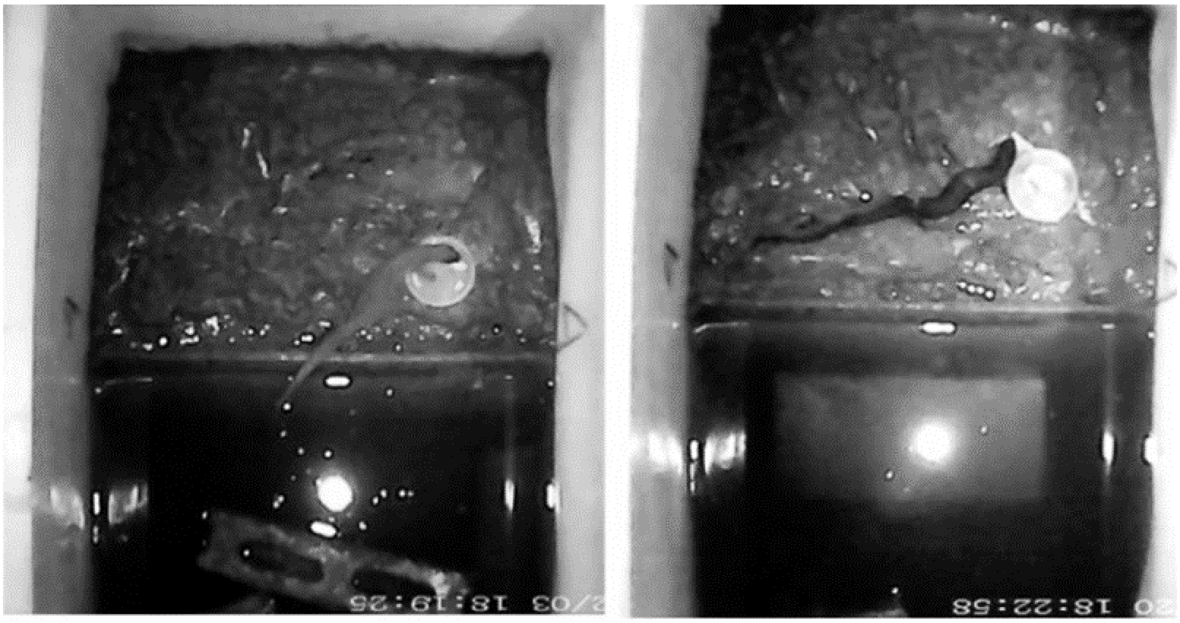

Figure 5. Individual "B" (left) and "D" (right) were observed feeding on frog meat after sunset. The image were taken before the lizards took the meat into the aquatic part of the experiment tank for consumption .

feed during the weekly observations. Three lizards, i.e. "D", "E" and "G" took more than 100 seconds (about 1.75 minutes) to feed during the early evening observations and fed 2-3 times during a month. On the other hand, feeding duration for lizards "C" and "H" were close to 100 seconds (about 1.5 minutes) and fed only once during the one-month experiment.

Predation Events

Predation on live frogs was successfully recorded for three individuals, i.e. "A", "E" and "G". The prey was taken by means of a grip of the upper and lower jaws for relatively long time, while the lizards shook their head to the right and left. It was probably the frog's movement that has triggered the attack; however we needed to verify this assumption using a close-up shot of a CCTV camera. The frog was slowly swallowed in whole, and seemingly no specific part of the frog was being taken first. Lizard "A" gripped the head of a live frog and remained holding the prey for 3'51" before swallowing it as a whole (Fig. 6). Similarly, lizard "G" took a live frog by its head (not shown) and took 15'57" to finish eating the prey. Body masses of the frogs were 5.99 g and 6.12 g for lizards "A" and "G", respectively.

On the other hand, lizard "E" bit the right hind limb of the frog and swallowed it in the same position as when it was first bitten (Fig. 7). It took 20'05" for lizard "E" to consume its prey of 7.96 g. As the frog stopped squeaking during the grip of the lizard's jaws, we assumed that it died before being swallowed.

These lizards remained in the smaller containers overnight before they were returned to their larger tanks in the morning of the following day. Thus, our experiment on predation is specifically designed to test for only one live frog during the course of noctural period. Lizard “C” was not successfully observed preying on the live frog but did took the prey during the course of the night in the second trial week. Similarly, individuals “E” and “G” were not recorded on camera for preying on the frog in the first and second trial week, respectively. However, live frogs were absent from their closed experimental tanks. Thus, we determined the latter lizards preyed on live frogs twice during the two trial weeks.

Table 4. Duration of observed feeding during the course of experiment

individual tag	**total duration (seconds)**	**duration of observed feeding in the evening (seconds)**				**Mean ± SD (seconds)**
		Week 1	**Week 2**	**Week 3**	**Week 4**	
A	90	0	19	51	20	23 ± 21
B	244	52	41	67	84	61 ± 19
C	90	0	0	90	0	23 ± 45
D	223	26	0	115	82	56 ± 52
E	138	0	105	33	0	35 ± 50
F	49	0	0	8	41	12 ± 20
G	178	0	0	101	77	45 ± 32
H	86	86	0	0	0	2 ± 43
I	75	23	0	52	0	19 ± 52
J	0	0	0	0	0	0
grand total	**1173**	**187**	**165**	**517**	**304**	

Figure 6. Individual “A” at its first attack to the head of its prey (left) and slowly swallowing it (right).

Figure 7. Individual "E" at its first attack to the right hind limb of its prey (left) and the beginning of taking the prey in whole (right)

DISCUSSION

Although *L. borneensis* is known to consume various items in captivity (Mendyk, 2015), wild animals of this species may specialize in commonly available preys in its natural semi-aquatic habitats, for example earthworms (Arida et al., 2018). Such small ground-dwelling animal maybe one of the natural preys for *L. borneensis*. Therefore, we set experimental observations on feeding behavior and predation of this lizard on another small ground-dwelling species for this study, i.e. *F. limnocharis*, which is a common frog across the western Indonesian islands. Our experiment was set in captivity due to the reclusive nature of this species, which poses great difficulties for observations in its natural habitats (Arida et al., 2018).

The Earless monitor is considered a nocturnal species (Harrisson & Haile, 1961) and has been found active in its natural habitat in the evening at about 20:30 (Langner et al., 2017). Similarly, lizards in our study seemed to actively feed during the early hours of the evening and were consistently observed to feed on frog meat in this nocturnal phase for a few weeks. Lizards seemed to spend extremely limited time for feeding even during their putative preferred phase. For example, lizard "D" only used ~1.6% of total observation time in the evening (115/7200 seconds) for feeding and was the longest to spend time feeding among all lizards in this study. Nevertheless, feeding might also took place between 19:15 and 23:00 or between 01:15 and 05:00, when lizards were not filmed for observation.

Observed feeding frequencies were variable among individuals, but feeding seemed to occur more often before sunset than after sunset across our samples (Table 2). This finding shows that most lizards were receptive of the feed available in the container before dark, suggesting crepuscularity rather than nocturnality. Feeding duration was also variable among individuals but generally short, with the longest being about 1.75 minutes (1.46% of a single recorded observation).

We consider a relationship between body size and feeding behavior, in which larger lizards tend to feed repeatedly, as they probably require more nutrition than smaller lizards. Larger lizards were more commonly observed feeding, especially before sunset, and also generally more receptive to feed than smaller lizards. Three lizards with relatively large body size, i.e. SVL of at least 18.00 cm were found as the most frequent feeders during the course of the experiment. These lizards, i.e. “A”, “B”, and “D” fed mostly before the sunset, alike lizards “E” and “G”, although the latter was relatively small in size, i.e. SVL=17.00 cm. The smallest lizard “F” of SVL=16.00 cm was observed to feed only after sunset, similar to individual “H”, which was as small in body size with SVL=16.80 cm (Table 1).

It is interesting to note, that two individual lizards showed a behavior of feeding under water of some depth. In our observations, lizards seemed to feed only inconsistently under water. Lizards “A” and “D” fed on frog flesh with their whole body and head submerged under water during the frog leg experiment, whereas most other individuals fed on frog meat at the side of the container filled with muddy soil. Underwater feeding may be a behavior to reduce energy expenditure because locomotion under water is less challenging than on land (Seymour, 1982). Nevertheless, *L. borneensis* is semi-aquatic and may by chance adjust to a depth of water or soil surface for feeding. It is most likely that a soggy environment is simply vital for this species to survive.

We found behavioral consistency of captive *L. borneensis* feeding on frog meat as well as preying on live frog. Thus, *F. limnocharis* used in this study (Fig. 7) may represent a natural prey for this species. Lizards took much longer time to consume its live prey in whole, whereas spending relatively short period to feed on pieces of frog meat. Both our experiments suggest that regardless of live or dead, frog is a suitable diet for captive *L. borneensis*.

We noticed increased body mass for most lizards at the end of the experiment, except for two, i.e. “D” and “G”. Lizards’ mean body mass at the end of our observation increased by 4.29 g (Fig. 4). Among all ten lizards, individual “E” was the largest, with 19.00 cm of SVL and body mass of 92.47 g at the onset of our experiment (Table 1). This individual was found on camera feeding only at two out of four observation weeks and did take frog meat consistently before sunset (Tables 2 and 3). At the end of the experiment, this specimen increased its body conditions to 20.10 cm of SVL and 98.20 g of body mass. This finding shows that a relatively large *L. borneensis* is still at growth given a suitable habitat conditions and prey in captivity. However, increased body size was inconsistent among all lizards, probably because of factors such as discrepancies in intake and energetics of each individual.

Despite our current understanding on the consistent feeding and predation of *F. limnocharis* by *L. borneensis* in our captive samples, natural diet of this species remains poorly understood. Known natural prey animals to date are freshwater shrimps of the genus *Macrobrachium* and fish of the genus *Clarias* (Langner, 2017). Despite low in gross energy, earthworms seem to be also preferred by this species (Arida et al., 2018), suggesting its lethargic nature. It is possible that *F. limnocharis* occurs in the natural habitats of *L. borneensis*, as it has a wide distribution area in Southeast Asia, including in secondary forests in West Kalimantan (Kurniawan et al., 2014; Saputra et al., 2016). Therefore, along with earthworms, freshwater shrimp and fish, this frog species is likely a natural prey for the Earless monitor.

Currently, three species of frogs are known to occur in the habitats of *L. borneensis* in the vicinity of Serimbu Village in West Kalimantan, i.e. *Limnonectes kuhlii*, *Ansonia spinulifer*, and *Leptobrachium abbotti* (Arida et al., 2018). Further experimental studies to determine natural prey of *L. borneensis* should apply these frog species cohabiting in its habitats on Borneo. Such a study will be helpful in the formulation of diets for captive individuals. Moreover, knowledge on diets and the relevant nutritional parameters are crucial for an effective captive husbandry (Augustine et al., 2016).

In conclusion, our limited observation on the feeding behavior of *L. borneensis* and its predation on *F. limnocharis* suggests that this frog species is one among the lizard's natural prey animals. Nevertheless, further studies are essential to confirm this notion. We believe our current results have contributed some knowledge and a new perspective on the natural diets of *L. borneensis*.

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SPECIES DISTRIBUTION UPDATE OF *MANSONIA* BLANCHARD, 1901 MOSQUITOES (DIPTERA: CULICIDAE) IN INDONESIA WITH THE ILLUSTRATED KEY FOR FEMALE MOSQUITO

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ABSTRACT

Mansonia is a genus of mosquitoes of which several species are confirmed vectors of lymphatic filariasis. Many countries including Indonesia are still struggling to eliminate lymphatic filariasis. Report of the *Mansonia* mosquito diversity and its distribution is essential to develop the control strategies. Six of eight *Mansonia* species have been confirmed as lymphatic filariasis vectors in Indonesia. This paper aims to update the distribution of the *Mansonia* mosquito in Indonesia. Species distribution data were summarized from various literature regarding the *Mansonia* mosquito. The data is complemented by the results of the National Research on Disease Vector and Reservoir (Rikhus Vektora) results conducted by the National Institute of Health Research and Development (NIHRD) in 2015-2018. There were new distribution records for four species of *Mansonia* mosquitoes in Indonesia. *Mansonia annulata* Leicester*,* *Ma. annulifera* (Theobald)*,* and *Ma. indiana* Edwards are now recorded distributed throughout the archipelago. Meanwhile, *Ma. bonneae* Edwards has a new distribution record in the Moluccas. The illustrated identification key for female *Mansonia* mosquitoes in Indonesia is provided in this paper.

Key words: distribution, Indonesia, *Mansonia*, mosquito

INTRODUCTION

The last inclusive checklist of mosquito species in Indonesia was published 40 years ago. The checklist resumed 457 mosquito species in total, and eight of them are in the genus *Mansonia* (O'Connor & Sopa, 1981). National attempt to update the mosquito diversity data was realized in National Research on Disease Vector and Reservoir (Rikhus Vektora) held by the National Institute of Health Research and Development (NIHRD), Indonesia Ministry of Health in 2015 to 2018. The research has collected thousands of mosquito specimens from 29 provinces in Indonesia.

Bonne-Wepster (1954) included *Mansonioides* Theobald and *Coquillettidia* Dyar as subgenera in genus *Taeniorhynchus* Lynch Arribalzaga, synonym for *Mansonia*. Following Ronderos & Bachmann (1963), Knight & Stone (1977) treated *Mansonia* and *Coquillettidia* as separate genera. *Mansonia* mosquito, especially subgenus *Mansonioides,* is generally characterized by: scutal scales at least two colors, scutellar scales always numerous, post-spiracular bristles always present, legs with many pale markings, tarsomeres banded with pale scales, wing speckled dorsally with pale and dark broad scales, many of which are strongly asymmetrical, and abdomen intersegmental membranes very strongly spiculate (Belkin, 1962). In the male, maxillary palpi are longer than the proboscis and turned upwards, with no hair tufts and the terminal segment is minute. The eighth tergite bears a row of stout spines (Wharton, 1962).

The immature stages of *Mansonia* are commonly found attached to the roots of aquatic plants in ponds, lakes, swamps, marshes, ditches, wells, ground pools, and flood pools in forest swamps (Gass et al., 1982). The larvae of *Mansonia* resemble those of *Coquillettidia* in having a sclerotized saw-toothed process at the tip of the siphon, which is modified for piercing submerged parts of aquatic plants to obtain oxygen from the aerenchyma. These larvae have a more sessile habit, hanging head downwards whilst attached to the plant tissues and filtering the water column for food. They are therefore not easily recognized by predators such as fish (Becker et al., 2010).

Genus *Mansonia* consists of two subgenera, i.e. *Mansonia* (15 species) and *Mansonioides* (10 species). *Mansonioides* is an Old World taxon, with species in the Afrotropical Region (sub-Saharan Africa and Madagascar), Oriental Region, Manchurian Subregion of the Palaearctic and the Australasian Region (Solomon Islands and northward from Queensland, Australia) (Service, 1990; Tanaka et al., 1979; Lee et al., 1988). All of *Mansonia* species members in Indonesia are included in subgenus *Mansonioides* (O'Connor & Sopa, 1981).

Mansonia mosquitoes, especially *Mansonioides* subgenus, are widely known as vectors for lymphatic filariasis. They are regarded as the nocturnal sub-periodic malayan filariasis in Java (*Ma. indiana* and *Ma. uniformis* (Theobald)), Sumatra (*Ma. annulata, Ma. bonneae, Ma. dives* (Schiner)*, Ma. indiana*, and *Ma. uniformis*), Kalimantan (*Ma. annulata* and *Ma. uniformis*), Sulawesi (*Ma. bonneae, Ma. dives*, and *Ma. uniformis*), and Moluccas (*Ma. uniformis*) (Hoedojo, 1989). *Mansonia annulifera* is also considered as a major vector for *B. malayi* (periodic) in South Asia region including Indonesia (Ramalingam, 1974; WHO, 2013). The updated distribution data of *Mansonia* mosquito is essential for vector control efforts, considering the 2025 target for the elimination status of lymphatic filariasis in Indonesia.

Ma. uniformis, a widespread species in the world, is a vector for several viruses such as Bunyamwera, Chikungunya, Spondweni, and Wesselbron (White & Faust, 2014), in addition to lymphatic filariasis. Converse et al. (1985) reported the isolation of Ingwavuma virus from *Ma. uniformis* caught in Bintan Island, Sumatra. This paper aims to deliver an update regarding distribution data and provide an illustrated key to aid identification of female *Mansonia* mosquitoes in Indonesia.

MATERIALS AND METHODS

The checklist and distribution data of *Mansonia* mosquito species in this paper update the checklist of mosquito species in Indonesia created by O'Connor & Sopa (1981). Species records, distribution data, and taxonomic information were summarized from several references related to the *Mansonia* mosquitoes and the national research reports of Rikhus Vektora in 2015-2018. Rikhus Vektora was lead by NIHRD in collaboration with local governments, district/city health offices, universities, research institutes, and non-government organizations (NGOs). The research collected mosquito specimens from 87 districts/cities in 29 provinces. However, *Mansonia* specimens were obtained from 76 districts/cities. This observational research was a cross-sectional study that was conducted for 30 days every year from 2015 to 2018. Each enumerator team, consisting of eight persons, collected data from six designated locations within a district/city during the period of time given. A total of 6,985 specimens collected from the research were reconfirmed in the laboratory to avoid misidentification committed in the field. Identification keys used in the process were Ramalingam (1974) for Oriental mosquitoes, and Lee et al. (1988) for Australasian mosquitoes. The distribution data of the *Mansonia* mosquito in this paper is limited to the Indonesian region and excludes Malaysian Borneo and Papua New Guinea. The illustrated key was arranged based on the described morphological characters of each species studied from related references.

RESULTS

The checklist, distribution data and taxonomic remarks of *Mansonia* mosquito species in Indonesia are presented in Table 1. Indonesia has eight species and all of them are included in the *Mansonioides* subgenus. Papua has the greatest diversity with seven species. Four species are distributed through the entire archipelago, i.e. *Ma. annulata*, *Ma. annulifera*, *Ma. indiana*, and *Ma. uniformis*. *Mansonia indiana* and *Ma. septempunctata* Theobald were described originally from Indonesia. This paper adds some distribution extension for four *Mansonia* species in Indonesia. *Mansonia annulata* is newly recorded from Java, the Lesser Sunda Island (LSI), Moluccas and Papua. *Mansonia annulifera* distribution is extended to LSI and Moluccas, while *Ma. bonneae* and *Ma. indiana* are newly recorded from Moluccas. Distribution of *Ma. papuensis* (Taylor) in Moluccas now has been deleted and recorded only in Papua. The map of *Mansonia* species distribution in Indonesia is presented below (Fig. 1).

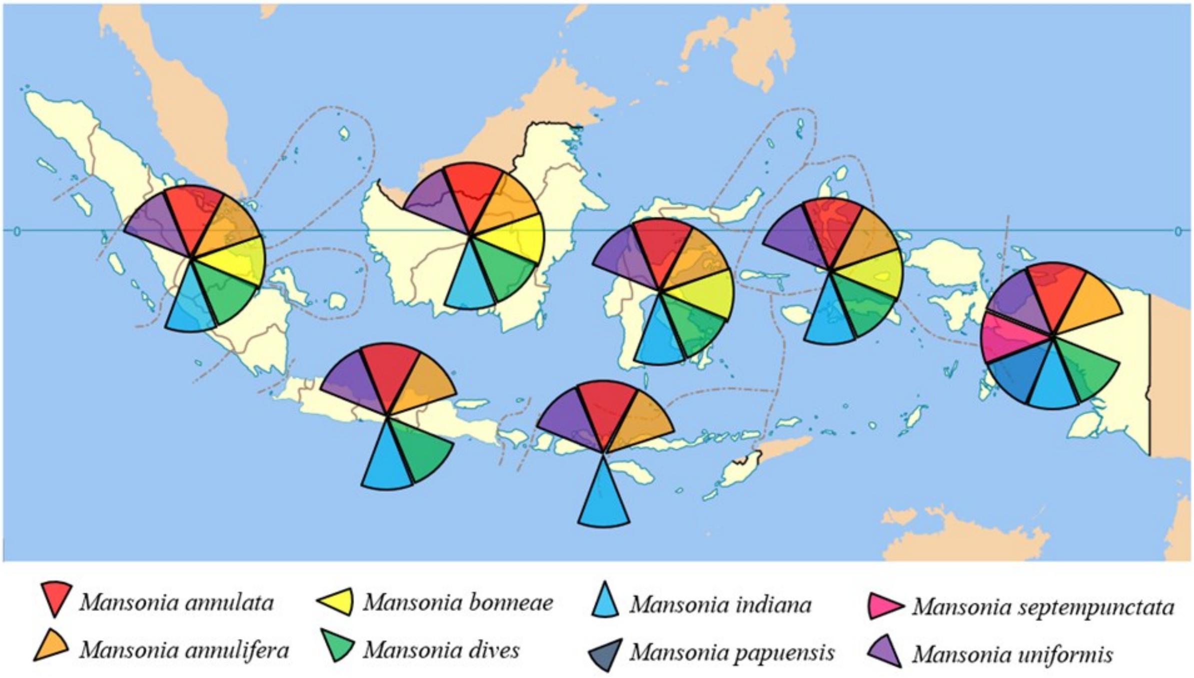


Figure 1. Distribution map of mosquito species of Genus *Mansonia* in Indonesia.

Table 1. Species checklist and distribution of *Mansonia* mosquito species in Indonesia

Valid species	Synonymy	Geographical distribution	[1] Remarks
Ma. annulata Leicester, 1908	-	Sumatra, Kalimantan, Java[1], LSI[1], Sulawesi, Moluccas[1], Papua[1]	Newly recorded from Java, LSI, Moluccas, and Papua
Ma. annulifera (Theobald, 1901)	*Ma. sequini* Laveran *Ma. septemguttata* Theobald	Sumatra, Kalimantan, Java, LSI[1], Sulawesi, Moluccas[1], Papua	Newly recorded from LSI and Moluccas
Ma. bonneae Edwards, 1930	-	Sumatra, Kalimantan, Sulawesi, Moluccas[1]	Newly recorded from Moluccas
Ma. dives (Schiner, 1868)	*Ma. annulipes* Walker *Ma. longipalpis* van der Wulp	Sumatra, Kalimantan, Java, Sulawesi, Moluccas, Papua	
Ma. indiana Edwards, 1930	-	Sumatra, Kalimantan, Java*, LSI, Sulawesi, Moluccas[1], Papua	Newly recorded from Moluccas
Ma. papuensis (Taylor, 1914)	-	~~Moluccas~~[1], Papua	Distribution record in Moluccas is deleted
Ma. septempunctata Theobald, 1905	*Ma. bonnewepsterae* van den Assem	Papua*	
Ma. uniformis (Theobald, 1901)	*Ma. australiensis* Giles *Ma. marquesensis* Dyar *Ma. reversus* Theobald	Sumatra, Kalimantan, Java, LSI, Sulawesi, Moluccas, Papua	

Note: *: type locality

DISCUSSION

All species records in LSI in this paper are considered new compared to the checklist compiled by O'Connor & Sopa (1981). *Ma. indiana* in LSI has been reported by Bonne-Wepster (1954) who found the species in Flores Island. *Mansonia uniformis* has been reported in Lombok Island (Lee et al., 1988) and Timor Island (Whelan & Hapgood, 2000). The latest record was reported from Timor Leste, and occurrence of this species in East Nusa Tenggara Province (Indonesia) in the same island is highly possible.

Females of *Ma. annulata* sometimes bite in swampy jungles during the day. Larvae weres collected from marshy pools near the forest edge (Macdonald, 1957). This species is known as a primary vector for *W. malayi* (Wharton, 1962). Now *Ma. annulata* has also been recorded from Purworejo and Serang (Java Island), West Lombok (LSI), Central and South Halmahera (North Moluccas Province) and Sarmi (Papua Province) (B2P2VRP, 2015a; B2P2VRP 2015c; B2P2VRP, 2016a; B2P2VRP, 2016c; B2P2VRP, 2016d).

Early record of *Ma. annulifera* from Papua New Guinea was based on Edwards (1913) erroneous synonymy of the Australasian species *Ma. septempunctata* with *Ma. annulifera*. The only other Australasian region record of *Ma. annulifera* is that of Bonne-Wepster (1938) from Merauke, Irian Jaya, and this may be a misidentification of *Ma. septempunctata*, which has been recorded (as *Ma. bonnewepsterae*) as abundant in the area (van den Assem & van Dijk, 1958). Females of *Ma. annulifera* are strongly anthropophilic (Bohart, 1945) and greedy biters (Bonne-Wepster, 1954). Horsfall (1955) considered this species a dependable component of the vector for *Wuchereria* species. Now *Ma. annulifera* has also been recorded from Jembrana (Bali Island/LSI) and from Central and South Halmahera (North Moluccas Province). Besides, it is confirmed that *Ma. annulifera* is also distributed in South, Central and North Kalimantan Provinces (B2P2VRP, 2015b; B2P2VRP, 2016c; B2P2VRP, 2017a; B2P2VRP, 2017b; B2P2VRP, 2018).

Bonne-Wepster (1930) recognized a male specimen of *Ma. annulipes* (now *Ma. dives* and formerly *Ma. longipalpis*) which had slightly different male terminalia and described it as *Ma. annulipes* var. AA. Edwards (1930) found two males in the collection at the British Museum with similar terminalia and designated one from Kuala Lumpur as the type of a new species, *Ma. bonneae*. Female specimens of the two species were not distinguishable until Edwards suggested that the presence of a small patch of white scales at the side of the scutum just in front of the wing roots would separate *Ma. dives* from *Ma. bonneae* (Wharton, 1962). This species has been newly recorded from Aru Islands (Moluccas Province) and Central and South Halmahera (North Moluccas Province) (B2P2VRP, 2016b; B2P2VRP, 2016c).

The name of *Ma. dives* has a quite long history. Edwards (1922) previously declared *dives* to be an unnecessary new name for *Culex annulipes* Walker. Later, *C. annulipes* Walker was transferred to the genus *Taeniorhynchus* (former name *Mansonia*). Edwards (1930) acknowledged that *annulipes* Walker was a junior homonym for *C. annulipes* Meigen (now as *Aedes annulipes* Meigen) and required a new name. Edwards rejected *dives* again because specimen described by Schiner for *dives* was a different species than *annulipes* Walker. Edwards (1925) had already synonymized *longipalpis* van der Wulp with *annulipes* Walker. However, Stone (1957) pointed out that even though Schiner may have misidentified *annulipes* Walker, *dives* is a valid substitute name for *annulipes* Walker and must be applied to that species (Lee et al., 1988).

Edwards (1930) proposed name *indiana* for Indonesian specimens described by Bonne-Wepster (1930) on the basis of a misidentification by Edwards himself, as *Taeniorhynchus africanus*. Most authors have continued to include New Guinea in the distribution of *Ma. indiana* on the basis Bonne-Wepster's record in Upper Digoel. This paper confirmed that *Ma. indiana* is indeed distributed in Papua based on species collection in Merauke. This species was also reported from South Halmahera (North Moluccas Province) (B2P2VRP, 2016c).

Mansonia papuensis is known only from New Guinea. Brug & Bonne-Wepster (1947) listed this species from Seram (Moluccas), but this record is questionable (Lee et al., 1988). There is no report of *Ma. papuensis* collection from any region in Moluccas, so the authors decided to delete this species distribution in Moluccas. In Irian Jaya, van Dijk (1958) found that larvae of *W. bancrofti* could develop to maturity in *Ma. papuensis* but the high mortality of experimental mosquitoes made it difficult to assess the susceptibility of this species. He then concluded that in experimental conditions the development of *W. bancrofti* in *Ma. papuensis* was a slow and laborious process (Lee et al., 1988).

Adults of *Ma. septempunctata* are pests, biting after sunset and also in daytime in wet and shady places. In Sentani Lake, they were collected from aquatic plants *Pistia stratiotes* and *Hydrocharis asiatica* in a restricted area where the water was proven to be heavily polluted with waste from native houses nearby (van den Assem & Bonne-Wepster, 1964). Van Dijk in 1958 caught specimens of *Ma. septempunctata* (in his paper recorded as *Ma. longipalpis*) on a microfilaria carrier and kept them alive afterwards in test tubes, dissecting the dead ones. In 22 specimens, he estimated 87 percent were infected, but he could not trace infective instars. The development of the microfilariae within the mosquito seemed inhibited in the presausage stage and a subsequent degeneration was noted (van den Assem, 1958).

Mansonia uniformis distribution is extensive. It is listed by Knight & Stone (1977) as Ethiopian (Afrotropical), Oriental and Australasian regions east to Bismarcks archipelago, Japan, Ryukyu-Retto. In Indonesia, *Ma. uniformis* is distributed throughout the archipelago. This species occurs in wet conditions in swampy areas and is certainly one of the most aggressive biters, ready to attack at day or night. They often bite in large numbers indoors at night and bite in the shade during the day (van den Assem, 1959). *Mansonia uniformis* is an important vector for *W. bancrofti* in areas with large swamps where anopheline mosquitoes are virtually absent (de Rook & van Dijk, 1959). Brug & de Rook (1933) stated that *Ma. uniformis* was hospitable to *W. malayi* in Seram, and it was also highly hospitable to *Brugia patei* and *B. pahangi* (Laurence & Pester, 1961).

Dalilah et al. (2017) reported the collection of *Ma. africana* in large numbers from Sungai Rengit Murni village in South Sumatra. This report is questionable, because *Ma. africana* is restricted in distribution to tropical Africa (Laurence, 1960). The author suggested that the species was probably *Ma. indiana*. Misidentification would likely occur because *Ma. africana* is closely related to *Ma. indiana* and *Ma. septempunctata* (Wharton, 1962). Bonne-Wepster had also misidentified *africanus* for some females from the Upper Digoel, Irian Jaya. Edwards (1930) then suggested that these specimens were *Ma. septempunctata* (Lee et al., 1988).

The role of *Mansonia* species as lymphatic filariasis vectors has been recorded by Directorate General of Infectious Disease Elimination and Environmental Health (PPM&PL), Ministry of Health. *Mansonia uniformis* is competent as a lymphatic filariasis vector in all main islands where they occur. Closest to *Ma. uniformis, Ma. indiana* was also recorded as vector in Java, Sumatra, Kalimantan and Sulawesi but has never been confirmed from the Moluccas and Papua region. Compared to other species that have entire achipelago distribution, for instance *Ma. annulifera*, it was only recorded as vector in Sumatra, Kalimantan, and Sulawesi. Meanwhile *Ma. annulata* was only confirmed as vector in Sumatra and Kalimantan (PPM&PL, 2008).

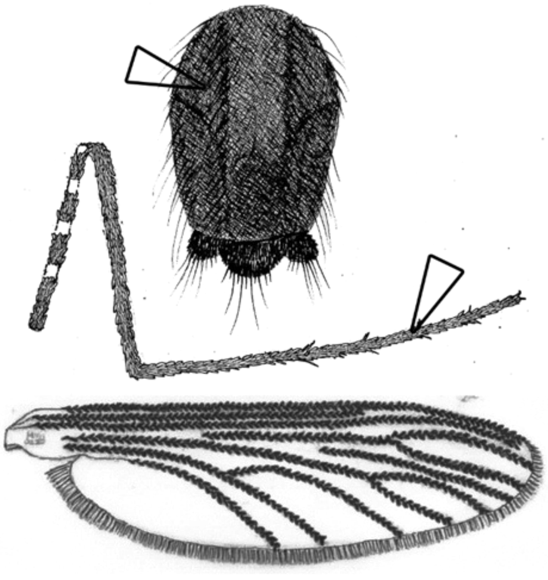
In conclusion, Indonesia has eight species of *Mansonia* mosquitoes that are entirely included in *Mansonioides* subgenus. The distribution data is updated for the following species: *Mansonia annulata* (Java, the Lesser Sunda Islands, Moluccas, and Papua), *Ma. annulifera* (the Lesser Sunda Islands and Moluccas)*, Ma. indiana* and *Ma. bonneae* (Moluccas). The distribution of *Ma. annulifera* (Kalimantan) and *Ma. indiana* (Papua) has been confirmed. Meanwhile, the distribution record of *Ma. papuensis* in Moluccas has been removed. The identification key of female *Mansonia* mosquitoes is provided in this paper.

IDENTIFICATION KEY FOR FEMALE *MANSONIA* MOSQUITO IN INDONESIA

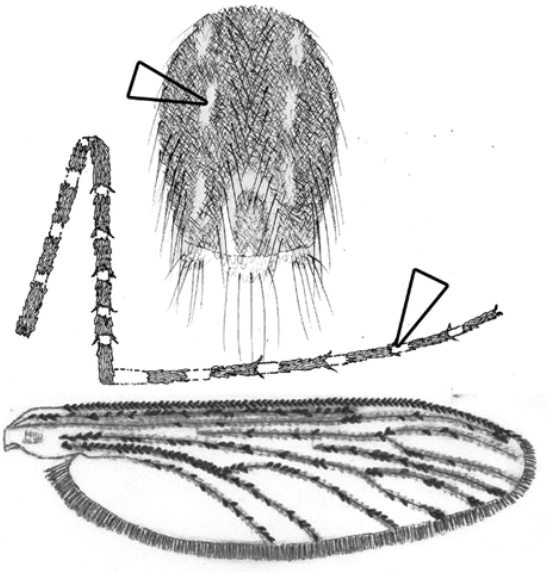
Modification from Ramalingam (1974)

1. Scutum entirely dark, wing dark scaled, tarsomere without distinct pale bands, small species (Fig. 1a) ……………………………………………………………… ***papuensis***

   Scutum with variable ornamentation, wing speckled, larger species (Fig. 1b) ………. 2



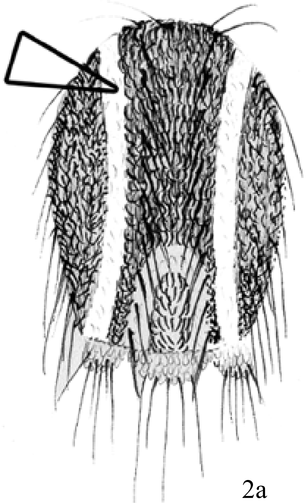
1a



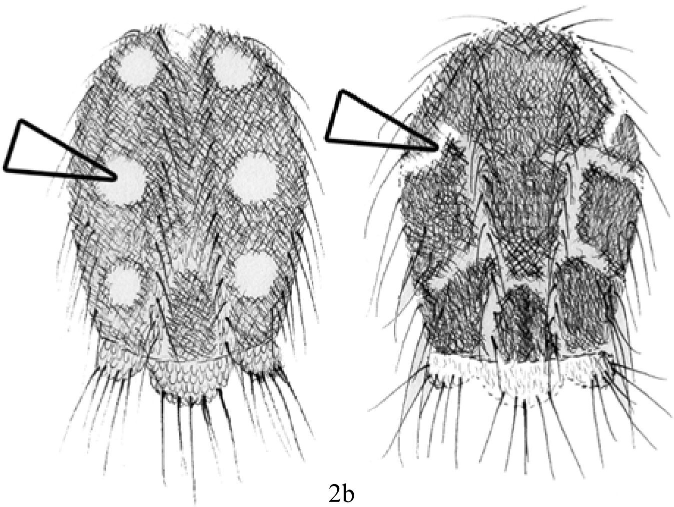
1b

2. Scutum with a pair of pale greenish longitudinal lines, brown colored mosquito (Fig. 2a) ……………………………………………………………………………… ***uniformis***

   Scutum with round spots or irregular patches of scales (Fig. 2b) …………………… 3



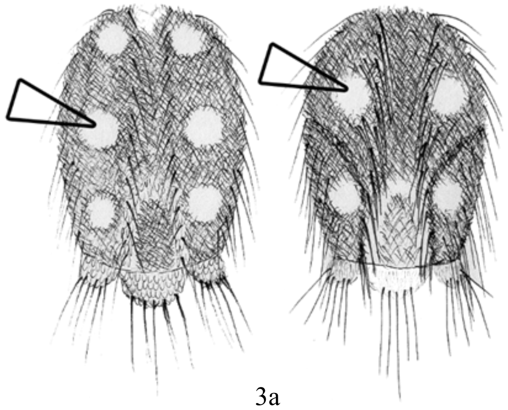
2a



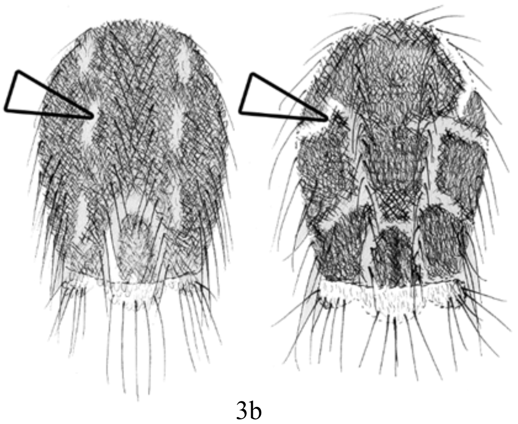
2b

3. Scutum with disctinct and regular round spots of light scales (Fig. 3a) ……………… 4

   Scutum with irregular patches of pale scales (Fig. 3b) …………………………… 7



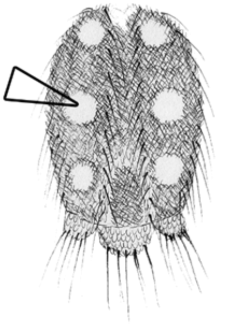
3a



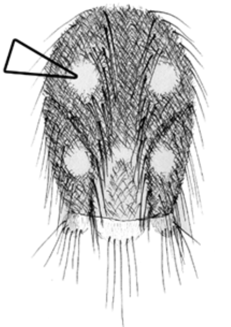
3b

4. Scutum with six distinct silvery spots, midlobe of scutellum with moderately wide flat white scales, small to medium species, pale or yellowish colored mosquito (Fig. 4a) ……………………………………………………………………………… ***annulifera***

   Scutum with four distinct rounded spots of white scales, femur with distinct white bands and scattered pale scales, medium species (Fig. 4b) …………………………………… 5



4a

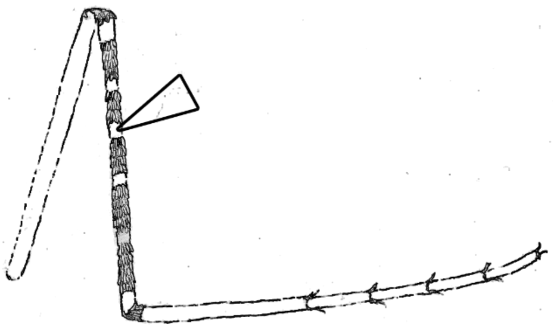


4b

5. Fore tibia with 10-15 scattered small white dots, ventral surface white from base to apex (Fig. 5a) ……………………………………………………………… ***septempunctata***

   Fore tibia with about six well-defined bands (Fig. 5b) ………………………………… 6

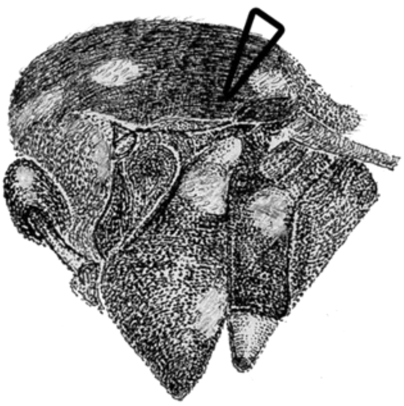
No available specimens



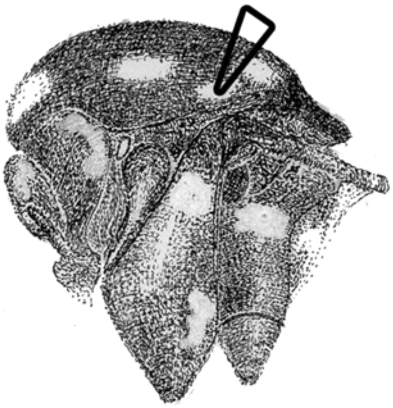
5a

5b

6. Supra alar area with wide or curved white scales (Fig. 6a) ……………………… ***dives***
   Supra alar area without wide or curved white scales (Fig. 6b) ………………… ***bonneae***

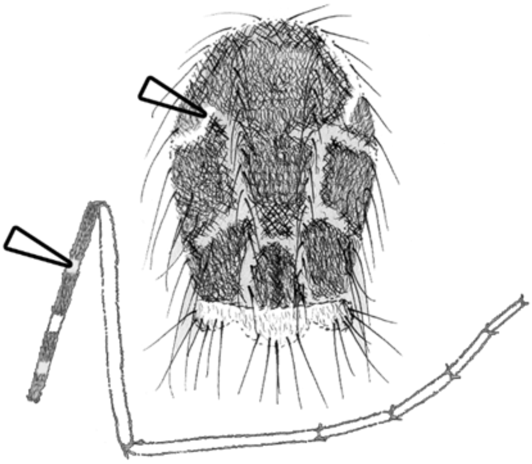


6a

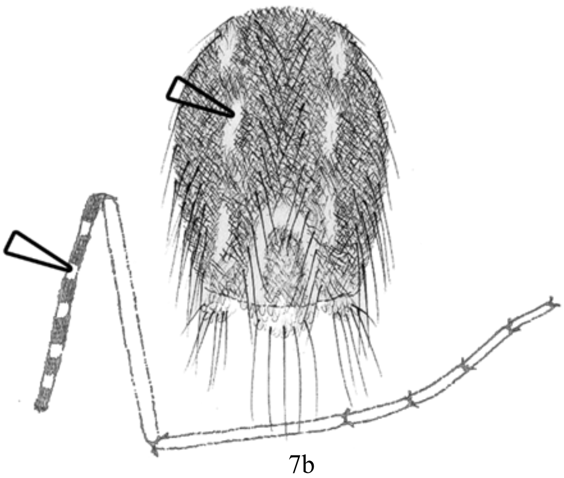


6b

7. Hind femur with three distinct pale bands, scutum dark with irregular pattern of narrow yellow scales (Fig. 7a) ……………………………………………………… ***annulata***
   Hind femur with about five pale bands, scutum golden-brown with irregular patches of white scales (Fig. 7b) ……………………………………………………… ***indiana***



7a



7b

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CAN *TROIDES HELENA* AND *PACHLIOPTA ADAMAS* CO-EXIST? A PERSPECTIVE FROM THE BUTTERFLY BREEDING FACILITY, CIBINONG SCIENCE CENTER, INDONESIA

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ABSTRACT

Troides helena and *Pachliopta adamas* utilize the same food plant species: *Aristolochia acuminata.* For the purpose of captive breeding and conservation, it is desirable to find out whether they can co-exist in captivity. Captive breeding research was conducted on the butterfly species within the period of October 2016 to September 2019. In total, 1,361 individuals were observed. Data on adult emergence of the species is presented to show the trends. Both species co-existed poorly at the facility when food plants were limited. It took 45.9 days for *T. helena helena* and 32.6 days for *P. adamas adamas* to grow from egg to imago stage. Habitat enrichment can encourage the species to come and establish the population.

Key words: captive breeding, co-exist, *Pachliopta adamas*, parental stocks, *Troides helena*

INTRODUCTION

Troides helena (Linnaeus, 1758) and *Pachliopta adamas* (Zinken, 1831) belong to the family of Papilionidae, the swallowtail butterflies. *Troides helena* is quite widely distributed across Sumatra, Kalimantan, Java, Bali, western part of Nusa Tenggara, Sulawesi, and also from northern India to Malaysia at 0-1000 m asl. (Endo & Ueda, 2004). This species is the most common protected butterfly species in Indonesia (Peggie, 2011; KLHK, 2018). *Pachliopta adamas* was included in *P. aristolochiae* sensu lato until the separation was proposed (Page & Treadaway, 1995). *Pachliopta adamas* occurs in Java including Bawean, Enggano, and Tanahjampea.

Both butterfly species inhabit forest areas where they are closely associated with the larval host plants, *Aristolochia acuminata* (previously known as *A. tagala*, see Yao, 2015) of family Aristolochiaceae (Igarashi & Fukuda, 1997). Veenakumari & Mohanraj (1994) reported *Thottea tomentosa*, also of Aristolochiaceae, as the sole larval food plant for the Andaman endemic *Pachliopta rhodifer*. In Java, *T. tomentosa* is utilized as the food plant by *Losaria coon*, another swallowtail butterfly (Tsukada & Nishiyama, 1982; Igarashi & Fukuda, 1997).

The two butterfly species in question are attractive and enjoyed in butterfly gardens, and are also in high demand by collectors. Therefore, it is desirable to have butterflies produced from captive breeding operations. To have a sustainable captive breeding program, we need to know the host plants (New et al., 1995) and how the species thrive in captivity (Peggie, 2018).

We have had a butterfly captive breeding facility since August 2016 through the Biovillage program of Indonesian Institute of Sciences. With this facility, we have been able to breed about 25 butterfly species to understand the life history and the biological aspects of many Indonesian butterfly species. In this paper, we focus on the Javan local subspecies: *T. helena helena* and *P. adamas adamas*. We aim to answer the questions: (1) whether habitat enrichment can encourage these butterfly species to come into the area; (2) how well *T. helena* and *P. adamas* can co-exist at the facility; (3) how long is the duration of the life cycle of *T. helena helena* and of *P. adamas adamas*.

MATERIALS AND METHODS

Study area

The research was conducted at the butterfly captive breeding facility of Indonesian Institute of Sciences (now National Research and Innovation Agency), located at Cibinong Science Center, Cibinong, Bogor, Indonesia. The butterfly facility covered an area of 800 m^2 which included a 10x20 m^2 butterfly aviary and a 4x6 m^2 rearing room, which were built in May - August 2016. The observations at the rearing room provide data on the early stages of *T. helena helena* and *P. adamas adamas*, and the observations at the butterfly aviary provide data on adult activities. The observations were conducted at ambient temperatures of 25-34°C. Various plants have been grown inside and outside the aviary to support butterflies, including the larval host plants, the flower plants, and plants for shading. The planting of various plants was started in May and June 2016. In September 2019, two smaller aviaries 6x6 m^2 were built to accommodate the need to protect the host plants and to facilitate the egg-laying observation. However, the facility was relocated in October 2020 to give way to the new building for biodiversity collections.

Materials

Parental stocks of *T. helena helena* and *P. adamas adamas* were individuals naturally came flying to the area.

Methods

We started the captive breeding butterfly facility in May 2016 and were planning to obtain the butterfly parental stocks when the food plants have grown well. Fortunately, both species came flying to the area in October 2016. Upon finding the parental stocks, we obtained the eggs or larvae on the leaves of the host plants, *A. acuminata*, planted in rows on the field across the rearing room. The eggs were collected into a petri dish and brought to the rearing room to be observed. Each larva was placed inside a plastic container with a mesh cover lid. Fresh leaves of the host plants were added daily and excreta were removed. Caterpillars were observed as they grew and molted into next instars, pupated, and emerged. All data were recorded in the data book.

When an adult butterfly emerged from the pupal case and the wings were fully expanded and dried, usually a few hours after emerging, the individual was marked using paint markers (Hagler & Jackson, 2001; Peggie, 2019). The date of emergence and sex were noted on the data book. Male and female of both species can be distinguished easily because they are dimorphic. The newly-emerged butterflies of the day were released into the aviary. Observation was then started on the butterflies flying in the aviary. Mating individuals and egg-laying individuals were photographed whenever possible and the individual numbers were recorded. Then eggs were collected on the host plants. To know the life span of adults, searching for wings of dead butterflies was conducted as well as recording the activity of the butterflies.

RESULTS

The observations of *T. helena helena* and *P. adamas adamas* were conducted within the period of October 2016 through September 2019, with 1,361 individuals in total (Table 1). We observed as much as we could, but obviously the data for each individual was not complete throughout the life stage. Out of 1,361 individuals, there were 941 of *T. helena helena* and 420 of *P. adamas adamas*. Out of 941 individuals of *T. helena helena*, 700 reached the adult stage, thus the early stage survival rate was 74.39%. Out of 420 individuals *P. adamas adamas* individuals, 348 reached the adult stage, with the survival rate of 82.86%.

Table 1. Summary of the numbers of individuals observed during the captive breeding research

Species observed	Number of individuals emerged as male	Number of individuals emerged as female	Number of successful individuals to adulthood	Number of failed individuals during pre-adult	Total
Troides helena helena	366	334	700	241	941
Pachliopta adamas adamas	188	160	348	72	420
Total	554	494	1,048	313	1,361

At the beginning, there were some obstacles related to the condition of the rearing room that was obviously too hot with fiber roof. Other factors included the attack of parasitoids on pre-adult stages, the scarcity of host plants, and the failure at eclosion to imago.

(1) Habitat enrichment can encourage both butterfly species to come into the area

Individuals of both species came flying across the area and the females laid eggs on the host plants so we did not need to go elsewhere to obtain the parental stocks. Otherwise, a permit would need to be requested from the Indonesian Ministry of Environment and Forestry as *T. helena* is one of the protected species in Indonesia. Larvae of *P. adamas adamas* were first observed on the leaves of *A. acuminata* on October 11, 2016. The females must have come to the area about 1–2 weeks prior to the date. As with *T. helena helena,* adults were first seen flying across the planting area on October 21, 2016, and later that afternoon and several days after that we found eggs for the parental stocks to start a new generation.

(2) How well *T. helena helena* and *P. adamas adamas* can co-exist at the facility?

At the time of observation, between October 2016 and September 2019, there were many butterfly species bred in the facility. We observed how well *T. helena helena* and *P. adamas adamas* could co-exist. The result of our observation (Fig. 1) showed that when *T. helena helena* was on the rise in January 2017, *P. adamas adamas* declined, and vice versa in June 2017 and January 2019. However, in March 2017 they seemed to co-exist quite well. The availability of sufficient host plants might be the issue in this case.

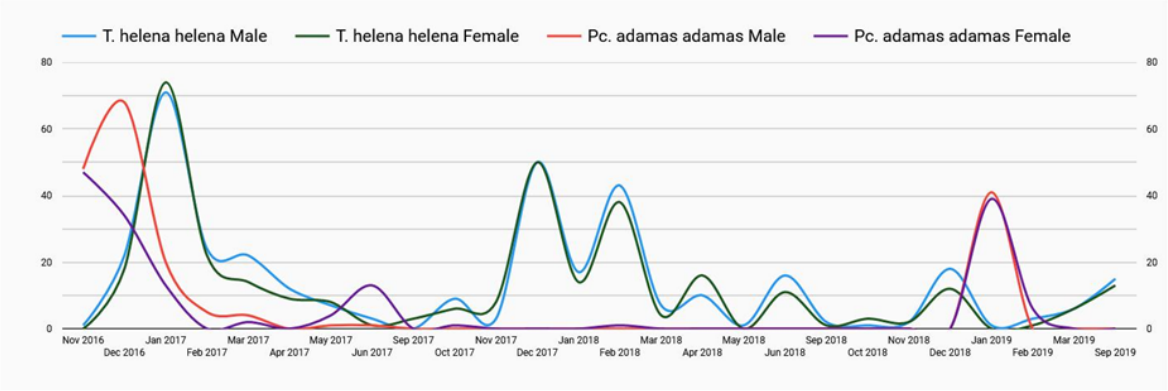

Figure 1. Adult emergence of *P. adamas adamas* and *T. helena helena* at the butterfly captive breeding facility between November 2016 and September 2019.

(3) The duration of the life cycle of *T. helena helena* and of *P. adamas adamas*

Based on daily observations of *T. helena helena*, data of 71 individuals which had complete records of each stage (Fig. 2, Table 2) showed that eggs hatch about 5–6 days after being laid. The duration of each instar for early instar larvae (L1, L2, and L3) varied between 2–4 days, with one individual (#2968) spent 5 days as L3. The duration of fourth instar larva (L4) varied between 3–5 days, with two individuals (#2779 and #2780) spent 6 days as L4. The duration of late instar larva (L5) varied between 3–12 days with an average of 8.2 days. The average duration spent as larvae was 20.8 days. The pupation process from prepupal to pupal stage lasts for one day. Pupal development lasts on average 18.6 days, with one individual (#2440) spent only 15 days and one individual (#2864) needed 22 days to eclosion. Therefore, the average duration from eggs to adults was 45.9 days. Observations in the aviary showed that many adults could live over 2 weeks and some individuals were recorded still alive for 21 days, but some lived only about a week.

Data of 12 individuals of *P. adamas adamas* which had complete records of each stage (Table 3) showed that the eggs hatch after 5 days. The larval stage consists of 5 instars. The duration of each instar for early instar larvae was on average 2 days, L4 varied between 2–3 days, and L5 varied between 4–5 days with one individual (#628) spent 2 days only as L5. The average duration spent as larvae was 12.2 days. The process from prepupal to pupal stage lasts for one day. Pupal development lasts about 14.4 days. Therefore, the average duration from eggs to adults is 32.6 days. Observations of adult longevity were conducted on other available individuals, not only on 12 individuals with complete data. Some adults could live over 2 weeks and some individuals were recorded still alive for 25 days.

Figure 2. QR code for access to the full data of *T. helena helena* life span.

Observations on adult butterflies (Table 4) showed that males did not mate on the first day of emergence. Some females, on the other hand, were approached by males when they had just eclosed. Some females were observed mating on day 2 and day 3 after emergence (Figs 3a, 3b). The ovipositing females fluttered around the host plant several times before laying eggs on the underside of leaves or on the bark (Fig. 3c). Some females were observed also visiting flowers in-between ovipositing activity. The smaller aviary was built later to enable the observation of egg laying behavior. However, when it was ready to be used with available plants inside, we needed to relocate to a different site, so the observation was halted.

Table 2. A sample page of life span of *T. helena helena* as recorded during the research in the butterfly aviary

No.	indivi-dual	egg date taken	L1 date [duration]	L2 date [duration]	L3 date [duration]	L4 date [duration]	L5 date [duration]	prepupa date [duration]	pupa date [duration]	adult date [duration]	sex	note on adult
1	615	not detected	11-Oct-16 [2]	13-Oct-16 [2]	15-Oct-16 [2]	17-Oct-16 [2]	23-Dec-16 [5]	24-Oct-16 [1]	25-Oct-16 [14]	08-Nov-16	female	
2	1733	22-Oct-16	27-Oct-16 [2]	29-Oct-16 [3]	01-Nov-16 [3]	04-Nov-16 [4]	08-Nov-16 [5]	13-Nov-16 [1]	14-Nov-16 [19]	03-Dec-16 [9]	male	mated on 5 Dec with 1735
3	1735	22-Oct-16	27-Oct-16 [2]	29-Oct-16 [3]	01-Nov-16 [3]	04-Nov-16 [4]	08-Nov-16 [6]	14-Nov-16 [1]	15-Nov-16 [18]	03-Dec-16	female	mated on 5 Dec with 1733
4	1973	22-Oct-16	26-Oct-16 [3]	29-Oct-16 [4]	02-Nov-16 [4]	06-Nov-16 [4]	10-Nov-16 [4]	14-Nov-16 [1]	15-Nov-16 [18]	03-Dec-16	female	mated on 12 Dec with 1977
5	1977	22-Oct-16	26-Oct-16 [3]	29-Oct-16 [4]	02-Nov-16 [4]	06-Nov-16 [4]	10-Nov-16 [4]	14-Nov-16 [1]	15-Nov-16 [19]	04-Dec-16 [14]	male	mated on 12 Dec with 1973
6	2780	12-Dec-16	17-Dec-16 [2]	19-Dec-16 [2]	21-Dec-16 [4]	25-Dec-16 [6]	31-Dec-16 [9]	09-Jan-17 [1]	10-Jan-17 [19]	29-Jan-17	male	mated on 2 Feb with 3101
7	2783	12-Dec-16	17-Dec-16 [2]	19-Dec-16 [2]	21-Dec-16 [4]	25-Dec-16 [5]	30-Dec-16 [5]	04-Jan-17 [1]	05-Jan-17 [19]	24-Jan-17	male	
8	3101	13-Dec-16	19-Dec-16 [3]	22-Dec-16 [4]	26-Dec-16 [4]	30-Dec-16 [5]	04-Jan-17 [9]	13-Jan-17 [1]	14-Jan-17 [18]	01-Feb-17 [14]	female	mated on 2 Feb with 2780
9	5003	13-Mar-17	16-Mar-17 [3]	19-Mar-17 [3]	22-Mar-17 [4]	26-Mar-17 [5]	31-Mar-17 [9]	09-Apr-17 [1]	10-Apr-17 [20]	30-Apr-17	female	
10	6303	10-Oct-17	13-Oct-17 [2]	15-Oct-17 [3]	18-Oct-17 [3]	21-Oct-17 [4]	25-Oct-17 [6]	31-Oct-17 [1]	01-Nov-17 [20]	21-Nov-17	female	
11	6323	10-Oct-17	15-Oct-17 [3]	18-Oct-17 [3]	21-Oct-17 [3]	24-Oct-17 [3]	27-Oct-17 [6]	02-Nov-17 [1]	03-Nov-17 [21]	24-Nov-17	female	
12	6341	10-Oct-17	15-Oct-17 [3]	18-Oct-17 [3]	21-Oct-17 [4]	25-Oct-17 [3]	28-Oct-17 [8]	05-Nov-17 [1]	06-Nov-17 [20]	26-Nov-17	female	

Table 3. Life span of *P. adamas adamas* as recorded during the research in the butterfly aviary

No.	**indivi-dual**	**egg date taken**	**L1 date [duration]**	**L2 date [duration]**	**L3 date [duration]**	**L4 date [duration]**	**L5 date [duration]**	**prepupa date [duration]**	**pupa date [duration]**	**adult date [duration]**	**sex**	**note on adult**
1	615	not detected	11-Oct-16 [2]	13-Oct-16 [2]	15-Oct-16 [2]	17-Oct-16 [2]	19-Oct-16 [5]	24-Oct-16 [1]	25-Oct-16 [14]	08-Nov-16	female	
2	622	not detected	not detected	not detected	not detected	11-Oct-16 [3]	14-Oct-16 [5]	19-Oct-16 [1]	20-Oct-16 [14]	03-Nov-16	female	
3	624	not detected	not detected	not detected	11-Oct-16 [2]	13-Oct-16 [2]	15-Oct-16 [5]	19-Oct-16 [1]	20-Oct-16 [13]	02-Nov-16	female	
4	625	not detected	not detected	not detected	11-Oct-16 [2]	13-Oct-16 [2]	15-Oct-16 [5]	19-Oct-16 [1]	20-Oct-16 [14]	03-Nov-16	female	
5	628	not detected	13-Oct-16 [2]	15-Oct-16 [2]	17-Oct-16 [2]	19-Oct-16 [2]	21-Oct-16 [2]	23-Oct-16 [1]	24-Oct-16 [14]	07-Nov-16 [9]	male	
6	1719	22-Oct-16	27-Oct-16 [2]	29-Oct-16 [2]	31-Oct-16 [2]	02-Nov-16 [2]	04-Nov-16 [4]	08-Nov-16 [1]	09-Nov-16 [14]	24-Nov-16	female	
7	1721	28-Oct-16	02-Nov-16 [2]	04-Nov-16 [2]	06-Nov-16 [2]	08-Nov-16 [3]	11-Nov-16 [5]	16-Nov-16 [1]	17-Nov-16 [14]	01-Dec-16	female	
8	1723	22-Oct-16	27-Oct-16 [3]	30-Oct-16 [3]	02-Nov-16 [2]	4-Nov-16 [2]	06-Nov-16 [4]	10-Nov-16 [1]	11-Nov-16 [15]	26-Nov-16	female	
9	1956	21-Oct-16	26-Oct-16 [2]	28-Oct-16 [2]	30-Oct-16 [2]	01-Nov-16 [3]	04-Nov-16 [5]	09-Nov-16 [1]	10-Nov-16 [16]	26-Nov-16	male	mated on 29 Nov with 1962
10	1962	22-Oct-16	27-Oct-16 [2]	29-Oct-16 [2]	31-Oct-16 [2]	02-Nov-16 [3]	05-Nov-16 [5]	10-Nov-16 [1]	11-Nov-16 [16]	27-Nov-16 [25]	female	mated on 29 Nov with 1956
11	2217	19-Nov-16	24-Nov-16 [4]	28-Nov-16 [2]	30-Nov-16 [2]	02-Dec-16 [2]	04-Dec-16 [4]	08-Dec-16 [1]	09-Dec-16 [14]	23-Dec-16	male	
12	2518	10-Dec-16	15-Dec-16 [2]	17-Dec-16 [2]	19-Dec-16 [3]	22-Dec-16 [3]	25-Dec-16 [5]	30-Dec-16 [1]	31-Dec-16 [14]	14-Jan-17	male	

Table 4. Observations on mating individuals of *T. helena helena* and additional information of the individuals

No.	individual number	date of emergence	M/F	observed mating	adult life span (days)
1	1733	3 Dec 2016	male	mated on 5 Dec 2016 (2 days old) with 1735	9
2	1735	3 Dec 2016	female	mated on 5 Dec 2016 (2 days old) with 1733	
3	1973	3 Dec 2016	female	mated on 12 Dec 2016 (9 days old) with 1977	
4	1977	4 Dec 2016	male	mated on 12 Dec 2016 (8 days old) with 1973	14
5	2759	27 Jan 2017	male	mated on 3 Feb 2017 (7 days old) with 2816	
6	2816	31 Jan 2017	female	mated on 3 Feb 2017 (3 days old) with 2759	
7	3012	27 Jan 2017	male	mated on 6 Feb 2017 (10 days) with 3064 and were still mated at 16:15	18
8	3064	30 Jan 2017	female	mated on 6 Feb 2017 (7 days) with 3012 and were still mated at 16:15	15
9	2780	29 Jan 2017	male	mated 2 Feb 2017 (4 days) with 3101	
10	3101	1 Feb 2017	female	mated 2 Feb 2017 (1 day) with 2780	14
11	3121	30 Jan 2017	male	mated on 8 Feb 2017 (9 days) with 3135	
12	3135	6 Feb 2017	female	mated on 8 Feb 2017 (2 days) with 3121	
13	6019	20 Oct 2017	male	mated on 2 Nov 2017 at 9:45 (13 days) with newly emerged 6119	
14	6119	2 Nov 2017	female	mated on 2 Nov 2017 at 9:45 (newly emerged) with 6019	

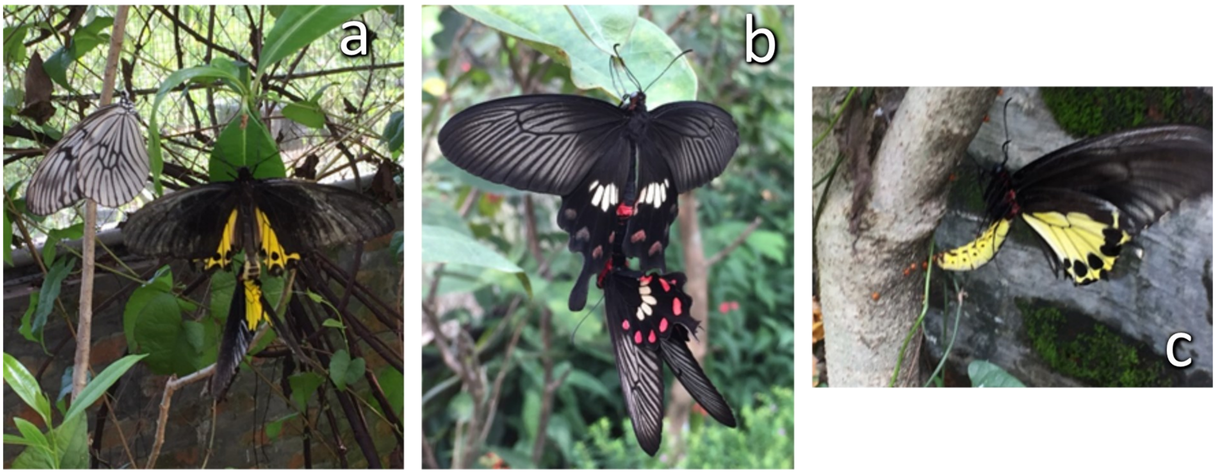

Figure 3. Observation in the aviary: **(a)** mating individuals of *T. helena helena* were noted, and another species: *Idea blanchardii* perched nearby; **(b)** mating individuals of *P. adamas adamas* were documented; **(c)** ovipositing female of *T. helena helena* on the branch of the host plants.

There were many other butterfly species in the aviary at one time or another. However, they seemed to co-exist well. There were plenty of flowers that they could use for nectar. When flower supplies were not sufficient, we put sugar solution as an addition. Individuals of *T. helena helena* were often seen taking the 10% sugar solution that was placed on *Hibiscus* flowers.

DISCUSSIONS

This research demonstrates that planting host plants can encourage butterflies to come to the planting area and start the population at a new site (Neville, 1993; Peggie, 2019; Jain et al., 2021). The two species, being forest inhabitants (Igarashi & Fukuda, 1997), have never been reported in the area prior to the establishment of the facility. However, four months after *A. acuminata* was planted, *P. adamas adamas* came to the area and laid eggs. About three weeks after that, individuals of *T. helena helena* were seen flying across and the female laid eggs. Apparently the butterfly species did notice the presence of the host plants and were attracted to come to the area. It is desirable to know the closest possible habitats of the species and do the mapping, preferably like that of Jain et al. (2021). But for now, we can only predict based on the association with the host plant. Because *A. acuminata* is a forest dweller, not an ornamental plant that regular household would have, possible habitats would be the Bogor Botanic Gardens (12.9 km away), or Sentul wooded areas (13.8 km away), or IPB campus (15.6 km away). Other smaller greeneries in the vicinity of our butterfly captive breeding facility are unlikely to be inhabited by both butterfly species without the presence of the host plants.

To know how well they could exist together in the captivity, our observation (Fig. 1) showed that at the beginning, in November 2016, *P. adamas adamas* male individuals were thriving but soon after male and female individuals of *T. helena helena* were released into the aviary, they started to decline in January 2017. Nonetheless, in March 2017 they seemed to co-exist quite well. The chart also showed that the trend of *T. helena helena* increased and decreased despite the low numbers of *P. adamas adamas* during many months. This indicates that the key factor to co-existence of both species seems to be the availability of sufficient host plants as also demonstrated by Curtis et al. (2015). We observed that both species did not chase each other away. Males of the same species were often seen approaching mating pairs, but the two species were never seen interacting negatively. However, larvae of *P. adamas adamas* often cut the lower stem of the host plants, to the extent that they would cause damage to the plants. This behavior needs attention for captive breeding operation. We would have had the opportunity to examine further if the facility was not relocated in October 2020. The plants including *A. acuminata* had grown so well in the area at the time of relocation and many of them did not survive the move.

It is not the aim of this paper to cover the life history of both species in great detail. The life history of *T. helena* was available from previous studies such as Nurjannah (2010) and excellent work of Tan (2011). The life history of *P. aristolochiae* observed in Assam, India was presented by Barua & Slowik (2007). We confirmed their findings of *T. helena*, but we found a slight deviation of the duration of each instar for early instar larvae and a quite large deviation of the duration of instar 4 and 5 (Table 2). The variations in the duration of early instars and late instars, understandably were due to the intensity of feeding activity. Some larvae spent 2 days as L1 and L2 but others spent 3 days. Also, as they matured to later instars, some would molt into the next instar in 3 days and others would take 4 or 5 days. The average duration spent as larvae was 20.8 days whether some started to grow faster at the beginning but usually they reached the pupation time at about the same. However, using only 10 individuals of *T. helena helena* reared at an IPB University's facility, about 15.6 km from our site, Nurjannah (2010) reported that the average duration taken as larval stage was 27 days, and it was 19 days for *T. helena hephaestus*, a Sulawesi subspecies. Our results on 71 individuals showed the average duration from eggs to adults was 45.9 days. Some eggs and larvae could not survive due to occasional attacks of parasitoids, as reported by Nacua et al. (2020), even within an enclosed environment. Nurjannah (2010) pointed out that species of Scelionidae (Hymenoptera) was a parasitoid of the eggs. A few pupae failed to eclose, and this could result from the poor development or possibly rough handling during their sensitive time of molting. Our observations indicated that they could endure some disturbances, except perhaps around their molting time. Most pupae of *T. helena helena* that were used for recording of pupal sound (Kurniati et al., 2018) successfully emerged as healthy individuals. Many adults could live well over 2–3 weeks, especially when they were eager eaters during larval stages.

As with *P. adamas adamas*, the larval stage consists of 5 instars and took 12.2 days on average. Barua & Slowik (2007) reported 4 instars for the larvae of *P. aristolochiae* in India. The average duration from eggs to adults was 32.6 days. Some adults could live over 2 weeks and some individuals were recorded still alive for 25 days.

The determination of the adult life span was obtained through finding broken wings and recording the activity of adults. Many individuals might live longer but we could not determine with certainty if we could not find the wings or took photos of them while they were still flying. This was quite challenging as they were usually on high places that we could not see the marks given on the wings indicating the number of the individual.

Observations on mating and egg laying behaviors were conducted whenever we saw the opportunities. Data presented on Table 4 showed that a newly emerged female (#6119) was approached and mated with a male (#6019) of 13 days old. This observation showed that a female can mate on the day of its emergence and that individuals can still mate at older age. The copulation also lasts for a long time, as we documented many pairs that were still in copulation until late in the afternoon.

Butterflies of both species would go to most flowers for nectars. Corbet (2000) and Tiple et al. (2009) pointed out that butterflies can use almost any flowers that can be reached by the proboscis (Corbet, 2000; Tiple et al., 2009). Even when there were so many other butterfly species inside the aviary, individuals of *T. helena helena* were also seen taking sugar solution that was placed on *Hibiscus* flowers on plastic trays.

Within three years (October 2016–September 2019), we observed a total of 1,361 individuals of the two species. As many as 700 individuals of *T. helena helena*, and 348 of *P. adamas adamas* eclosed successfully into imago, and they had been marvelous sights in the aviary and outside. The research was quite satisfying and we appreciated the lessons learned from the obstacles to improve the conditions.

CONCLUSION

This research has given some insights into the knowledge of both species for maintaining a sustainable captive breeding program. Habitat enrichment by planting the host plants can encourage butterflies to come and populate the area. When food plants are sufficient, *T. helena* and *P. adamas* can co-exist at the facility. Data on the duration of the life cycle of *T. helena helena* and of *P. adamas adamas* were presented.

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DIVERSITY OF THE CLOSED-NESTED HONEY BEES (APIDAE: *APIS* SPP.) AND THE TRADITIONAL HONEY COLLECTING AND BEEKEEPING IN FOUR ISLANDS OF INDONESIA

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ABSTRACT

The closed-nested honey bees are an important group that has been successfully bred traditionally and in a modern way. The traditional honey beekeeping practices are still favorable by local people living near natural habitats. Many rural areas in Indonesia are well known as producers of honey from the traditional honey collecting and traditional honey beekeeping of the closed-nested honey bees. However, there is limited information on the diversity of the honey bees that had supported the honey productions and their traditional honey beekeeping. This research was to provide an overview of the diversity of the honey bee species that are used in the wild honey collecting and their traditional honey beekeeping in four selected study sites in the islands of Java, Bawean, Kalimantan, and Peleng. We recorded three species of closed-nested native honey bees in the traditional honey collecting and traditional honey beekeeping, namely *Apis cerana*, *A. koschevnikovi*, and *A. nigrocincta*. We observed that traditional beekeeping of *A. cerana* was carried out in Tasikmalaya and Bawean Island, and that of *A. cerana* and *A. koschevnikovi* were carried out in Kayan Hilir. On Peleng Island, people do not do beekeeping but collect honey directly from the forest. Honey collecting and beekeeping practices are related to changes in the seasons of the flowering period in their habitats. The knowledge of the flowering period is needed to know the seasonal movement of honey bees from forest to village and vice versa.

Key words: *Apis cerana, A. koschevnikovi*, *A. nigrocincta,* Indonesia, traditional honey collecting and beekeeping

INTRODUCTION

Indonesia has the highest diversity of honey bees (*Apis* spp.) in the world (Hadisoesilo, 2001; Engel, 2012; Kahono et al., 2018). Except for some of the endemic subspecies in other countries, almost all species in the world occur in Indonesia, and most of them are island endemic (Otis, 1991; Hadisoesilo, 2001; Kahono, 2018).

There are two kinds of bee nesting types, single comb attached under branches or other hard substances at the open and multi combs hanging in many kinds of cavities (Otis, 1991; Hadisoesilo, 1997, 2001; Kahono et al., 2018). Three species of *Apis* nested in the cavities of the trees, rocks, and parts of buildings are *Apis nigrocincta*, *A. koschevnikovi*, and *A. cerana*. *Apis koschevnikovi* is endemic to Sumatra and Borneo, and *A. nigrocincta* is endemic to Wallacean region. *Apis cerana* was originally distributed in the eastern part of the Wallacean line, however, it is recently spread across the country (Hadisoesilo & Otis, 1996; Hadisoesilo et al., 1999; Kahono, 2018; Kahono et al., 2018).

The open-nested honey bees have never been successfully kept in a hive. Only some practices to attract incoming immigrant colonies of *A. dorsata* have been successfully developed in Indonesia (e.g., Hamidi, 2001; Purba, 2001a, b; Hadisoesilo & Kuntadi, 2007; Mikael et al., 2015; Jack et al., 2019; Jamiat et al., 2019). The successful practices of attracting colonies of *A. dorsata* have been the local identities (Hadisoesilo & Kuntadi, 2007; Gratzer et al., 2019; Kahono et al., recent data). The closed-nested or cavity-nested honey bees are the honey bee's species that live in natural hollows and human-made things such as parts of buildings. These honey bees are able to be bred in the traditional beekeeping of man-made hives, boxes, and natural tree trunk hollows. Since the introduction of the European framed honey bee, *A. mellifera* in 1985 to Java, the traditional honey beekeeping in some locations has been gradually changed to the framed modern style (Mashudi et al., 1998; Kahono et al., 2018). The framed modern honey beekeeping requires extra time, funds, and human effort. The introduction of the framed modern styles to the people of Nanggewer village, Pagerageung, Tasikmalaya (West Java), and Peleng Island (West Sulawesi) was not successful. Local people in both localities preferred to continue their traditional activities to collect the honey directly from the forest and to conduct traditional honey beekeeping (Kahono et al., recent data).

Traditional honey collecting is honey collecting from forests or the wild surroundings that are especially done by native inhabitants or indigenous tribes living in surrounding forests. It involved collecting the honey from cavities of the trees, limestones, undergrounds, and parts of buildings, with traditionally-made gears like man-made baskets, smoke torches, and sometimes with prayer or mantra. Traditional honey beekeeping (or traditional apiculture) is the keeping and maintenance of the honey bee colonies in traditional methods that have been carried out from generation to generation by local honey beekeepers (Onwumere et al., 2012; Sharma et al., 2014; Yilmaz, 2016). Some islands and rural areas are well known as producers of honey, however, there is limited information on the diversity of the honey bees producing the honey and the kind of traditional beekeeping practices that they have conducted.

The traditional honey collecting and beekeeping practices involve the knowledge on how to manage the bees in a local environment, which needs an awareness of local communities to the honey bees, its models, and the condition of its environments. These traditional practices may disappear if they are not passed on to the young generation. Serious habitat change, less suitable food resources, and awareness of local communities are factors to be considered. The study of traditional honey collecting and traditional honey beekeeping of close-nested honey bee species that show seasonal colony movement among two different ecosystem conditions has not been conducted yet. These data might be important to understand how to utilize them sustainably. The primary contribution of this paper is to provide an overview of the traditional close-nested honey collecting and beekeeping in the case of four different islands in Indonesia, namely Java, Bawean, Kalimantan, and Peleng.

MATERIALS AND METHODS

The study was conducted at four different locations and times: (1) in Nanggewer village, Pagerageung, Tasikmalaya, West Java in September 2015; (2) in Teluk Jati village, Tambak, Bawean Island, Gresik, East Java in May 2017; (3) in Data Dian village, Kayan Hilir, Malinau (North Kalimantan) in November 2014, and (4) in Alul village, Bulagi and Leme-leme Darat village, Buko, Banggai Kepulauan (Central Sulawesi) on 25 June-14 July 2019 (Fig. 1). Hereafter, we use the names of Tasikmalaya, Bawean Island, Kayan Hilir, and Peleng Island for further narrations. The type of villages that were used for the research is located surrounding the forests or wild environments and the people living in the villages were mainly native people. In the study sites of Tasikmalaya, Bawean Island, Kayan Hilir, and Peleng Island live Sundanese, Maduranese, Dayaknese, and Tolakinese tribes, respectively. We conducted research on the three main targets: the diversity of closed-nested honey bees, the traditional activities on the collection of honey in the forest or the wild, and

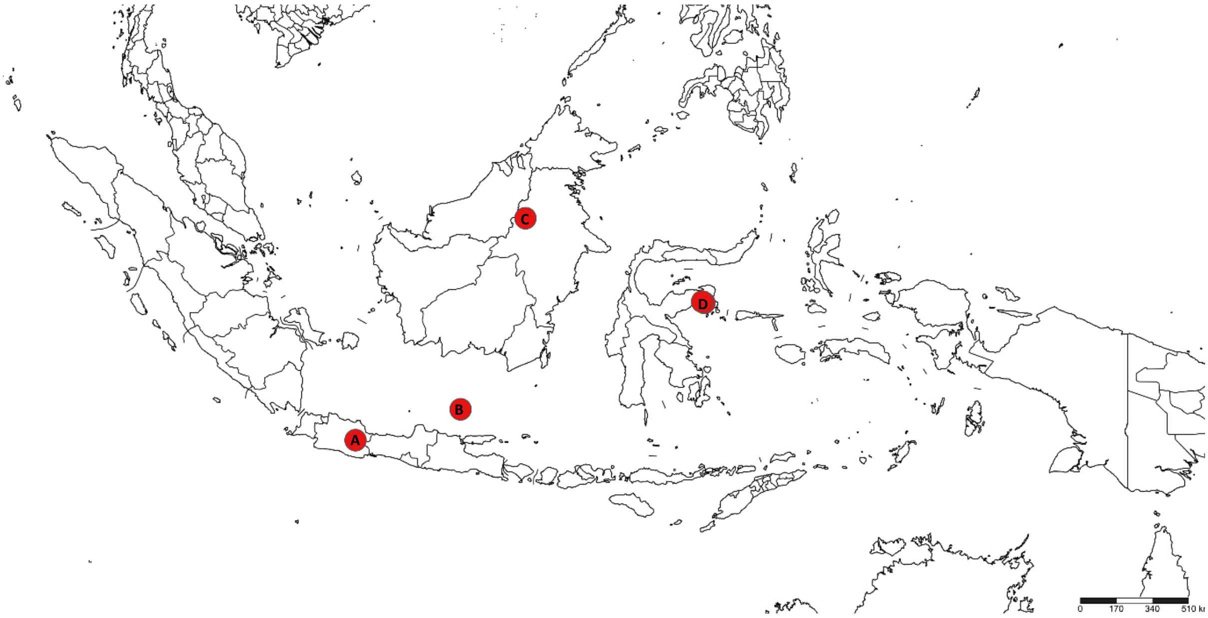

Figure 1. A map of the study sites: (A) Nanggewer Village, Pagerageung District, Tasikmalaya (West Java); (B) Teluk Jati Village, Tambak District (Bawean Island), Gresik (East Java) Regency; (C) Data Dian Village, Kayan Hilir District, Malinau Regency (North Kalimantan); (D) Alul Village, Bulagi District and Leme-leme Darat village, District Buko, Banggai Kepulauan Regency (Central Sulawesi).

traditional honey beekeeping. To obtain data on the honey bee diversity, specimens were collected at the close-nested honey bee colonies from each locality and the identification was done at the Laboratory of Entomology, Museum Zoologicum Bogoriense.

General information on both traditional honey collecting and honey beekeeping was gathered from the local government, local honey sellers, and local non-government organizations (NGOs). Descriptive qualitative describing the research by the selection of informants by snowball sampling technique (Naderifar, 2017) by determining the key informants to determine other informants who also know the local wisdom of the community such as honey collectors, honey beekeepers, and elderly people who know the history of their own traditional honey beekeeping and knowledge related to the ecology of the honey bee, climate, and phenology.

RESULTS

Diversity

All three Indonesian close-nested honey bees were recorded in this study: *A. cerana*, *A. koschevnikovi*, and *A. nigrocincta* (Table 1). *Apis cerana* was found in all locations, while *A. koschevnikovi* was only found in Kayan Hilir, and *A. nigrocincta* was only in Peleng Island with a low-frequency number of colonies. These three species can be distinguished from the body appearances directly by normal eyes without magnifications. Compared to *A. cerana*, the body color and size of *A. koschevnikovi* is a bit reddish and larger, while *A. nigrocincta* is a bit yellowish but similar in body sizes. All three belong to a group of multi-layers combs honey bee.

Table 1. Diversity of the close-nested honey bees in the four study sites

Species	Bawean Island	Tasikmalaya	Peleng Island	Kayan Hilir
Apis cerana	√	√	√	√
Apis koschevnikovi	-	-	-	√
Apis nigrocincta	-	-	√	-

All of these species were subject to traditional honey collecting and traditional honey beekeeping. The traditional honey collecting and the beekeeping of *A. cerana* were conducted by local people of the whole study sites of Tasikmalaya, Kayan Hilir, Bawean Island, and Peleng Island, while *A. koschevnikovi* and the honey collecting of *A. nigrocincta* were conducted only in Kayan Hilir and Peleng Island, respectively.

The Traditional Honey Bee Collection

These activities include collecting honey and parental colonies from the wild colonies, collecting honey and brood for food from the wild colonies, collecting parental colonies by inducement, and allowing wild colonies to move naturally to the urban area (Table 2).

The traditional honey collecting and the honey beekeeping practices in all study sites were usually not the main jobs but seasonal work besides their main job as farmers and animal breeders. In the period of honey collecting time, more people took more time to conduct the traditional honey collecting and honey beekeeping. People conducted the honey collecting in the wild only in one day, alone or sometimes accompanied by a younger family member. In Tasikmalaya and Bawean, the local honey collectors entered the forest or the wild surroundings to collect both honey and the broods in the combs for food of only one species, *A. cerana*. The same activity was also done to the species of *A. cerana* and *A. koschevnikovi* in Kayan Hilir and to the species of *A. cerana* and *A. nigrocincta* in Peleng Island. In Tasikmalaya, Bawean Island, and Kayan Hilir, the people who first discovered the honey bee nest was the owner and could collect the honey directly from the nest. In Peleng Island, people who first discovered the nest would make signs to the honey bee colonies to indicate ownership of the nest of the honey bee by bark incisions (Fig. 2), sometimes twigs tipped at the nest, ties, paint, or other marks. Those marks indicated that the colony belonged to the person, and others are prohibited from taking the honey.

Table 2. Main activities of the honey collecting and the traditional honey beekeeping

Activity	Bawean Island (*A. cerana*)	Tasikmalaya (*A. cerana*)	Peleng Island (*A. cerana* & *A. nigrocincta*)	Kayan Hilir (*A. cerana* & *A. koschevnikovi*)
Collect honey and parental colonies from the wild colonies	√	√	-	√
Collect honey and brood for food from the wild colonies	√	√	√	√
Collect parental colonies by inducement	unframed log and unframed wooden box	unframed wooden box	-	unframed log and unframed wooden box
Allow wild colonies moving naturally to the urban area	natural, unframed wooden box	natural, unframed wooden box	natural, artificial palm cavities	-

2019/07/05

Figure 2. A sign to indicate ownership of the nest of the honey bee at Peleng Island.

Different from the practice of honey collecting of the giant honey bees (*A. dorsata*) that frequently involved praying or reading the bee mantra before the collection (Kahono unpublished data), the honey collecting at the observed locations did not involve such ceremonies. The honey collectors entering the forests brought a traditional smoker made from dry leaves covered by fresh leaves of shrubs or burned cigarettes to drive the honey bees not to become aggressive and to drive the bees away beside the combs. They used a parang knife that farmers usually use for the agricultural activity to cut the honeycombs. In the case of harvesting near the village, they deposited the combs in the baskets. However, they put the honey nests and brood nests in separate plastic bags when harvesting honey in the wild.

The Traditional Honey Beekeeping

The traditional honey beekeeping of *A. cerana* was conducted at Tasikmalaya, Bawean, and Kayan Hilir, beekeeping of *A. koschevnikovi* was only conducted at Kayan Hilir. Honey beekeeping was initiated by the collection of parental colonies from the forest or the wild inside the cavities of the living and the dead trees (Fig. 3), the limestones, and the underground. However, collecting of the parental colonies of both *A. cerana* and *A. nigrocincta* was not carried out at Peleng Island.

At the same time as the honey collecting at Tasikmalaya, Bawean Island, and Kayan Hilir, they also collected both the combs that contain broods and the parental colonies that contain a queen, many workers, and some drones. The combs were put in plastic buckets and the colony members were put into a wooden collecting box sized about 40x30x30cm with a movable door side and a mosquito net for aeration (Fig. 4a). This box was useful for transferring the colony from the forest or the wild to the village or urban areas for honey beekeeping.

These honey bee parental colony collections were also done by honey bee colony induction at Tasikmalaya, Kayan Hilir, and Bawean Island by putting unframed logs (Fig. 4b) or unframed wooden boxes in the forest or the wild and keeping them there for several weeks to attract wild swarming honey bee colonies. When the induction boxes had been occupied and the brood had been built, in order to avoid their large predators such as the forest mouse and Javan eagle, and especially the honey bear and orangutan in Kayan Hilir; the colonies were immediately transferred to surrounding villages or rural areas and kept in the traditional hives or unframed boxes in order to ease the maintenance and keep the colonies safe. After the honey was harvested, a few colonies were kept stay in the hives and most of them escaped to the wild. These traditional beekeeping activities follow the natural phenology patterns of different times and periods of mass flowering between the forest trees, the wild, and urban plants that have been practiced since ancestral time.

a b

Figure 3. a. Honey bee colony inside dead trees; b. artificial nest cavities from cut *Onchosperma* palm trees.

a b

Figure 4. Traditional honey beekeeping: (a) with a wooden box to collect parental colony at Tasikmalaya; (b) colony induction by putting an unframed log.

The honey production at all study sites was sold to local residents and even sometimes sold to local markets, while the broods were for the consumption of their own family. The honey production in Bawean Island and Peleng Island were also sold out to the mainland of Java and Sulawesi, respectively. Some Bawean people have also exported the honey to Malaysia. These activities have helped the family's health and income.

DISCUSSION

The identification guide to the Indonesian honey bees has been published (Ruttner, 1988; Otis, 1991; Engel, 2012), and their large islands' national distribution has been compiled (Hadisoesilo & Kuntadi, 2007; Kahono et al., 2018). It is interesting to reveal the local wisdom of the ownership of the colonies. The ownership of close-nested honey bee colonies (*A. cerana* and *A. nigrocincta*) and of the giant honey bee (*A. dorsata*) in Peleng island is the temporary ownerships and it is the same as that of *A. dorsata* at the districts Nanga Lauk, Kapuas Hulu, Pontianak (Rosadi, 2020), at Malasari, district Nanggung, Kabupaten Bogor, West Java, and some other area in Sumatra (Kahono unpublished data). In many cases, the ownerships of sialang nesting trees of *A. dorsata* in Sumatra have become permanent ownerships.

The traditional beekeeping practices have been done in all study sites since ancestral times as local knowledge passed on to the descendants. These traditional activities follow the patterns of different times and periods of mass flowering between the forest and the wild trees and urban plants. The local honey collectors get used to their local knowledge of the time, the location, and the way to collect the honey. There are direct relationships between the existence of honey bees and the supporting environments (Winfree, 2010). Local people understand the major flowering season in the humid tropical country that generally starts from the end of the wet season until the middle of the dry season, as mentioned in Backer & Brink (1963). Natural forest and artificial human-made habitats show various distinctions of the major flowering seasons. The distance among ecosystem types is an important factor for the honey bee colonies to move from unfavorable ecosystems to better ones.

There are differences in the range of migrating and swarming flights of different species (Solberg, 1985; Dyer & Seely, 1994). The honey bee is a well-known seasonal migratory insect, *A. dorsata* is capable of long-distance migratory flight (Jack et al., 2019), however, the capability of the close-nested honey bee's movement is not so high compared to other bigger giant honey bees. The ecosystems surrounding the forest become important habitats to the migration of the honey bees (Winfree, 2010; Kahono, 2011; Kahono et al., 1999). Local people have followed the alternation of time periods or flowering dynamics between the forest trees and other wild plants alternating with plants in the rural environment. They believe that the honey bees adapt to those seasonal flowering patterns so that their movements instinctively follow the seasonal flowering patterns. The three species of honey bees seasonally move from forests to the rural areas and vice versa. During the flowering season of crops and other agricultural plants in the villages and rural areas, the bee colonies would come from the forest or the wild nearby, and vice versa from the forests or the wild to the villages or to the rural areas. The patterns of food resources dynamics between habitats over time require the ability of insects to move and adapt (Drake & Gatehouse, 1995; Waldbauer, 1996). The honey collecting was conducted based on those seasonal flowering alterations between the forest and the villages.

The environmental changes have made the honey bees move seasonally to find a better environment. With that knowledge, local people developed their traditional knowledge on honey collecting and honey beekeeping based on seasonal environmental changes. The annual seasonal movement of the endemic species of close-nested honey bee *A. nigrocincta* and the introduced species of *A. cerana* among the forest and the rural areas at Peleng island has been well known by local people. The bees nested in the forest and moved to the rural area in a certain period and the cycle continued annually. Before the colonies emigrated to the rural areas and surrounding villages at the end of the year, the local people had prepared artificial nest cavities from cut *Onchosperma* palm trees (Fig. 3b) for the emigrant colonies. However, there was very few *A. cerana* because from the 18 new emigrated colonies to the rural areas, 16 colonies (88,9%) were *A. nigrocincta* (Kahono et al., 2019).

The methods of the traditional honey beekeeping in the four study sites were strictly different from those in Turkey, India, Nigeria, and other countries (Onwumere & Onwukwe, 2012; Yilmaz, 2016). The collection of the parental colonies was conducted in the middle or the end periods of flowering at the forest in which the honey and the full broods were also collected. Traditional beekeeping practices can be applied continuously mainly due to the stability of the environment (Kahono et al., 2019) and some other socio-cultural conditions of the local communities. Although modern hives can be easily carried to different places, in some conditions modern beekeeping fails to be applied. For example, many colonies with a modern frame of honey beekeeping of *A. cerana* were introduced to Peleng Island and Tasikmalaya, but the keeping was not successful and the bees died or escaped to nature. Surprisingly *A. cerana* in Tasikmalaya and *A. cerana* and *A. nigrocincta* in Peleng Island conducted the same seasonal migration pattern that was also done by the giant honey bee *A. dorsata binghami* as reported by Nagir et al. (2016). Those honey bees' occupation dynamics were synchronized to the seasonal fluctuation of the flowering plants.

The distance of migration and foraging territory of smaller honey bees, in this case, *A. cerana* and *A. nigrocincta* were shorter and narrower compared to those of the giant honey bee. The physiological and ecological factors of the variety of species are consistent concerning insect migration (Dingle, 1972). Seasonal mass colony migrations were performed by the giant honey bee *A. dorsata* (Koeniger & Koeniger, 1980; Kahono et al., 1999). The mass seasonal migrations of close-nested honey bees *A. cerana* and *A. nigrocincta* in Peleng island and *A. cerana* at Tasikmalaya and Bawean Island were strongly triggered by the different phenology of both forests and urban habitats. The mass migration of the close-nested honey bees that were related to the seasonal flowering changes in Indonesia has not been reported before. The taste of honey in Peleng Island was different between the two close-nested species and *A. dorsata binghami*. The honey produced by *A. cerana* and *A. nigrocincta* were quite bitter compared to that of *A. dorsata binghami*. The differences in taste indicate that the nectar selected by the honey bees may come from different species of plants with different chemical compositions (Ball, 2007; Ajibola, 2015). To know the chemical composition, further biochemical research is necessary to be done.

Honey bees are important for honey production and also for the environment. About 90% of the world's plant species are pollinated by animals, and the primary animal pollinators in most ecosystems are bees (Bawa, 1990; Neff & Simpson, 1993; Linder, 1998). Clearly, bees are the most important group for pollination in the forests, in the wild, and in agricultural ecosystems, thus knowledge about honey collecting and honey beekeeping needs to be documented.

CONCLUSION

The diversity of the closed-nested honey bees at the four study sites was *A. cerana*, *A. koschevnikovi*, and *A. nigrocincta*. The traditional honey collecting and honey beekeeping depend on the flowering periods. People at Peleng Island did not conduct honey beekeeping but collected honey directly from the forest.

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LIST OF LAND SNAILS IN JAVA AND SEVERAL ADJACENT ISLANDS

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ABSTRACT

The malacofauna of Java has been most studied among the Indonesian islands, but the list of land snails in the area remains outdated. This study presents an updated check list of land snails in Java and its adjacent islands. This list is a compilation data from field work in Java conducted in 2013-2016, records from various museums in Europe and Indonesia, collections from private collectors, data from citizen sciences, and literatures. In total, 263 land snail species were recorded in Java and its adjacent islands. The number comprises of 36 families i.e. Subclass Neritimorpha (2 families), Caenogastropoda (6 families), and Heterobranchia (28 families). About 40% are species endemic to Java and among them have restricted distribution to certain areas. In addition, 5% or 13 introduced species were recorded in Java.

Key words: biodiversity, Gastropoda, Indonesia, Mollusca, terrestrial

INTRODUCTION

Java is among the main islands in Indonesia which covers 129km^2 or 6.7% of the whole of archipelago (BPS, 2017). Administratively, Java is divided into six provinces: Banten, DKI Jakarta, West Java, Central Java, DI Yogyakarta, and East Java. It is located between 6° 37’18” S (Panaitan Island, Banten) to 7°11’18” S (Kangean Islands, East Java) and 112° 38’47” E (Bawean Island, East Java) to 114°31’34” E (Alas Purwo, East Java). The island is covered by volcanic features, alluvial sediments, and areas of uplifted coral limestone. During the Quaternary period, the size of Java’s land coverage changed due to the sea-level fluctuations. Nevertheless, the lowland and montane forest in the area were larger in the Last Glacial Maximum (LGM) compared to the present condition (Cannon et al., 2009). The forest present today in Sumatra, Borneo, Peninsular Malaysia, and Java are believed to be refugia for the region’s biodiversity.

Java is the most populous island in the world and, accordingly, most of its area has been strongly modified by man. The island has suffered massive land use change throughout time. The area was divided into several land use types where only 5% of the island is covered by natural forest (Whitten et al., 1997; Purba et al., 2014). Forest in Java covers a total of 3,086,200 ha, consisting of 74,100 ha of primary forest, 788,200 ha of secondary forest and 2,240,000 ha of plantations (KLHK, 2016). The greatest threat to forest areas in Java today comes from anthropogenic factors, i.e. land conversions (forest destruction). In addition to habitat loss, the existence of forest inhabitants is also endangered by hunting/trade, invasive alien species, and climate change (Hughes, 2017).

There are 27,474 described land snails in the world (Molluscabase.org, 2021). Yet, the scientific knowledge of the species diversity is scarce. Land snail species tend to have very small ranges, sensitive to changes associated with human disturbance, and are, thus, especially prone to extinction by habitat destruction (Schilthuizen et al., 2005; Douglas et al., 2013).

The work of land snails in Java is the most complete compared to other islands in the Indonesian archipelago. The earliest recorded discovery of land snail in Java was conducted by Johan Coenraad van Hasselt (JC van Hasselt) in 1821-1823 and recorded 40 land snail species (Martens, 1867). The most comprehensive systematic work on land snails in Java was by Möllendorf (1897) and van Benthem Jutting (1941, 1948, 1950, 1952) who described 71 species and 171 species respectively. In addition, Vermeulen (1996) discovered four new species and added the list.

The number of land snail research in Java are also growing in the 21st century (Dharma, 2005; Heryanto et al., 2003; Heryanto, 2008, 2011, 2012, 2017; Marwoto, 2011; Nurinsiyah, 2015; Nurinsiyah et al., 2016; Nurinsiyah & Hausdorf, 2019; Mujiono & Priawandiputra, 2020; Nurinsiyah & Hausdorf, 2020; Nurhayati et al., 2021). In addition, discoveries of new land snail species in Java are rising (Dharma, 2007, 2014; Nurinsiyah & Hausdorf, 2017a, 2017b; Greķe, 2019; Nurinsiyah et al., 2019). In this paper, I aim to provide an updated checklist of land snails in Java and its adjacent islands, which administratively belong to the provinces in Java.

MATERIALS AND METHODS

The study is based on the material collected from field survey in Java and surrounding islands including Sempu and Madura Islands in 2013-2016. The list was also based on the examination of land snail collections from the Museum Zoologicum Bogoriense, Bogor, Indonesia (MZB), the Natural History Museum, London, United Kingdom (NHM), the Naturalis Biodiversity Center, formerly Rijksmuseum van Natuurlijke Historie, Leiden, The Netherlands (RMNH), the Senckenberg Museum, Frankfurt, Germany (SMF), the former Zoologisch Museum, Amsterdam, The Netherlands (ZMA; now in the RMNH), the Museum für Naturkunde, Berlin, Germany (ZMB), and the Zoological Museum of the University of Hamburg, Germany (ZMH). Finally, the list was completed with literature study. The checklist covers land snails from the Java mainland as well as its adjacent islands for instance the Panaitan, Peucang, and Dua islands (Banten), thousand islands in Jakarta Bay, Nusa Kambangan (Central Java), Sempu, Nusa Barung, Madura, Bawean and Kangean islands

(East Java). I excluded the list of land snails from Krakatau Islands because administratively they belong to Lampung Province (Sumatra).

Identification and validation processes referred to van Benthem Jutting (1948, 1950, 1952), Loosjes (1953), Butot (1955), Winter (1983), Dharma (1992, 2007, 2014), Winter & Vermeulen (1998), Vermeulen & Whitten (1998), Gomes & Thomé (2004), Heryanto (2011), and Páll-Gergely et al. (2020). The systematic arrangement and taxonomy status of the determined gastropods follows the classification of Bouchet et al. (2017) and Molluscabase.org.

RESULTS

A total of 263 land snail species of 36 families, i.e. Subclass Neritimorpha (2 families), Caenogastropoda (6 families), and Heterobranchia (28 families) were recorded in Java and adjacent islands (Table 1). Among them, 246 species were recorded in the main island of Java. Seventeen species were recorded only in the adjacent islands and not on the main island of Java. About 40% (104 species) of the 263 land snail species recorded were endemic to Java and its adjacent islands.

Table 1. Land snail of Java (*endemic species to Java and its adjacent islands; **introduced species to Java) The presence is indicated with (+)

No	**Subclass**	**Family**	**Species**	**Distribution**	
				Java	**Adjacent Islands**
1	Neritimorpha	Helicinidae	*Geophorus oxytropis* (Gray, 1839)	+	
2	Neritimorpha	Helicinidae	*Geophorus rollei (*Sykes, 1901)*		+
3	Neritimorpha	Helicinidae	*Sulfurina biconical* (Martens, 1867)	+	
4	Neritimorpha	Hydrocenidae	*Georissa javana* Möllendorff, 1897	+	+
5	Neritimorpha	Hydrocenidae	*Georissa laeviuscula* Möllendorff, 1897	+	
6	Caenogastropoda	Alycaeidae	*Chamalycaeus fruhstorferi* (Möllendorff, 1897)*	+	+
7	Caenogastropoda	Alycaeidae	*Chamalycaeus reticulatus* (Möllendorff, 1897)*	+	
8	Caenogastropoda	Alycaeidae	*Dicharax candrakirana* Nurinsiyah & Hausdorf, 2017*		+
9	Caenogastropoda	Alycaeidae	*Dicharax longituba* (Martens, 1864)	+	
10	Caenogastropoda	Alycaeidae	*Pincerna crenilabris* (Möllendorff, 1897)	+	
11	Caenogastropoda	Alycaeidae	*Stomacosmethis jagori* (Martens, 1860)	+	+
12	Caenogastropoda	Cyclophoridae	*Cyclophorus kibleri* Fulton, 1907*	+	
13	Caenogastropoda	Cyclophoridae	*Cyclophorus perdix* (Broderip & Sowerby, 1830)	+	+
14	Caenogastropoda	Cyclophoridae	*Cyclophorus rafflesi* (Broderip & Sowerby, 1830)	+	+

Table 1. (continued)

No	Subclass	Family	Species	Distribution	
				Java	Adjacent Islands
15	Caenogastropoda	Cyclophoridae	*Cyclotus discoideus* Sowerby, 1843	+	
16	Caenogastropoda	Cyclophoridae	*Cyclotus kangeanus* Schepman, 1909*		+
17	Caenogastropoda	Cyclophoridae	*Ditropopsis fruhstorferi* (Möllendorff, 1897)*	+	
18	Caenogastropoda	Cyclophoridae	*Japonia ciliocincta* (Martens, 1865)	+	
19	Caenogastropoda	Cyclophoridae	*Japonia trochulus* (Martens, 1867)		+
20	Caenogastropoda	Cyclophoridae	*Lagocheilus ciliferus* (Mousson, 1849)	+	+
21	Caenogastropoda	Cyclophoridae	*Lagocheilus convexus* Möllendorff, 1897*	+	
22	Caenogastropoda	Cyclophoridae	*Lagocheilus grandipilus* Böttger, 1891	+	
23	Caenogastropoda	Cyclophoridae	*Lagocheilus humilis* Möllendorff, 1897*	+	
24	Caenogastropoda	Cyclophoridae	*Lagocheilus macromphalus* Möllendorff, 1897*	+	
25	Caenogastropoda	Cyclophoridae	*Lagocheilus obliquistriatus* Bullen, 1904	+	+
26	Caenogastropoda	Cyclophoridae	*Leptopoma altum* Möllendorff, 1897	+	
27	Caenogastropoda	Cyclophoridae	*Leptopoma perlucidum* (Grateloup, 1840)	+	+
28	Caenogastropoda	Cyclophoridae	*Opisthoporus corniculus* (Mousson, 1849)*	+	+
29	Caenogastropoda	Cyclophoridae	*Pterocyclos sluiteri* O. Böttger, 1890*	+	
30	Caenogastropoda	Diplommatinidae	*Arinia yanseni* Nurinsiyah & Hausdorf, 2017	+	
31	Caenogastropoda	Diplommatinidae	*Diplommatina auriculata* Möllendorff, 1897	+	+
32	Caenogastropoda	Diplommatinidae	*Diplommatina baliana* Fulton, 1899	+	+
33	Caenogastropoda	Diplommatinidae	*Diplommatina calcarata* Möllendorff, 1897*	+	
34	Caenogastropoda	Diplommatinidae	*Diplommatina canaliculata* Möllendorff, 1887	+	
35	Caenogastropoda	Diplommatinidae	*Diplommatina cyclostoma* Möllendorff, 1897*	+	
36	Caenogastropoda	Diplommatinidae	*Diplommatina diplostoma* Rensch, 1931	+	
37	Caenogastropoda	Diplommatinidae	*Diplommatina halimunensis* Nurinsiyah & Hausdorf, 2017*	+	
38	Caenogastropoda	Diplommatinidae	*Diplommatina heryantoi* Nurinsiyah & Hausdorf, 2017*	+	

Table 1. (continued)

No	Subclass	Family	Species	Distribution	
				Java	**Adjacent Islands**
39	Caenogastropoda	Diplommatinidae	*Diplommatina heteroglypha* van Benthem Jutting, 1948*	+	
40	Caenogastropoda	Diplommatinidae	*Diplommatina javana* Möllendorff, 1897	+	
41	Caenogastropoda	Diplommatinidae	*Diplommatina kakenca* Nurinsiyah & Hausdorf, 2017*	+	
42	Caenogastropoda	Diplommatinidae	*Diplommatina majapahit* Greķe, 2019*	+	
43	Caenogastropoda	Diplommatinidae	*Diplommatina nevilli* (Crosse, 1879)	+	+
44	Caenogastropoda	Diplommatinidae	*Diplommatina perpusilla* Möllendorff, 1897*	+	
45	Caenogastropoda	Diplommatinidae	*Diplommatina planicollis* Möllendorff, 1897*	+	
46	Caenogastropoda	Diplommatinidae	*Diplommatina ristiae* Nurinsiyah & Hausdorf, 2017*	+	
47	Caenogastropoda	Diplommatinidae	*Diplommatina sulcicollis* Möllendorff, 1897*	+	
48	Caenogastropoda	Diplommatinidae	*Diplommatina tetragonostoma* Möllendorff, 1897*	+	
49	Caenogastropoda	Diplommatinidae	*Opisthostoma javanicum* van Benthem Jutting, 1932	+	+
50	Caenogastropoda	Diplommatinidae	*Opisthostoma uranoscopium* van Benthem Jutting, 1932*	+	
51	Caenogastropoda	Diplommatinidae	*Palaina gedeana* Möllendorff, 1897	+	
52	Caenogastropoda	Diplommatinidae	*Palaina nubigena* Möllendorff, 1897*	+	
53	Caenogastropoda	Pupinidae	*Pupina bipalatalis* Böttger, 1890*	+	
54	Caenogastropoda	Pupinidae	*Pupina compacta* Möllendorff, 1897*	+	
55	Caenogastropoda	Pupinidae	*Tylotoechus junghuhni* Martens, 1867*	+	
56	Caenogastropoda	Pupinidae	*Tylotoechus treubi* Böttger, 1890	+	
57	Caenogastropoda	Pupinidae	*Tylotoechus verbeeki* Möllendorff, 1897*	+	
58	Caenogastropoda	Assimineidae	*Anaglyphula tiluana* (Möllendorff, 1897)*	+	
59	Caenogastropoda	Assimineidae	*Omphalotropis columellaris* Quadras & Möllendorff, 1893	+	+
60	Heterobranchia	Ellobiidae	*Carychium javanum* Möllendorff, 1897	+	+
61	Heterobranchia	Ellobiidae	*Auriculastra semiplicata* (Adams & Adams, 1854)	+	
62	Heterobranchia	Ellobiidae	*Ellobium aurisjudae* (Linnaeus, 1758)	+	+

Table 1. (continued)

No	Subclass	Family	Species	Distribution	
				Java	**Adjacent Islands**
63	Heterobranchia	Ellobiidae	*Ellobium aurismidae* (Linnaeus, 1758)	+	+
64	Heterobranchia	Ellobiidae	*Ellobium tornatelliforme* (Petit de la Saussaye, 1843)	+	
65	Heterobranchia	Ellobiidae	*Ellobium scheepmakeri* (Petit de la Saussaye, 1850)	+	+
66	Heterobranchia	Ellobiidae	*Melampus castaneus* Megerle von Mühlfeld, 1816	+	
67	Heterobranchia	Ellobiidae	*Melampus cumingianus* (Récluz, 1846)	+	+
68	Heterobranchia	Ellobiidae	*Melampus fasciatus* (Deshayes, 1830)	+	+
69	Heterobranchia	Ellobiidae	*Melampus granifer* (Mousson, 1849)	+	
70	Heterobranchia	Ellobiidae	*Melampus luteus* (Quoy & Gaimard, 1832)	+	+
71	Heterobranchia	Ellobiidae	*Cassidula aurisfelis* (Bruguière, 1789)	+	+
72	Heterobranchia	Ellobiidae	*Cassidula faba* (Pfeiffer, 1853)	+	
73	Heterobranchia	Ellobiidae	*Cassidula nucleus* (Gmelin, 1791)	+	+
74	Heterobranchia	Ellobiidae	*Cassidula sowerbyana* (Pfeiffer, 1853)	+	
75	Heterobranchia	Ellobiidae	*Cassidula sulculosa* (Mousson, 1849)		+
76	Heterobranchia	Ellobiidae	*Laemodonta monilifera* (Adams & Adams, 1854)		+
77	Heterobranchia	Ellobiidae	*Laemodonta siamensis* (Morelet, 1875)	+	
78	Heterobranchia	Ellobiidae	*Laemodonta typica* (Adams & Adams, 1854)	+	
79	Heterobranchia	Ellobiidae	*Pythia castanea* (Lesson, 1831)		+
80	Heterobranchia	Ellobiidae	*Pythia imperforata* (Adams, 1850)	+	+
81	Heterobranchia	Ellobiidae	*Pythia pantherina* (Adams, 1850)	+	+
82	Heterobranchia	Ellobiidae	*Pythia plicata* (Gray, 1825)	+	+
83	Heterobranchia	Ellobiidae	*Pythia scarabaeus* (Linnaeus, 1758)	+	+
84	Heterobranchia	Ellobiidae	*Pythia trigona* (Troschel, 1838)	+	+
85	Heterobranchia	Ellobiidae	*Pythia undata* (Lesson, 1831)	+	+
86	Heterobranchia	Veronicellidae	*Filicaulis bleekeri* (Keferstein, 1865)	+	

Table 1. (continued)

No	Subclass	Family	Species	Distribution	
				Java	Adjacent Islands
87	Heterobranchia	Veronicellidae	*Laevicaulis alte* (Férussac, 1822)**	+	
88	Heterobranchia	Veronicellidae	*Semperula maculata* (Templeton, 1858)	+	+
89	Heterobranchia	Veronicellidae	*Semperula wallacei* (Issel, 1874)	+	
90	Heterobranchia	Veronicellidae	*Valiguna siamensis* (Martens, 1867)*	+	+
91	Heterobranchia	Rathouisiidae	*Atopos ouwensi* Collinge, 1908*	+	
92	Heterobranchia	Achatinidae	*Allopeas clavulinum* (Potiez & Michaud, 1838)**	+	+
93	Heterobranchia	Achatinidae	*Allopeas gracile* (Hutton, 1834)**	+	+
94	Heterobranchia	Achatinidae	*Geostilbia aperta* (Swainson, 1840)**	+	+
95	Heterobranchia	Achatinidae	*Glessula sumatrana* (Martens, 1864)	+	
96	Heterobranchia	Achatinidae	*Lissachatina fulica* (Bowdich, 1822)**	+	+
97	Heterobranchia	Achatinidae	*Paropeas achatinaceum* (Pfeiffer, 1846)	+	+
98	Heterobranchia	Achatinidae	*Paropeas acutissimum* (Mousson, 1857)	+	
99	Heterobranchia	Achatinidae	*Subulina octona* (Bruguière, 1789)**	+	+
100	Heterobranchia	Streptaxidae	*Gulella bicolor* (Hutton, 1834)**	+	+
101	Heterobranchia	Charopidae	*Corinomala baliana* (Rensch, 1930)	+	
102	Heterobranchia	Charopidae	*Discocharopa aperta* (Möllendorff, 1888)	+	+
103	Heterobranchia	Charopidae	*Philalanka micromphala* van Benthem Jutting, 1952	+	
104	Heterobranchia	Charopidae	*Philalanka nannophya* Rensch, 1932	+	+
105	Heterobranchia	Charopidae	*Philalanka setifera* Vermeulen, 1996	+	
106	Heterobranchia	Charopidae	*Philalanka thienemanni* Rensch, 1932	+	+
107	Heterobranchia	Charopidae	*Philalanka tjibodasensis* (Leschke, 1914)	+	
108	Heterobranchia	Charopidae	*Thysanota conula* (Blanford, 1865)	+	
109	Heterobranchia	Endodontidae	*Beilania philippinensis* (Semper, 1874)	+	
110	Heterobranchia	Helicodiscidae	*Stenopylis coarctata* (Möllendorff, 1894)	+	+

Table 1. (continued)

No	Subclass	Family	Species	Distribution	
				Java	Adjacent Islands
111	Heterobranchia	Succineidae	*Succinea gracilis* (Lea, 1841)*		+
112	Heterobranchia	Succineidae	*Succinea listeri* (Smith, 1889)*	+	+
113	Heterobranchia	Succineidae	*Succinea minuta* (Martens, 1867)	+	
114	Heterobranchia	Succineidae	*Succinea obesa* (Martens, 1867)	+	+
115	Heterobranchia	Achatinellidae	*Elasmias manilense* (Dohrn, 1863)	+	+
116	Heterobranchia	Achatinellidae	*Elasmias sundanum* (Möllendorff, 1897)	+	
117	Heterobranchia	Achatinellidae	*Lamellidea cylindrica* (Sykes, 1900)		+
118	Heterobranchia	Achatinellidae	*Lamellidea subcylindrica* (Möllendorff & Quadras, 1894)	+	+
119	Heterobranchia	Achatinellidae	*Truncatella guerinii* Villa & Villa, 1841	+	+
120	Heterobranchia	Pupillidae	*Pupoides coenopictus* (Hutton, 1834)		+
121	Heterobranchia	Cerastidae	*Rhachis zonulata* (Pfeiffer, 1846)**	+	+
122	Heterobranchia	Enidae	*Apoecus alticola* (Dharma, 1996)*	+	
123	Heterobranchia	Enidae	*Apoecus apertus* (Martens, 1863)		+
124	Heterobranchia	Enidae	*Apoecus glandula* (Mousson, 1848)	+	
125	Heterobranchia	Enidae	*Apoecus prillwitzi* (Möllendorff, 1897)*	+	
126	Heterobranchia	Enidae	*Apoecus tenggericus* (Möllendorff, 1897)	+	
127	Heterobranchia	Enidae	*Apoecus tenuiliratus* (Möllendorff, 1897)*	+	
128	Heterobranchia	Enidae	*Apoecus thraustus* (Möllendorff, 1897)	+	
129	Heterobranchia	Gastrocoptidae	*Gastrocopta euryomphala* Pilsbry, 1934		+
130	Heterobranchia	Gastrocoptidae	*Gastrocopta pediculus* (Shuttleworth, 1852)	+	+
131	Heterobranchia	Gastrocoptidae	*Gastrocopta recondita* (Tapparone-Canefri, 1883)	+	
132	Heterobranchia	Gastrocoptidae	*Gastrocopta servilis* (Gould, 1843)**	+	+
133	Heterobranchia	Gastrocoptidae	*Gyliotrachela fruhstorferi* (Möllendorff, 1897)*	+	
134	Heterobranchia	Gastrocoptidae	*Paraboysidia boettgeri* (Möllendorff, 1897)	+	

Table 1. (continued)

No	Subclass	Family	Species	Distribution	
				Java	Adjacent Islands
135	Heterobranchia	Pyramidulidae	*Pyramidula javana* (Möllendorff, 1897)*	+	
136	Heterobranchia	Truncatellinidae	*Truncatellina insulivaga* (Pilsbry & Hirase, 1904)*	+	
137	Heterobranchia	Valloniidae	*Pupisoma perpusillum* (Möllendorff, 1897)*	+	
138	Heterobranchia	Valloniidae	*Pupisoma circumlitum* Hedley, 1897	+	+
139	Heterobranchia	Valloniidae	*Pupisoma dioscoricola* (Adams, 1845)	+	+
140	Heterobranchia	Valloniidae	*Pupisoma moleculina* (van Benthem Jutting, 1940)	+	
141	Heterobranchia	Valloniidae	*Pupisoma orcella* (Stoliczka, 1873)	+	
142	Heterobranchia	Vertiginidae	*Insulipupa malayana* (Issel, 1874)	+	+
143	Heterobranchia	Vertiginidae	*Nesopupa nannodes* (Quadras & Möllendorff, 1898)	+	+
144	Heterobranchia	Vertiginidae	*Nesopupa novopommerana* Rensch, 1932	+	
145	Heterobranchia	Clausiliidae	*Juttingia fucosa* (Loosjes, 1963)*	+	
146	Heterobranchia	Clausiliidae	*Oospira cornea* (Küster, 1844)*	+	+
147	Heterobranchia	Clausiliidae	*Oospira fruhstorferi* (Möllendorff, 1897)*	+	
148	Heterobranchia	Clausiliidae	*Oospira javana* (Pfeiffer, 1841)*	+	+
149	Heterobranchia	Clausiliidae	*Oospira junghuhni* (Küster, 1844)	+	
150	Heterobranchia	Clausiliidae	*Oospira nubigena* (Möllendorff, 1897)*	+	
151	Heterobranchia	Clausiliidae	*Oospira orientalis* (Pfeiffer, 1842)*	+	
152	Heterobranchia	Clausiliidae	*Oospira salacana* (Böttger, 1890)*	+	
153	Heterobranchia	Clausiliidae	*Oospira schepmani* (Möllendorff, 1897)*	+	
154	Heterobranchia	Clausiliidae	*Phaedusa corticina* (Pfeiffer, 1842)	+	+
155	Heterobranchia	Clausiliidae	*Phaedusa moluccensis* (Martens, 1864)	+	
156	Heterobranchia	Phylomycidae	*Meghimatium bilineatum* (Benson, 1842)*	+	
157	Heterobranchia	Phylomycidae	*Meghimatium striatum* van Hasselt, 1824	+	
158	Heterobranchia	Agriolimacidae	*Deroceras laeve* (Müller, 1774)**	+	

Table 1. (continued)

No	Subclass	Family	Species	Distribution	
				Java	**Adjacent Islands**
159	Heterobranchia	Trochomorphidae	*Geotrochus bicolor* (Martens, 1864)	+	
160	Heterobranchia	Trochomorphidae	*Geotrochus conus* (Pfeiffer, 1841)*	+	
161	Heterobranchia	Trochomorphidae	*Geotrochus multicarinatus* (Böttger, 1890)*	+	
162	Heterobranchia	Trochomorphidae	*Trochomorpha concolor* Böttger, 1890*	+	
163	Heterobranchia	Trochomorphidae	*Trochomorpha froggatti* (Iredale, 1941)	+	+
164	Heterobranchia	Trochomorphidae	*Trochomorpha strubelli* Böttger, 1890*	+	+
165	Heterobranchia	Chronidae	*Kaliella barrakporensis* (Pfeiffer, 1853)	+	
166	Heterobranchia	Chronidae	*Kaliella dendrophila* (van Benthem Jutting, 1950)	+	
167	Heterobranchia	Chronidae	*Kaliella doliolum* (Pfeiffer, 1846)	+	+
168	Heterobranchia	Chronidae	*Kaliella microconus* (Mousson, 1865)	+	+
169	Heterobranchia	Chronidae	*Kaliella micula* (Mousson, 1857)	+	
170	Heterobranchia	Chronidae	*Kaliella platyconus* Möllendorff, 1897	+	+
171	Heterobranchia	Chronidae	*Kaliella scandens* (Cox, 1872)	+	+
172	Heterobranchia	Chronidae	*Vitrinopsis fruhstorferi* (Möllendorff, 1897)	+	
173	Heterobranchia	Dyakiidae	*Dyakia clypeus* (Mousson, 1857)	+	
174	Heterobranchia	Dyakiidae	*Dyakia rumphii* (Pfeiffer, 1842)	+	
175	Heterobranchia	Dyakiidae	*Elaphroconcha bataviana* (Pfeiffer, 1842)	+	+
176	Heterobranchia	Dyakiidae	*Elaphroconcha javacensis* (Férussac, 1821)	+	+
177	Heterobranchia	Dyakiidae	*Elaphroconcha patens* (Martens, 1898)*	+	
178	Heterobranchia	Dyakiidae	*Inozonites imitator* Möllendorff, 1897*	+	
179	Heterobranchia	Euconulidae	*Coneuplecta macrostoma* (Möllendorff, 1897)*	+	
180	Heterobranchia	Euconulidae	*Coneuplecta olivacea* Vermeulen, 1996	+	+
181	Heterobranchia	Euconulidae	*Coneuplecta sitaliformis* (Möllendorff, 1897)	+	+
182	Heterobranchia	Euconulidae	*Guppya gundlachi* (Pfeiffer, 1840)**	+	

Table 1. (continued)

No	Subclass	Family	Species	Distribution	
				Java	Adjacent Islands
183	Heterobranchia	Euconulidae	*Liardetia acutiuscula* (Möllendorff, 1897)	+	
184	Heterobranchia	Euconulidae	*Liardetia convexiconica* (Möllendorff, 1897)	+	+
185	Heterobranchia	Euconulidae	*Liardetia densetorta* (Möllendorff, 1897)	+	
186	Heterobranchia	Euconulidae	*Liardetia javana* (Böttger, 1890)	+	
187	Heterobranchia	Euconulidae	*Liardetia pisum* (Möllendorff, 1897)*	+	
188	Heterobranchia	Euconulidae	*Liardetia reticulata* van Benthem Jutting, 1950	+	
189	Heterobranchia	Euconulidae	*Liardetia viridula* (Möllendorff, 1897)	+	
190	Heterobranchia	Euconulidae	*Lamprocystis gedeana* Möllendorff, 1897*	+	
191	Heterobranchia	Helicarionidae	*Durgella pusilla* (Martens, 1867)	+	
192	Heterobranchia	Helicarionidae	*Durgella sundana* Rensch, 1930	+	
193	Heterobranchia	Helicarionidae	“*Helicarion*” *albellus* Martens, 1867	+	+
194	Heterobranchia	Helicarionidae	“*Helicarion*” *perfragilis* Möllendorff, 1897	+	
195	Heterobranchia	Helicarionidae	“*Helicarion*” *radiatulus* (Möllendorff, 1897)	+	
196	Heterobranchia	Ariophantidae	*Hemiplecta humphreysiana* (Lea, 1840)	+	+
197	Heterobranchia	Ariophantidae	*Hemiplecta kangeanensis* Schepman, 1913*		+
198	Heterobranchia	Ariophantidae	*Macrochlamys amboinensis* (Martens, 1864)**	+	
199	Heterobranchia	Ariophantidae	*Macrochlamys infans* (Reeve, 1854)	+	
200	Heterobranchia	Ariophantidae	*Macrochlamys spiralifer* Vermeulen, 1996	+	
201	Heterobranchia	Ariophantidae	*Microcystina chionodiscus* Vermeulen, 1996	+	+
202	Heterobranchia	Ariophantidae	*Microcystina circumlineata* (Möllendorff, 1897)	+	+
203	Heterobranchia	Ariophantidae	*Microcystina exigua* (Möllendorff, 1897)	+	
204	Heterobranchia	Ariophantidae	*Microcystina fruhstorferi* (Möllendorff, 1897)*	+	
205	Heterobranchia	Ariophantidae	*Microcystina gratilla* van Benthem Jutting, 1950	+	+
206	Heterobranchia	Ariophantidae	*Microcystina muscorum* van Benthem Jutting, 1959	+	+

Table 1. (continued)

No	Subclass	Family	Species	Distribution	
				Java	Adjacent Islands
207	Heterobranchia	Ariophantidae	*Microcystina nana* (Möllendorff, 1897)	+	+
208	Heterobranchia	Ariophantidae	*Microcystina sinica* Möllendorff, 1885	+	+
209	Heterobranchia	Ariophantidae	*Microcystina subglobosa* (Möllendorff, 1897)*	+	+
210	Heterobranchia	Ariophantidae	*Microcystina vitreiformis* (Möllendorff, 1897)	+	+
211	Heterobranchia	Ariophantidae	*Microparmarion austeni* Simroth, 1893*	+	
212	Heterobranchia	Ariophantidae	*Microparmarion strubelli* Simroth, 1893	+	
213	Heterobranchia	Ariophantidae	*Parmarion martensi* Simroth, 1893	+	
214	Heterobranchia	Ariophantidae	*Parmarion pupillaris* (Humbert, 1829)	+	
215	Heterobranchia	Camaenidae	*Amphidromus alticola* Fulton, 1896*	+	
216	Heterobranchia	Camaenidae	*Amphidromus banksi* Butot, 1954*		+
217	Heterobranchia	Camaenidae	*Amphidromus filozonatus* (Martens, 1867)*	+	+
218	Heterobranchia	Camaenidae	*Amphidromus furcillatus* (Mousson, 1849)	+	+
219	Heterobranchia	Camaenidae	*Amphidromus heerianus* (Pfeiffer, 1871)*	+	+
220	Heterobranchia	Camaenidae	*Amphidromus javanicus* (Sowerby, 1833)*	+	
221	Heterobranchia	Camaenidae	*Amphidromus jeffabbasorum* Thach, 2016*	+	
222	Heterobranchia	Camaenidae	*Amphidromus palaceus* (Mousson, 1849)	+	
223	Heterobranchia	Camaenidae	*Amphidromus perversus* (Linnaeus, 1758)	+	+
224	Heterobranchia	Camaenidae	*Amphidromus porcellanus* (Mousson, 1849)*	+	
225	Heterobranchia	Camaenidae	*Amphidromus sancangensis* Dharma, 2007*	+	
226	Heterobranchia	Camaenidae	*Amphidromus winteri* (Pfeiffer, 1849)*	+	
227	Heterobranchia	Camaenidae	*Bradybaena similaris* (Férussac, 1821)**	+	+
228	Heterobranchia	Camaenidae	*Chloritis crassula* (Philippi, 1844)*	+	
229	Heterobranchia	Camaenidae	*Chloritis fruhstorferi* Möllendorff, 1897*	+	+
230	Heterobranchia	Camaenidae	*Chloritis helicinoides* (Mousson, 1848)*	+	+

Table 1. (continued)

No	Subclass	Family	Species	Distribution	
				Java	Adjacent Islands
231	Heterobranchia	Camaenidae	*Chloritis transversalis* (Mousson, 1857)	+	+
232	Heterobranchia	Camaenidae	*Ganesella bantamensis* (Smith, 1887)*	+	
233	Heterobranchia	Camaenidae	*Landouria abdidalem* Nurinsiyah, Neiber & Hausdorf, 2019*	+	
234	Heterobranchia	Camaenidae	*Landouria ciliocincta* (Möllendorff, 1897)*	+	
235	Heterobranchia	Camaenidae	*Landouria conoidea* (Leschke, 1914)	+	
236	Heterobranchia	Camaenidae	*Landouria davini* Dharma, 2015*	+	
237	Heterobranchia	Camaenidae	*Landouria dharmai* Nurinsiyah, Neiber & Hausdorf, 2019	+	
238	Heterobranchia	Camaenidae	*Landouria epiplatia* (Möllendorff, 1897)*	+	
239	Heterobranchia	Camaenidae	*Landouria intumescens* (Martens, 1867)*	+	
240	Heterobranchia	Camaenidae	*Landouria kangeanensis* (Schepman, 1913)*		+
241	Heterobranchia	Camaenidae	*Landouria leucochila* (Gude, 1905)*	+	
242	Heterobranchia	Camaenidae	*Landouria madurensis* Nurinsiyah, Neiber & Hausdorf, 2019*		+
243	Heterobranchia	Camaenidae	*Landouria menorehensis* Nurinsiyah, Neiber & Hausdorf, 2019*	+	
244	Heterobranchia	Camaenidae	*Landouria monticola* van Benthem Jutting, 1950*	+	
245	Heterobranchia	Camaenidae	*Landouria moussoniana* (Martens, 1867)*	+	
246	Heterobranchia	Camaenidae	*Landouria naggsi* Nurinsiyah, Neiber & Hausdorf, 2019*	+	
247	Heterobranchia	Camaenidae	*Landouria nodifera* Nurinsiyah, Neiber & Hausdorf, 2019*	+	
248	Heterobranchia	Camaenidae	*Landouria nusakambangensis* Nurinsiyah, Neiber & Hausdorf, 2019*		+
249	Heterobranchia	Camaenidae	*Landouria pacitanensis* Nurinsiyah, Neiber & Hausdorf, 2019*	+	
250	Heterobranchia	Camaenidae	*Landouria pakidulan* Nurinsiyah, Neiber & Hausdorf, 2019*	+	+
251	Heterobranchia	Camaenidae	*Landouria parahyangensis* Nurinsiyah, Neiber & Hausdorf, 2019*	+	
252	Heterobranchia	Camaenidae	*Landouria petrukensis* Nurinsiyah, Neiber & Hausdorf, 2019*	+	
253	Heterobranchia	Camaenidae	*Landouria rotatoria* (Pfeiffer, 1842)*	+	
254	Heterobranchia	Camaenidae	*Landouria schepmani* (Möllendorff, 1897)*	+	

Table 1. (continued)

No	Subclass	Family	Species	Distribution	
				Java	Adjacent Islands
255	Heterobranchia	Camaenidae	*Landouria sewuensis* Nurinsiyah, Neiber & Hausdorf, 2019*	+	
256	Heterobranchia	Camaenidae	*Landouria smimensis* (Mousson, 1848)*	+	
257	Heterobranchia	Camaenidae	*Landouria sukoliloensis* Nurinsiyah, Neiber & Hausdorf, 2019*	+	
258	Heterobranchia	Camaenidae	*Landouria tholiformis* Nurinsiyah, Neiber & Hausdorf, 2019*	+	
259	Heterobranchia	Camaenidae	*Landouria tonywhitteni* Nurinsiyah, Neiber & Hausdorf, 2019*	+	
260	Heterobranchia	Camaenidae	*Landouria winteriana* (Pfeiffer, 1842)	+	
261	Heterobranchia	Camaenidae	*Landouria zonifera* Nurinsiyah, Neiber & Hausdorf, 2019*	+	
262	Heterobranchia	Camaenidae	*Pseudopartula arborascens* Butot, 1955*	+	+
263	Heterobranchia	Camaenidae	*Pseudopartula galericulum* (Mousson, 1849)	+	

Many of the endemic species in Java are restricted to a small region. Among the total number of species that occur in Java, 53% (139 species) were recorded in karst areas. Twenty-five species occur exclusively in karst areas. Each of the fourteen of these karst-exclusive species were each found only in a single karst area. For instance, among 27 *Landouria* species in Java, 21 species have restricted distributions and are only recorded in small range areas in Java (Nurinsiyah et al., 2019). From 23 diplommatinids, 12 species were recorded only in non-karst (volcanic/mountain) areas. The records of these small range endemic forest species might indicate that small scale forest refugia probably existed during the glacial period.

DISCUSSION

Based on the extremely high species richness of plants and vertebrates, Indonesia is listed as one of the mega diversity countries (Reid, 1998). Furthermore, the country is also included among the 25 biodiversity hotspots (Sundaland) based on the number of endemic species and the degree of threat (Myers et al., 2000). Fourteen percent of the land snail species known in Indonesia occur in Java (Hausdorf, 2019). The number of land snail species in Java is slightly differ from Sumatra and Sulawesi, which have larger areas (Table 2). The land snail species diversity in the two latter islands might be underestimated due to the lack of malacological study in these areas. This is the case not only for snails, but also for other invertebrate taxa that are often neglected.

Table 2. Land snail species diversity in the archipelago (source: adapted from Hausdorf, 2019)

Island	**Area (km^2)**	**Number of Species**
Sumatra	473,481	276
Java & adjacent islands	129,438	263
Bali & Nusa Penida	5,780	126
Borneo	743,330	558
Sulawesi	180,680	253

The 263 land species in Java and adjacent islands is a great increment from the previous comprehensive list which was 171 land snail species (van Benthem Jutting, 1941, 1948, 1950, 1952). The additional species came from new record of native species, new record of introduced species, and newly described species. In the past two decades there were 26 new species of Gastropods have been described from Java. There were also fossil species of Gastropods described (Dharma, 2007, 2021) but they are not included in the list. Whitten et al. (1997) listed seven introduced species from Java i.e. *Allopeas gracile*, *Lissachatina fulica*, *Subulina octona*, *Gulella bicolor*, *Rachis zonulata*, *Gastrocopta servilis,* and *Bradybaena similaris*. The number was added to 13 introduced species (Nurinsiyah & Hausdorf, 2019). The widely distributed introduced species occur mainly in the disturbed areas and modified habitats. The proportion of introduced species abundance in an area can be use as indicator for habitat disturbance (Nurinsiyah et al., 2016).

Among the 17 land snail species found on the adjacent islands (not in mainland), nine species are endemic to a particular island. The species of *Geophorus rollei*, *Cyclotus kangeanus*, *Hemiplecta kangeanensis*, and *Landouria kangeanensis* were found only in Kangean island (van Benthem Jutting, 1941). The island is located more than 120km from the mainland Java even though administratively belongs to the Province of East Java. There are also species endemic to adjacent island located less than 1km away from the mainland Java. *Dicharax candrakirana* is endemic to Sempu Is. and *Landouria nusakambangensis* is endemic to Nusa Kambangan Is. (Nurinsiyah & Hausdorf, 2017b; Nurinsiyah et al., 2019). The former island is a nature reserve, whereas the latter is a prison island which public have limited access to enter the area. However, there is a concession area for limestone quarry in the northern part of the Nusa Kambangan Is. Although more than 50% of the concession area is designated for conservation forest, land coverage and habitat sustainability for the forest inhabitants needs to be ensured.

Terrestrial mollusk is one of the fauna groups that is often overlooked and abandoned from the conservation spotlight. It was estimated that this group may have lost 7% of the total described species on Earth (Régnier et al., 2015). Although the work of land snails in Java is the most complete compared to other islands in the Indonesian archipelago, monitoring the sustain population in Java is crucial. Furthermore, there will always be a yet discovered taxa or systematically problematic taxa in this well-known island awaiting scientific discovery.

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