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International Dragonfly Fund - Report
Journal of the International Dragonfly Fund

1- 25

Rory A. Dow & F.R. Stokvis

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Published: 13.08.2018

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ISSN 1435-3393

The International Dragonfly Fund (IDF) is a scientific society founded in 1996 for the improvement of odonatological knowledge and the protection of species.
Internet: http://www.dragonflyfund.org/

This series intends to publish studies promoted by IDF and to facilitate cost-efficient and rapid dissemination of odonatological data..

Editorial Work: Rory A. Dow, Milen Marinov and Martin Schorr
Layout: Martin Schorr
IDF-home page: Holger Hunger
Printing: Colour Connection GmbH, Frankfurt
Impressum: Publisher: International Dragonfly Fund e.V., Schulstr. 7B, 54314 Zerf, Germany. E-mail: oestlap@online.de
Responsible editor: Martin Schorr

Cover picture: ***Idionyx* species cf *yolanda***
Photographer: Rory A. Dow

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Odonata from Gunung Melatai and two other locations in Kapit Division, Sarawak, with a review of the genus *Heliogomphus* in Borneo, Peninsular Malaysia and Singapore

Rory A. Dow[1,2] & Frank R. Stokvis[1]

[1]Naturalis Biodiversity Center, P.O. Box 9517, 2300 RA Leiden, The Netherlands
E-mail: rory.dow230@yahoo.co.uk
[2]Sarawak Museum Campus Project, Jabatan Muzium Sarawak, Jalan Barrack, 9300 Kuching, Sarawak, Malaysia

Abstract
Records of Odonata from Gunung Melatai, Nanga Gaat and the Kastima Logging area, all in Sarawak's Kapit Division, are presented. The most notable records are of *Matronoides cyaneipennis* Förster, 1897 and *Heliogomphus blandulus* Lieftinck, 1929. A distribution map for *Matronoides cyaneipennis* and updated distribution maps for three species from the *Coeliccia borneensis*-group are given. Tentative identifications to species of previously published records of *Idionyx* females are given. The genus *Heliogomphus* in Borneo, Peninsular Malaysia and Singapore is reviewed and a simple one marker molecular analysis is presented for the genus in this region. Based on re-examination of specimens from the genus and the molecular results, an additional member of the genus is reported from Borneo: *H.* sp. cf *olivaceus* Lieftinck, 1961. Although both morphological and molecular results remain incomplete, it does appear likely that there is at least one more species of *Heliogomphus* present in Borneo than has been recognised until now, and that *H. borneensis* Lieftinck, 1964 may be a junior synonym of *H. kelantanensis* (Laidlaw, 1902).

Key words: Odonata, *Coeliccia borneensis*-group, *Heliogomphus*, *Idionyx*, *Matronoides*, gene trees, COI.

Introduction

In September 2015 the first author made an IDF funded trip to Gunung Melatai (peak approximately 1880m a.s.l.), a mountain at the border between Sarawak and Indonesia, in Sarawak's Kapit Division. Unfortunately the trip coincided with the 2015 El Niño event, and large fires burning in West Kalimantan created a severe haze in many parts of Sarawak. In the Gunung Melatai area the haze was so severe that visibility was down to 500m on most days and there was effectively no sunshine. Other factors contributed to this trip being probably the least successful that the first author has made in Sarawak with IDF funding. The vehicle broke down almost immediately on departure from Kapit Town, and the resulting delay led to a missed appointment at a gate in the Nanga Gaat area on the logging road leading to Gunung Melatai. This gate is normally locked and only opened by arrangement with the timber company (WTK Holdings Berhad) which has the timber licences in the Gunung Melatai area, since this was during a public holiday, once the appointment was missed there was no one to open it for several days, leaving the party stranded in the Nanga Gaat area. The first author made the most of this delay by sampling in the Nanga Gaat area, and these results are also included here. Once the Melatai area was reached, it was discovered that the terrain was so steep and landslide prone that working there was extremely hazardous. Areas of as-yet unlogged forest were accessible via a narrow logging road driven across an extremely steep slope of the mountain, and at the end of another logging road almost at the border, but even in the uncut forest there were signs of landslides everywhere and it was evident that most of the streams we sampled had been seriously affected by landslides in the not-too-distant past. The furthest and highest parts of the logging road on Melatai had to be judged too dangerous to use after the vehicle was almost hit by a landslide, which would have pushed it into the ravine below. Attempts to reach higher altitudes in the uncut areas by walking up ridges (the normal method) were thwarted on every occasion because parts of the ridge were encountered that had collapsed during landslides and were still too unstable to traverse. These factors limited the sampling that could be conducted and the altitude that that could be reached, and the lack of sunlight undoubtedly reduced the number and variety of odonates flying. There were also many frustrating sightings of interesting looking Anisoptera, including *Chlorogomphus*, which stubbornly refused to be caught.

We have also included records from another part of Kapit Division, the Kastima logging area in Belaga district, made during a short survey as part of a High Conservation Value Forest (HCVF) assessment in 2016. Fig. 1 shows the positions in Sarawak of all of the areas reported on here.

Figure 1. Positions of the sampled areas in Sarawak. Base image from Google Earth.

This paper is divided into two parts. The first part deals with the results of the surveys outlined above. One of the most significant finds during the Gunung Melatai trip was a mature male of the poorly known *Heliogomphus blandulus* Lieftinck, 1929. This find, re-examination of specimens in the collection of the first author and some in the Naturalis Biodiversity Center, and interesting but as-yet inadequate molecular results for the genus suggested to us that a brief review of the genus might be useful. In the second part of the paper we give such review, summarising available knowledge of *Heliogomphus* in Borneo, Peninsular Malaysia and Singapore and present COI gene trees for the genus in this region.

Part I: Species collected at Gunung Melatai, Nanga Gaat and the Kastima Logging area

Locations

Nanga Gaat locations:

1. Streams in disturbed forest: (a) ca 113-150m 1.7352N, 113.3384E; (b) ca 243m, 1.7472N, 113.3487E; (c) ca 310m, 1.7412N, 113.3846E.
2. A pond by a logging road, ca 148m, 1.7398N, 113.3402E.
3. By logging roads etc.

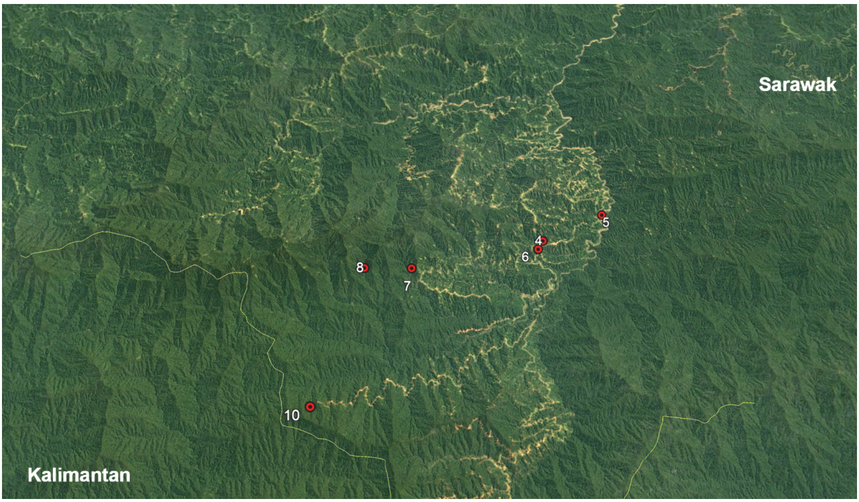


Figure 2. Sampling sites in the Gunung Melatai area. Base image from Google Earth.

Gunung Melatai Locations (Fig. 2 shows the Gunung Melatai locations in more detail):

4. Stream at camp site, logged forest, ca 630-680m, 1.3211N, 113.6733E.
5. Stream down road from camp, logged forest, ca 396-418m, 1.3328N, 113.6909E.
6. Small streams near camp, logged forest, ca 600m, 1.3181N, 113.6716E.

7. Stream system crossing road at ca 900m, sampled to ca 1050m, unlogged forest but heavily disturbed by past landslides around the stream, 1.3095N, 113.6316E.
8. Stream system crossing road at ca 1000m, sampled to ca 1350m, unlogged forest, disturbed by landslides, 1.3058N, 113.6182E.
9. Other stream systems crossing the road above 1000m, unlogged forest, but only sampled near road due to extreme steepness.
10. Streams in unlogged forest very near border with Kalimantan, ca 1200m, 1.2643N, 113.6034E.
11. Pools on and beside old logging tracks, by logging road etc.

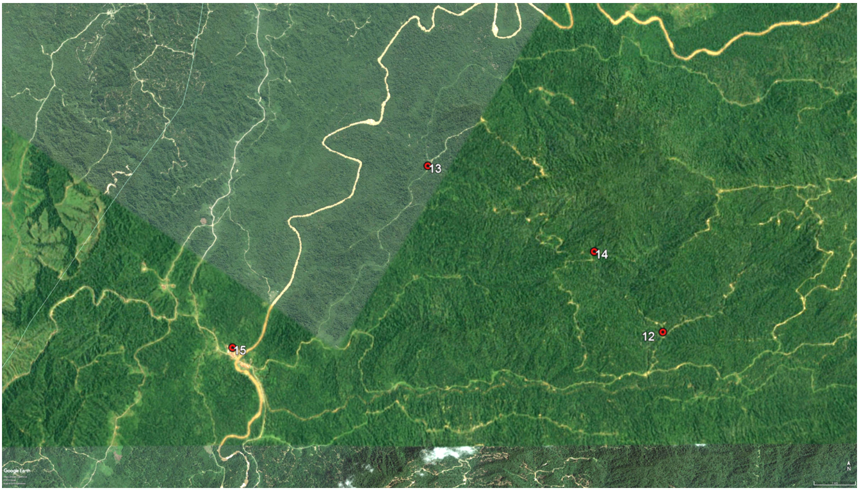


Fig. 3. Sampling sites in the Kastima logging area. Base image from Google Earth.

Kastima Logging area locations (Fig. 3 shows the Kastima locations in more detail):
12. Sungai Kayan and tributaries, disturbed forest, ca 180-270m, 2.838N, 113.8327E.
13. Sungai Pesun and tributaries, disturbed forest, ca 160-200m, 2.8712N, 113.7856E.
14. Stream on steep hill, disturbed forest, ca 450-550m, 2.8541N, 113.8184E.
15. Ponds etc., at the logging camp and besides logging roads, coordinates at camp, 2.8347N, 113.7464E.

List of species

Frequently occurring collectors names are abbreviated as follows (anak abbreviated as ak): MB - Manau ak Budi, RD - R.A. Dow, LS - Luke Southwell.

Zygoptera

Platystictidae

Drepanosticta acteaon Laidlaw, 1934

Material listed in Dow (2017), locations **7**, **8**, **14.**

Drepanosticta attala Lieftinck, 1934

12 – ♂, 21.vi.2016, RD.

Drepanosticta species cf *crenitis* Lieftinck, 1933

1b – ♀, 5.ix.2015, MB. **1c** – ♀, 6.ix.2015, RD. **14** – ♀, 23.vi.2016, RD.

Drepanosticta dulitensis Kimmins, 1936

1c – ♂, 6.ix.2015, RD. **8** – ♂, 10.ix.2015, MB. **10** – ♂, ♀, 15.ix.2015, RD. **14** – ♂, 23.vi.2016, RD.

Drepanosticta rufostigma (Selys, 1886)

Material listed in Dow (2017); locations **1a**, **1b**, **1c**, **5**, **8**, **12**, **13**, **14.**

Drepanosticta versicolor Laidlaw, 1913

1c – 4 ♂♂, 6.ix.2015, RD. **4** – ♂, 10.ix.2015, RD. **6** – 5 ♂♂, 13.ix.2015, RD. **14** – 2 ♂♂, 23.vi.2016, RD.

Telosticta longigaster Dow & Orr, 2012

1a – 2 ♂♂, 5.ix.2015, RD. **1b** – 2 ♂♂, 5.ix.2015, MB. **1c** – 3 ♂♂, 6.ix.2015, RD. **7** – 9 ♂♂, 8.ix.2015, RD. **8** – ♂, 12.ix.2015, MB; 2 ♂♂, 12.ix.2015, RD; 2 ♂♂, 14.ix.2015, MB; ♂, 14.ix.2015, LS. **10** – ♂, 2 ♀♀, 15.ix.2015, MB & LS; 5 ♂♂, 15.ix.2015, RD. **13** – ♂, 22.vi.2016, RD. **14** – 3 ♂♂, ♀, ♂+♀, 23.vi.2016, RD.

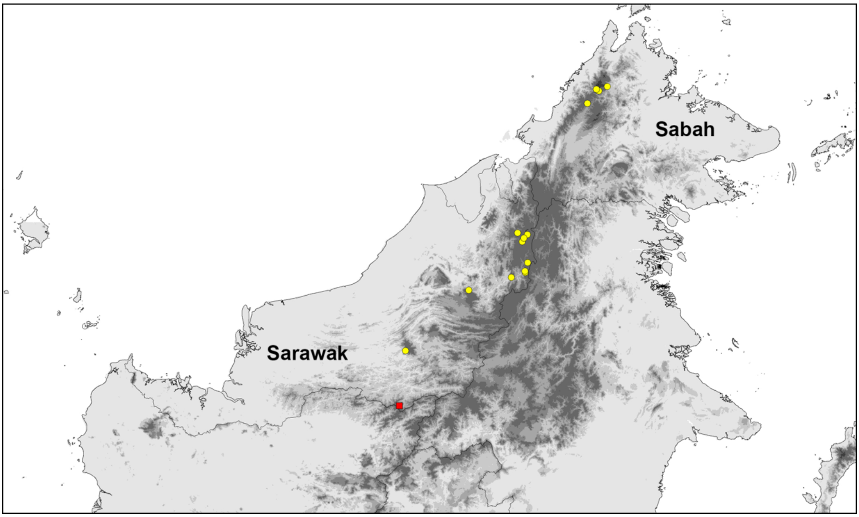


Fig. 4. Known distribution of *Matronoides cyaneipennis*. Red square: Gunung Melatai record; yellow circles: other records. Map made using DIVA-GIS.

Calopterygidae

Matronoides cyaneipennis Förster, 1897

A population found on Gunung Melatai is the most southern yet found of this species. Fig. 4 shows the known distribution of *M. cyaneipennis*, note that some of the data used to create this map has not yet been published.

8 – ♀, 10.ix.2015, LS; ♂, 11.ix.2015, RD; 3 ♂♂, 12.ix.2015, RD; ♀, 14.ix.2015, MB; ♂, 14.ix.2015, RD; ♀, 14.ix.2015, LS.

Neurobasis longipes Hagen, 1887

12 – ♂, 21.vi.2016, RD. **13** – ♂, 23.vi.2016, M. Tarang & N. Megom.

Vestalis amaryllis Lieftinck, 1965

6 – ♂, 13.ix.2015, RD.

Vestalis amnicola Lieftinck, 1965

4 – 9 ♂♂, 10.ix.2015, RD. **5** – ♂, 13.ix.2015, RD. **6** – ♂, 13.ix.2015, MB; 3 ♂♂, 13.ix.2015, LS. **7** – 3 ♂♂, 8.ix.2015, RD. **8** – 2 ♂♂, 12.ix.2015, RD; 3 ♂♂, 14.ix.2015, LS.

Vestalis amoena Hagen in Selys, 1853

12 – 5 ♂♂, 21.vi.2016, RD. **13** – 4 ♂♂, 22.vi.2016, RD; 2 ♂♂, 22.vi.2016, M. Tarang & N. Megom.

Vestalis atropha Lieftinck, 1965

1a – 3 ♂♂, 5.ix.2015, RD. **1c** – 2 ♂♂, 6.ix.2015, MB; ♂, 6.ix.2015, RD; 2 ♂♂, 6.ix.2015, LS. **12** – ♂, 21.vi.2016, RD. **13** – ♂, 22.vi.2016, RD; ♂, 22.vi.2016, M. Tarang & N. Megom. **14** – 4 ♂♂, 23.vi.2016, RD.

Vestalis beryllae Laidlaw, 1915

1b – ♂, 5.ix.2015, MB. **1c** – ♂, 6.ix.2015, MB. **8** – ♂, 12.ix.2015, RD. **14** – 2 ♂♂, 23.vi.2016, RD.

Chlorocyphidae

Heliocypha biseriata (Selys, 1859)

1a – ♂, 5.ix.2015, RD. **12** – ♂, 21.vi.2016, RD. **13** – ♂, 22.vi.2016, RD. **14** – ♂, ♀, 22.vi.2016, M. Tarang & N. Megom.

Rhinocypha aurofulgens Laidlaw, 1931

1a – ♂, 5.ix.2015, RD. **5** – 3 ♂♂, 13.ix.2015, RD. **12** – 3 ♂♂, 21.vi.2016, RD.

Rhinocypha spinifer Laidlaw, 1931

8 – ♂, 12.ix.2015, MB.

Rhinocypha species cf *spinifer* Laidlaw, 1931

1c – ♀, 6.ix.2015, RD.

Devadattidae

Devadatta aran Dow, Hämäläinen & Stokvis, 2015

7 – 2 ♂♂, ♀, 10.ix.2015, MB & LS; **14** ♂♂, 12.ix.2015, MB; 3 ♂♂, 12.ix.2015, RD; 2 ♂♂, 14.ix.2015, MB; ♀, 14.ix.2015, RD. **8** – 4 ♂♂, 8.ix.2015, RD. **9** – 3 ♂♂, 12.ix.2015, LS. **10** – 7 ♂♂, 15.ix.2015, MB & LS; 5 ♂♂, 15.ix.2015, RD.

Devadatta clavicauda Dow, Hämäläinen & Stokvis, 2015

6 – ♂, 13.ix.2015, RD.

Devadatta somoh Dow, Hämäläinen & Stokvis, 2015

1a – 5 ♂♂, 5.ix.2015, RD. **1b** – 2 ♂♂, ♀, 5.ix.2015, MB. **1c** – 5 ♂♂, ♀, 6.ix.2015, RD; ♂, 6.ix. LS. **14** – 5 ♂♂, 23.vi.2016, RD.

Euphaeidae

Euphaea impar Selys, 1859

1c – ♂, 6.ix.2015, MB; ♂, 6.ix.2015, RD; ♂, 6.ix.2015, LS. **12** – ♂, 21.vi.2016, RD. **13** – ♂, 22.vi.2016, RD.

Euphaea subcostalis Selys, 1873

1a – 4 ♂♂, 5.ix.2015, RD. **1c** – ♂, 6.ix.2015, RD. **4** – ♂, 10.ix.2015, RD. **5** – ♂, ♀, 13.ix.2015, MB. **12** – 6 ♂♂, 21.vi.2016, RD. **13** – 8 ♂♂, 22.vi.2016, RD. **14** – ♂, 23.vi.2016, RD; 3 ♂♂, 23.vi.2016, M. Tarang & N. Megom.

Euphaea subnodalis (Laidlaw, 1915)

4 – 5 ♂♂, 10.ix.2015, RD. **5** – 2 ♂♂, 13.ix.2015, MB.

Philosinidae

*Rhinagrion borneense (*Selys, 1886)

12 – ♂, 21.vi.2016, RD.

Platycnemididae

Dow (2010) includes distribution maps of *Coeliccia borneensis*-group species; these have become out-dated. Up-to-date distribution maps for the *C. borneensis*-group species listed in this paper are given here; note that some of the data used to create these maps have not yet been published.

Coeliccia borneensis (Selys, 1866)

The currently known distribution of this species or complex of species is shown in Fig. 5.

1c – ♂, 6.ix.2015, RD. **7** – 10 ♂♂, 2 ♀♀, 8.ix, RD; ♂, 9.ix.2015, RD. **10** – ♀, 15.ix.2015, MB & LS; 7 ♂♂, 15.ix.2015, RD.

Coeliccia campioni Laidlaw, 1918

The currently known distribution of this species is shown in Fig. 6.

1c – ♂, 6.ix.2015, RD. **6** – 5 ♂♂, 13.ix.2015, RD. **14** – ♂, 23.vi.2016, RD.

Coeliccia cyaneothorax Kimmins, 1936

1b – ♂, 5.ix.2015, MB. **4** – 4 ♂♂, 10.ix.2015, RD. **12** – ♂, ♂+♀, 21.vi.2016, RD.

Coeliccia kenyah Dow, 2010

The currently known distribution of this species is shown in Fig. 6.

14 – 6 ♂♂, 23.vi.2016, RD.

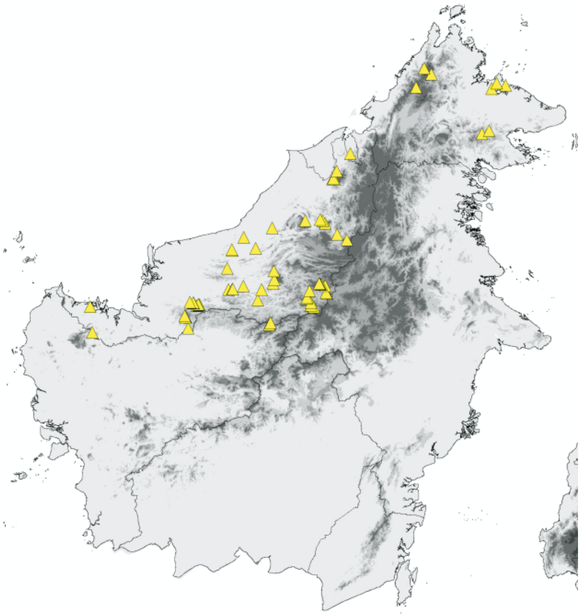


Fig. 5. Known distribution of *Coeliccia borneensis*. Map made using DIVA-GIS.

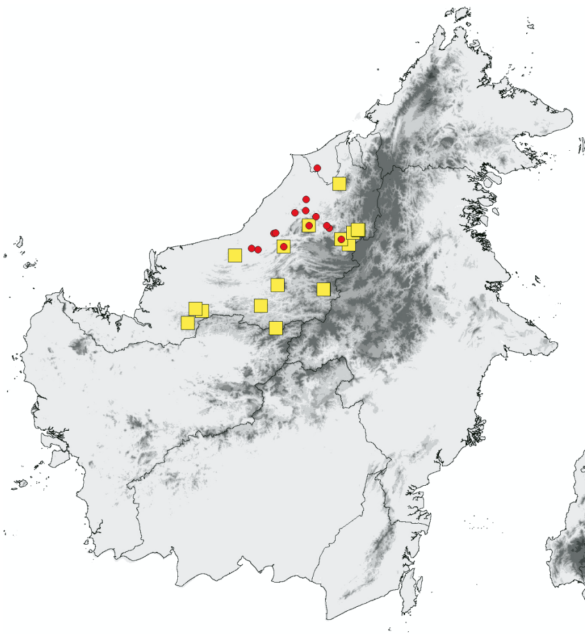


Fig. 6. Known distributions of *Coeliccia campioni* (yellow square) and *C. kenyah* (red circle). Map made using DIVA-GIS.

Coeliccia nigrohamata Laidlaw, 1918

1c – 2 ♂♂, 6.ix.2015, MB; 2 ♂♂, 6.ix.2015, RD. **4** – 3 ♂♂, ♀, 10.ix.2015, RD. **5** – ♂, 13.ix.2015, RD. **6** – ♂+♀, 13.ix.2015, RD. **7** – ♂, 8.ix.2015, RD. **12** – 2 ♂♂, 21.vi.2016, RD.

Coeliccia species cf *nemoricola* Laidlaw, 1912

7 – ♂, 8.ix.2015, RD. **8** – ♂, 11.ix.2015, RD; ♂, 12.ix.2015, RD.

Prodasineura dorsalis (Selys, 1860)

13 – ♂, 22.vi.2016, RD.

Prodasineura hyperythra (Selys, 1886)

13 – ♂, 22.vi.2016, RD.

Prodasineura verticalis (Selys, 1860)

13 – ♂, 22.vi.2016, RD; ♂, 22.vi.2016, M. Tarang & N. Megom.

Coenagrionidae

Agriocnemis femina (Brauer, 1868)

15 – ♂, 21.vi.2016, RD.

Argiocnemis species

2 – ♂, 5.ix.2015, RD.

Ceriagrion bellona Laidlaw, 1915

4 – 3 ♂♂, ♀, 10.ix.2015, RD. 15 – ♂, ♀, 23.vi.2016, RD.

Ceriagrion cerinorubellum (Brauer, 1865)

15 – ♂, 23.vi.2016, RD.

Pseudagrion microcephalum (Rambur, 1842)

15 – 2 ♂♂, 23.vi.2016, RD.

Pseudagrion perfuscatum Lieftinck, 1937

5 – ♂, 13.ix.2015, RD. **6** – ♂, 13.ix.2015, MB. **12** – 2 ♂♂, 21.vi.2016, RD.

Stenagrion dubium (Laidlaw, 1912)

1a – ♂, 5.ix.2015, RD. **1b** – 2 ♂♂, 5.ix.2015, MB. **1c** – ♂, 6.ix.2015, MB; 3 ♂♂, 6.ix.2015, RD. **4** – ♂, 10.ix.2015, RD. **6** – ♂, ♂+♀, 13.ix.2015, LS. **7** – 2 ♂♂, ♂+♀, 8.ix.2015, RD. **8** – 4 ♂♂, 10.ix.2015, MB & LS; 7 ♂♂, 12.ix.2015, MB; 3 ♂♂, 12.ix.2015, RD; 3 ♂♂, 12.ix.2015, LS; 3 ♂♂, 14.ix.2015, MB; ♂, 14.ix.2015, RD; ♂, 14.ix.2015, LS. **10** – 10 ♂♂, 15.ix.2015, MB & LS; 2 ♂♂, 15.ix.2015, RD. **12** – ♂, 21.vi.2016, RD. **14** – 2 ♂♂, 23.vi.2016, RD.

Xiphiagrion cyanomelas (Selys, 1876)

15 – ♂+♀, 21.vi.2016, RD.

Anisoptera

Aeshnidae

Gynacantha species

12 – ♀, 21.vi.2016, RD.

Indaeschna grubaueri (Förster, 1904)

11 – ♂, 13.ix.2015, RD.

Tetracanthagyna species

1b – ♀, 5.ix.2015, MB.

Gomphidae

Heliogomphus blandulus Lieftinck, 1929

There are few records definitely of this species, see part II of this paper.

5 – ♂, 10.ix.2015, MB & LS.

Ictinogomphus decoratus melaenops (Selys, 1858)

2 – ♂, 5.ix.2015, RD.

Leptogomphus williamsoni Laidlaw, 1912

Material listed in Dow, Stokvis & Ngiam (2017). Location **1b**.

Macromiidae

Macromia westwoodii Selys, 1874

9 – 3 ♂♂, 12.ix.2015, LS.

Synthemistidae

Identification of the females of the three *Idionyx* species known from Borneo is problematic. The only significant differences apart from size and extent and degree of tinting of the wings (both of which will be variable within species) between female specimens appear to be in the markings of the metepimeron. Until now the first author has been hesitant to identify the females of this genus based on the markings of the metepimeron. However after examining long series of both sexes, differences in the markings of this part of the synthorax appear consistent in males. No intermediate forms have been found in the females examined and, assuming that the markings are consistent between the sexes, it does seem that this is likely to be a simple and reliable method to distinguish at least one of the species from the others (see below) and tentatively to distinguish the others as well. Revised identifications of previously published female *Idionyx* records are given in Table 1.

Idionyx ?montana Karsch, 1891

A female *Idionyx* from location 1c is tentatively assigned to *I. montana* on the basis of similarity of the marking of the metepimeron to males of that species.

1c – ♀, 6.ix.2015, RD.

Idionyx species cf *yolanda* Selys, 1871

Another female *Idionyx* from location 1c can be associated with the unnamed species referred to as *Idionyx* species cf *selysi* in various publications (Dow & Reels 2009, Dow & Reels 2010, Dow 2012b, Dow, Reels & Butler 2013a, 2013b, Dow, Reels & Ngiam 2015a) by the yellow marking on the metepimeron divided into two (in agreement with the male) instead of one continuous mark in males of the

Table 1. Revised, tentative, identifications of some previously published records of *Idionyx* females.

New ID	Previous ID	Location	Date of collection	Publication
Idionyx ? montana	*Idionyx ?yolanda*	Hose Mountains	5.iv.2011	Dow & Ngiam 2012
	Idionyx species	Ulu Balui	17.vi.2013	Dow & Ngiam 2014
	Idionyx species	Sg Kahei area, Ulu Balui	6.ix.2013	Dow & Ngiam 2014
	Idionyx species	Ulu Moh	27.viii.2014, 29.viii.2014	Dow & Ngiam 2015
	Idionyx species	Borneo Highlands	17.vii.2015	Dow, Butler & Reels 2016
	Idionyx sp	Ulu Mujok	21.viii.2016 (one of two females from this location and date)	Dow et al. 2018
	Idionyx sp	LEWS: Nanga Bloh	1.xi.2011, 6.xi.2017	Dow et al. 2018
Idionyx ? yolanda	*Idionyx* species	Usun Apau	2.v.2012	Dow, Reels & Ngiam 2015b
	Idionyx sp.	Ulu Mujok	2.viii.2015, 3.viii.2015, 21.viii.2016 (one of two females from this location and date)	Dow et al 2018
Idionyx species cf *yolanda*	*Idionyx* species	Gn Mulu NP	2005-2006	Dow & Reels 2008
	Idionyx new species	Hose Mountains	15.iv.2011	Dow & Ngiam 2012
	Idionyx species	Sg Kahei area, Ulu Balui	16.vi.2013	Dow & Ngiam 2014 (one of two listed from this date, other currently unavailable)
	Idionyx species	Tapak Mageh, Ulu Balui	2.ix.2013	Dow & Ngiam 2014
	Idionyx sp.	LEWS: Nanga Bloh	9.iii.2016, 4.xi.2017, 10.xi.2017	Dow et al. 2018

other species known to occur in Borneo (at least in examples available to the first author for examination). Fig. 7 shows a female specimen. Males of this species have been compared with the type of *I. selysi* (in the Natural History Museum, London) and are clearly distinct from it. In fact they are more closely related to

I. yolanda, but differ from it in details of the anal appendages, accessory genitalia, synthorax markings and some other features, as well as in the possession of a large spine on the dorsum of S10. Given the closer relationship with *I. yolanda* we have dropped the label cf *selysi* for this species and list it as *Idionyx* species cf *yolanda* until it is described. Note that *I. selysi* is incorrectly listed as a synonym of *I. yolanda*, a species from which it differs in many respects, in the Catalogue of Life (http://www.catalogueoflife.org/col/search/scientific/; accessed 17.vi.2018). **1c** – ♀, 6.ix.2015, RD.

Fig. 7: Supposed female of *Idionyx* species cf *yolanda* (photo of a specimen from Kubah National Park).

Libellulidae

Brachydiplax chalybea Brauer, 1868

15 – ♂, 21.vi.2016, RD.

Cratilla metallica (Brauer, 1878)

8 – ♂, 14.ix.2015, RD. **11** – 2 ♂♂, 13.ix.2015, RD.

Lyriothemis biappendiculata (Selys, 1878)

8 – ♂, 12.ix.2015, RD. **12** – ♂, 21.vi.2016, RD.

Lyriothemis cleis Brauer, 1868

1c – ♂, 6.ix.2015, RD. **11** – ♂, 13.ix.2015, RD.

Nannophya pygmaea Rambur, 1842

6 – 2 ♂♂, 13.ix.2015, MB.

Neurothemis fluctuans (Fabricius, 1793)

2 – 2 ♂♂, 5.ix.2015, RD. **12** – ♂, 21.vi.2016, RD. **13** – ♂, 22.vi.2016, RD.

Orchithemis pulcherrima Brauer, 1878

15 – ♀, 21.vi.2016, RD.

Orthetrum chrysis (Selys, 1891)

12 – ♂, 21.vi.2016, RD. **15** – ♂, 23.vi.2016, M. Tarang, N. Megom & A. Jukie.

Orthetrum glaucum (Brauer, 1865)

1a – ♂, 5.ix.2015, RD. **4** – ♂, 10.ix.2015, RD. **6** – ♀, 13.ix.2015, MB. **11** – ♂, 8.ix.2015, RD. **13** – ♀, 22.vi.2016, M. Tarang, N. Megom & A. Jukie. **15** – 3 ♂♂, 2 ♀♀, 23.vi.2016, M. Tarang, N. Megom & A. Jukie.

Orthetrum pruinosum schneideri Förster, 1903

1a – ♂, 5.ix.2015, RD. **4** – ♂, 10.ix.2015, RD. **9** – 2 ♂♂, 12.ix.2015, LS. **11** – ♂, 8.ix.2015, RD. **12** – ♂, 21.vi.2016, RD.

Orthetrum testaecum (Burmeister, 1839)

2 – ♂, 5.ix.2015, RD. **5** – ♂, 13.ix.2015, RD. **13** – ♂, 22.vi.2016, RD.

Pantala flavescens (Fabricius, 1798)

15 – ♂, 22.vi.2016, RD.

Rhyothemis triangularis Kirby, 1889

2 – ♂, 5.ix.2015, RD.

Tholymis tillarga (Fabricius, 1798)

15 – ♂, 21.vi.2016, RD.

Trithemis aurora (Burmeister, 1839)

12 – ♂, 21.vi.2016, RD. **13** – ♂, 22.vi.2016, RD.

Trithemis festiva (Rambur, 1842)

3 – ♂, 5.ix.2015, RD. **4** – ♂, 10.ix.2015, RD. **6** – ♂, 13.ix.2015, MB. **12** – ♂, ♂+♀, 21.vi.2016, RD. **13** – 4 ♂♂, 23.vi.2016, M. Tarang & N. Megom.

Tyriobapta torrida Kirby, 1889

2 – ♂, 5.ix.2015, RD. **12** – ♂, 21.vi.2016, RD; ♂, 22.vi.2016, M. Tarang & N. Megom

Urothemis signata insignata (Selys, 1872)

15 – ♂, 23.vi.2016, RD.

Zygonyx ida errans Lieftinck, 1953

3 – ♂, 6.ix.2015, RD. **4** – 3 ♂♂, ♀, 10.ix.2015, RD. **5** – ♂, ♀, 13.ix.2015, RD.

Part II: *Heliogomphus* in Borneo, Peninsular Malaysia and Singapore

Introduction

Adults of *Heliogomphus* are amongst the most elusive of the Gomphidae in Borneo and Peninsular Malaysia. Most records of the genus are of larvae or teneral individuals and most of the fully mature examples that have been collected are female; mature male specimens are very rarely collected. Small, but intriguing differences between some of the few available specimens and the named species from the genus, and the limited molecular data available suggests that there might be at least one more species. Here we review the genus in Borneo, Singapore and Peninsular Malaysia, and present COI gene trees for the genus in the region.

Review of records

Three named species of *Heliogomphus* have been recorded from Borneo, Singapore and Peninsular Malaysia: *Heliogomphus blandulus* Lieftinck, 1929, *H. borneensis* Lieftinck, 1964 and *H. kelantanensis* (Laidlaw, 1902). *Heliogomphus kelantanensis* was the first of these to be described (Laidlaw 1902a), as *Gomphus consobrinus*, a preoccupied name changed to *G. kelantanensis* in Laidlaw (1902b: foot note on page 382). It was then treated as a *Leptogomphus* (Williamson 1907, Laidlaw 1914, 1922). Later Laidlaw (1925) transferred the species to *Heliogomphus*, a genus erected in Laidlaw (1922). The species was described from a mature male from Kuala Aring in Kelantan; a teneral female from the same location is also listed in Laidlaw (1902a) but this was "too much withered to describe." Later records of the species are few and far between, and in some cases possibly suspect. Lieftinck (1933) described the supposed larva from an exuvia collected with a freshly emerged female; however given that the female of the species had not been described the identification might be considered insecure in this case. Furtado (1969) recorded the species based on exuviae from Sungai Gombak in Selangor; again it cannot be considered certain that this record really refers to *H. kelantanensis*. Norma-Rashid (2009) lists the species from Kenaboi Forest Reserve in Negeri Sembilan without details or further comment. All other records of the genus from Peninsular Malaysia that we are aware of are of females (Vick 1993) or larvae (Che Salmah et al. 2005) not assigned to a species. *Heliogomphus kelantanensis* has also been recorded from Singapore, firstly by Murphy (1997) at Nee Soon Swamp Forest. More recently a female was collected on Pulau Ubin (Ngiam & Cheong 2016). The anal appendages of male *H. kelantanensis* are not typical of the genus; the superior appendages are not lyrate in form, unlike those of most species.

The first species of the genus recorded from Borneo was *H. blandulus*, described from Sungai Bika in the basin of the Kapuas River in West Kalimantan (Lieftinck 1929, Laidlaw 1931). *Heliogomphus blandulus* has typical male anal appendages for the genus. Later Dow & Ngiam (2012) recorded a teneral male from the Hose Mountains in Sarawak and then (Dow & Ngiam 2014) a male and the supposed female from Ulu Balui, also in Sarawak. The only other definite published record is that in this publication. Luke et al. 2017 recorded *Heliogomphus* cf *blandulus* from the south-east of Sabah; it has not yet been possible to re-examine this specimen.

The second species described from Borneo was *H. borneensis*, from both sexes from locations in East Kalimantan (Lieftinck 1964). This species was noted to be very similar to *H. kelantanensis* but differed in small details of the male anal appendages: "Very near *H. kelantanensis* (Laidlaw), but differing slightly in the shape of the anal appendages and in details of coloration" (Lieftinck: 1964: 90). The differences apparent between males of the two species in Lieftinck (1964: Figs 1–4) are indeed very slight and could easily be merely intraspecific variation. Later the species was recorded from Gunung Mulu National Park in Sarawak (Dow & Reels 2008), the Maliau Basin in Sabah (Ng et al. 2008), the Hose Mountains (Dow & Ngiam 2012) and the Samunsam Wildlife Sanctuary in Sarawak (Dow 2016); it has also been recorded from a location in Bintulu Division, Sarawak (Dow et al. in preparation). Dow (2012a) recorded *Heliogomphus ?borneeensis* from Gunung Penrissen in Sarawak based on teneral males and females and Dow et al. (2018) recorded possible teneral specimens from the Lanjak Entimau Wildlife Sanctuary in Sarawak. The first author has a specimen from Mount Matang in Kuching Division. Additionally a teneral female from the Tunoh area of Kapit Division, listed as *H*. species in Dow & Ngiam (2015a: 27, collected 18.vi.2013), is a good match in its markings to *H. borneensis* and is listed as *H. borneensis* cf in the molecular analyses below.

A male of a species similar to, but different from *H. blandulus* was collected at Gunung Mulu National Park in 2007. Re-examination of this specimen has revealed that it is close but possibly not identical to *H. olivaceus* Lieftinck, 1961, described from Busuanga Island in the Palawan region of the Philippines (Lieftinck 1961)and later also reported from Palawan itself (Asahina 1980). This brings the number of *Heliogomphus* species known from Borneo to three. The teneral male from the Ulu Mujok area of the Lanjak Entimau Wildlife Sanctuary, listed as *Heliogomphus* cf *blandulus* in Dow et al. (2018), is re-identified here as *H.* cf *olivaceus*. Additionally two females (and a larva) have been matched to this species using DNA (see the next section), and another two females have been matched to these in turn, based on morphological similarity. One of these females (from Kubah National Park) was reported in Dow, Reels & Butler 2013b as *Heliogomphus* species. The other female is also from Gunung Mulu National Park, while the larva is from the Nanga Bloh area of the Lanjak Entimau Wildlife Sanctuary. These locations are spread across Sarawak, so the species is clearly widely distributed in the state. The female of this species has no significant horns, tubercles or ridges on the vertex behind or between the ocelli or on the occiput, and has a very constant ratio of width of occiput (measured at the narrowest point) to the total width of the head at the same point: 0.23. The lack of ornamentation on the dorsum of the head is unique among females from Borneo examined and the occiput is narrower than in any other females examined whose condition allowed this measurement to be made. The female of *H. olivaceus* from the Philippines has not been described and there are some differences between males from Sarawak and, judging from the published descriptions and illustrations, those from the Palawan region. For these reasons it is not certain that the species from Sarawak is the same as that in the Philippines.

A number of female specimens from south-western Sarawak in the first author's collection (from the Matang Range, Gunung Gading and Gunung Penrissen), provisionally associated with *H. borneensis*, possess a pair of widely spaced horns on the vertex behind the ocelli, while the occiput is particularly wide. The ratio of width of occiput (measured at the narrowest point) to the total width of the head at the same point is 0.26-0.29. Horns have not been found on the occiput of any females from other parts of Sarawak examined by the first author and are not mentioned in the description of the female of *H. borneensis* in Lieftinck (1964). However the only mature male with non-lyrate superior anal appendages available from south-western Sarawak (that from Mount Matang mentioned above) is in good agreement with male *H. borneensis*.

All other published records of the genus from Borneo that we are aware are of larvae (Dow 2008, Dow & Reels 2010, Dow, Reels & Butler 2013a, 2013b, Steinhoff 2015, Dow, Butler & Reels 2016, Luke et al. 2017, Dow et al. 2018), or females and teneral males not assigned to a species (Orr 2001, van Tol 2006, Dow, Reels & Butler 2013b, Dow & Ngiam 2015, Dow, Reels & Ngiam 2015a, 2015b, Dow, Butler & Reels 2016, Dow et al. 2018). Also Asahina (1966) recorded a female of a *Microgomphus* species from Sarawak, but from the illustrations provided, this may be a *Heliogomphus* species rather than any *Microgomphus* species known from Borneo.

A number of other *Heliogomphus* species are known from adjacent regions: *H. drescheri* Lieftinck, 1929 from Java and Sumatra, *H. gracilis* (Krüger, 1899) from Sumatra, *H. bakeri* Laidlaw, 1925 and, as already mentioned, *H. olivaceus* Lieftinck, 1961 from the Philippines. The widespread *H.* selysi (Fraser, 1925) has been recorded from Thailand; another species known from Thailand that has been placed in *Heliogomphus* has very recently been shown (Makbun & Fleck 2018) to belong in *Microgomphus*: *M. svihleri* (Asahina, 1970). All of these *Heliogomphus* species have the typical lyrate male superior anal appendages.

Molecular analyses

The dataset used here includes 29 *Heliogomphus* specimens (adult and larval) from Peninsular Malaysia, Sarawak and Brunei (see Table 2) as well as from other areas (Table 3). The mitochondrial marker COI was amplified from these samples and the gene trees resulting from the neighbour joining, Maximum Likelihood (ML) and Bayesian Inference (BI) of these sequences, plus others from outside of Borneo, are shown in Figs. 8-9.

Methods

DNA extraction and amplification. Genomic DNA was extracted from legs, using a NucleoMag 96 Tissue kit (Macherey-Nagel Gmbh & Co.) on a KingFisher Flex magnetic particle processor (Thermo Scientific). A volume of 150 µl was used for elution. A 658 bp fragment of the mtDNA cytochrome c oxidase I (COI) gene was amplified using primer combinations provided in Table 4. 25 µl of PCR reaction mix contained 5 µl of 5x Phire II Reaction Buffer (ThermoFisher), 1 µl of each primer (10 pM), 0.5 µl of Phire Hot Start II DNA Polymerase (ThermoFisher), 0.5 µl of dNTPs and 1 µl of DNA template. The amplification protocol consisted of 30 sec at 98°C followed by 40 cycles of 5 s at 98°C, 5 s at 50°C and 15 s at 72°C, and a final 5 min at 72°C.

Table 2: Collection codes and BOLD Process IDs for *Heliogomphus* specimens used for molecular analysis, and including the *Micrograomphus* outgroup. Specimens listed are from Brunei and Malaysia, the state, and approximate location are listed for each specimen. Male is indicated by m, female by f and larva by l. The collection codes can be used to locate the COI sequences on the BOLD website, and also appear as BOLD Sample IDs there.

Species	RMNH number	Sex/ stage	Country/ Province	Location & date	BOLD process ID
Heliogomphus blandulus	RMNH.INS.500718	m	Brunei, Tem-burong	Kuala Belalong Field Studies Centre (KBFSC), 19.xi.2004	ODOBP8083-16
	RMNH.INS.509658	m	Malaysia, Sarawak	Sungai Kahei, 16.vi.2013	ODOBP7112-16
Heliogomphus olivaceus cf	RMNH.INS.228970	m	Malaysia, Sarawak	Gunung Mulu National Park, 30.xii.2012.	ODOBP7463-16
	RMNH.INS.500028	f	Malaysia, Sarawak	Gunung Mulu National Park, 11.ix.2008	ODOBP7703-16
	RMNH.INS.506899	f	Malaysia, Sarawak	Kubah National Park, 3.ix.2012	ODOBP5240-16
	RMNH.INS.557693	l	Malaysia, Sarawak	Lanjak Entimau Wildlife Sanctuary, Nanga Bloh, 23.viii.2013	ODOBP4721-16
Heliogomphus borneensis cf	RMNH.INS.509663	f	Malaysia, Sarawak	Between the Hose Mountains and Kapit town, 18.vi.2013	ODOBP7117-16
Heliogomphus kelantanensis cf	RMNH.INS.505762	f	Malaysia, Johor	Panti Forest Reserve, 25.iv.2009	ODOBP3344-16
Heliogomphus sp.	RMNH.INS.500033	l	Malaysia, Sarawak	Gunung Mulu National Park, 11.ix.2008	ODOBP7706-16
	RMNH.INS.506333	f	Malaysia, Sarawak	Usun Apau National Park, 24.iv.2012	ODOBP3750-16
	RMNH.INS.506348	f	Malaysia, Sarawak	Usun Apau National Park, 3.v.2012	ODOBP3764-16
	RMNH.INS.506352	m	Malaysia, Sarawak	Usun Apau National Park, 1.v.2012	ODOBP3768-16
	RMNH.INS.506819	f	Malaysia, Sarawak	Gunung Penrissen, 24.vii.2012	ODOBP5165-16
	RMNH.INS.509693	l	Malaysia, Sarawak	Kubah National Park, 1.vii.2013	ODOBP4201-16
	RMNH.INS.557667	l	Malaysia, Sarawak	Lanjak Entimau Wildlife Sanctuary, Nanga Bloh, 21.viii.2013	ODOBP4696-16
	RMNH.INS.557669	l	Malaysia, Sarawak	Lanjak Entimau Wildlife Sanctuary, Nanga Bloh, 21.viii.2013	ODOBP4698-16
	RMNH.INS.557692	l	Malaysia, Sarawak	Lanjak Entimau Wildlife Sanctuary, Nanga Bloh, 23.viii.2013	ODOBP4720-16
	RMNH.INS.557696	l	Malaysia, Sarawak	Lanjak Entimau Wildlife Sanctuary, Nanga Bloh, 25.viii.2013	ODOBP4724-16
	RMNH.INS.557864	l	Brunei, Belait	Sungai Ingei, 24.ii.2014	ODOBP4888-16
Microgomphus sp.	RMNH.INS.557644	l	Malaysia, Sarawak	Bukit Sarang, 9.viii.2013	ODOBP4673-16

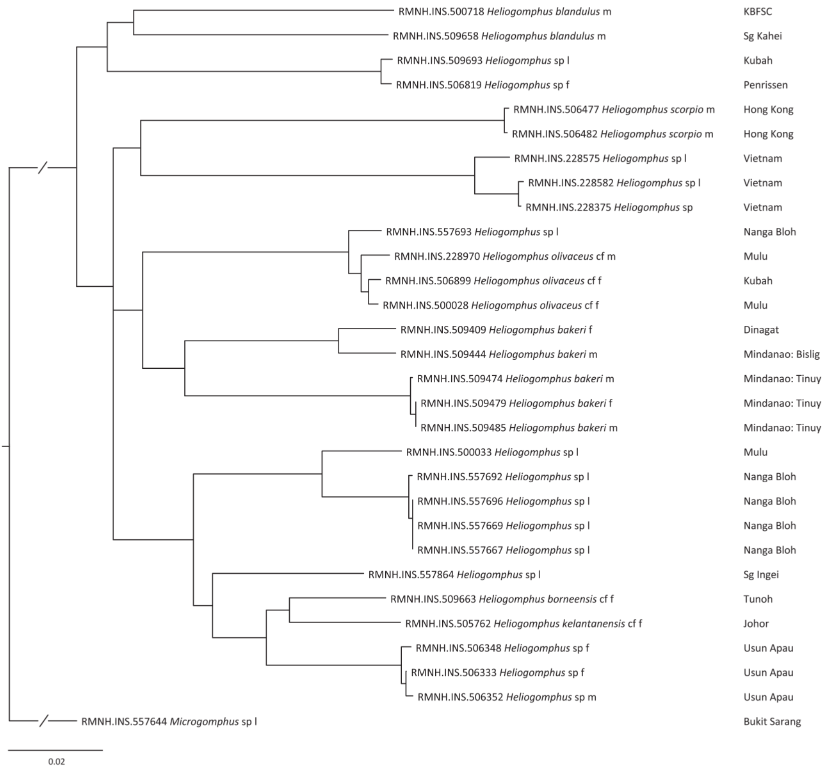
Table 3: Collection codes and BOLD Process IDs for *Heliogomphus* specimens used for molecular analysis. Specimens listed are from outside of Borneo and Malaysia, the country and island or province are listed for each specimen. Male is indicated by m, female by f and larva by l. The collection codes can be used to locate the COI sequences on the BOLD website, and also appear as BOLD Sample IDs there.

Species	RMNH number	Sex/ stage	Country/ Province/Island	Location & date	BOLD process ID
Heliogomphus bakeri	RMNH.INS.509409	f	The Philippines, Dinagat	Paraggua, 23.iii.2013	ODOBP6869-16
	RMNH.INS.509444	m	The Philippines, Mindanao	Between Trento and Bislib, 25.iii.2013	ODOBP6904-16
	RMNH.INS.509474	m	The Philippines, Mindanao	Near Tinuy-An Falls, 26.iii.2013	ODOBP6933-16
	RMNH.INS.509479	f	The Philippines, Mindanao	Near Tinuy-An Falls, 26.iii.2013	ODOBP6938-16
	RMNH.INS.509485	m	The Philippines, Mindanao	Near Tinuy-An Falls, 26.iii.2013	ODOBP6944-16
Heliogomphus scorpio	RMNH.INS.506477	m	China, Hong Kong	Sha Lo Tung, 30.v.2012	ODOBP3887-16
	RMNH.INS.506482	m	China, Hong Kong	Sha Lo Tung, 30.v.2012	ODOBP3892-16
Heliogomphus sp.	RMNH.INS.228375	l	Vietnam, Dak Lak	Chu Yang Sin National Park, 3.vi.2007	ODOBP7304-16
	RMNH.INS.228575	l	Vietnam, Dak Lak	Chu Yang Sin National Park, 10.vi.2007	ODOBP7326-16
	RMNH.INS.228582	l	Vietnam, Dak Lak	Chu Yang Sin National Park, 10.vi.2007	ODOBP7333-16

Bi-directional Sanger sequencing was performed at Macrogen Europe and at BaseClear, Leiden, The Netherlands. Sequences were edited with Sequencher 4.10.1 (Gene Codes Corporation) and checked for stop-codons in Geneious 8.1.8 (Kearse et al. 2012). All sequence data and additional geographic and ecological data as well as photographs of the specimens were uploaded to the Barcode of Life Data System (BOLD; Ratnasingham & Hebert 2007).

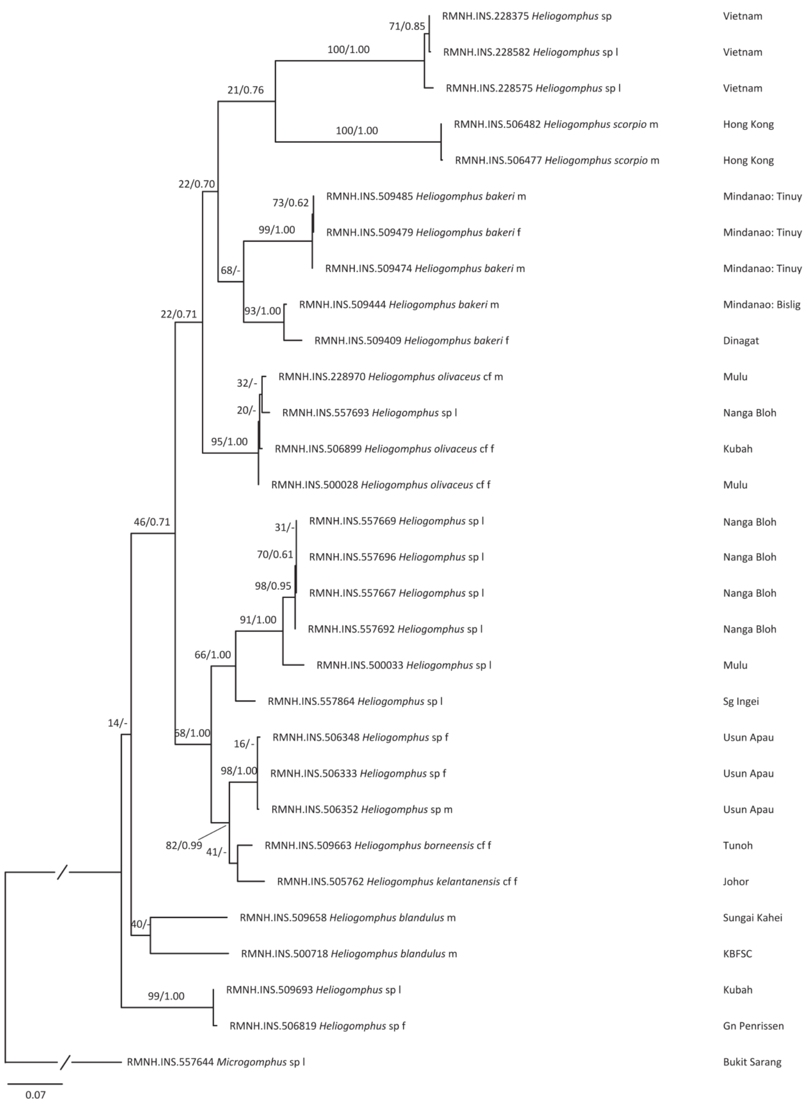
Phylogenetic and neighbour joining analyses. Multiple sequence alignments were performed using MAFFT 7 (Katoh et al. 2009) under default parameters. The neighbour joining analysis was performed in Geneious 8.1.8 (Kearse et al. 2012) using the uncorrected p-distance model. Partitioning, Maximum likelihood (ML) and Bayesian inference (BI) were performed on the Naturalis OpenStack computing cloud, using the PhylOstack

Fig. 8. Neighbour joining COI gene tree for *Heliogomphus* taxa. RMNH collection codes are shown for each specimen, as well as the sex of the specimen (Male is indicated by m, female by f and larva by l) and an indication of where it was collected; the reader is also referred to Tables 2 and 3.



pipeline (Doorenweerd 2016). Alignments of different markers were concatenated using VoSeq 1.7.4. (Peña & Malm 2012). Optimal partitioning of the three codon positions of COI was performed with PartitionFinder 2 (Lanfear et al. 2012), using RAxML 8 (Stamatakis 2014) with the GTR substitution model, BIC model selection, rcluster scheme and a minimum subset size of 300 bp. ML analyses were run with RAxML using the GTRCAT model. The best Maximum Likelihood tree was calculated using the –D parameter. A multiparametric bootstrap search was performed, which automatically stopped based on the extended majority rule criterion. The Bayesian inference was performed with ExaBayes 1.5 (Aberer et al. 2014) using the GTR substitution model. Four independent runs with four Monte Carlo Markov Chains each, were run for 1,000,000 generations during which convergence, with a standard deviation of split frequencies < 2 %, had been reached. The effective sample size was

Fig. 9. COI gene tree for *Heliogomphus* taxa from Maximum Likelihood (ML) and Bayesian Inference (BI). The best ML tree is shown, with posterior probabilities from the BI analysis also depicted on the branches. Bootstrap values and posterior probabilities are shown if less than 100 or 1.0 respectively. RMNH collection codes are shown for each specimen, as well as the sex (Male is indicated by m, female by f and larva by l) of the specimen and an indication of where it was collected; the reader is also referred to Tables 2 and 3.



confirmed using Tracer 1.6.0 (Rambaut et al. 2014). Bootstrap supports and posterior probabilities were depicted on the branches of the best ML tree using P4 (Foster 2004). The trees resulting from the neighbour joining and phylogenetic analyses were all rooted with the same taxon as outgroup: a species of *Microgomphus*. The resulting trees were visualised in FigTree 1.4.3 (Rambaut 2014).

Results

The neighbour joining tree (Fig. 8) shows wide separations even between some samples considered to belong to the same species, for instance *H. blandulus* and *H. bakeri*. If one accepts (which we do not) the idea that a three percent (or some similar, arbitrarily chosen, value) difference between COI sequences indicates distinct species, then this gene tree suggests that at least six species of *Heliogomphus* are present in Sarawak and Brunei and that the Philippine *H. bakeri* is composed of two separate species. However we suspect that at least some of the differences seen in this gene tree are merely the combined result of large variability in COI within species in this group plus insufficient samples included, e.g. with more samples, especially from intermediate locations, some of the apparent differences would become blurred.

The gene tree produced using phylogenetic methods (Fig. 9) tells a somewhat different story, although the basic groupings are preserved. The two *H. blandulus* samples cluster together, albeit with low support. *Heliogomphus* species cf *olivaceus* from Gunung Mulu National Park is clearly separated from the two confirmed *H. blandulus* samples, and forms a well-supported clade with females and a larva from other locations across Sarawak. This clade is (with poor support) the sister of a clade consisting of species from outside of Borneo; however the taxon sampling from outside of Borneo is insufficient to draw any firm conclusion from this even if the support values were higher. In any case an analysis with additional markers is needed to deal with the broader relationships within the genus. The *H.* species cf *kelantanensis* sample from Johor falls into a clade consisting of samples from Brunei and Sarawak east of the Lupar River and including a *H.* cf *borneeensis* female which might be the true *H. borneensis*. Large differences between samples from different populations are seen in this clade. Although the whole clade is divided into two clades (with moderate (ML) or complete (BI) support), this cannot be taken as strong evidence that two species are represented, given the high variability between populations. The whole clade has complete (BI) or moderate (ML) support. Two samples from south-western Sarawak form a clade that is the sister (with very poor support) of all the rest: a female from Gunung Penrissen and a larva from Kubah National Park in the Matang Range. Possibly this south-western clade will be found to be associated with the horned females mentioned above, but since it is not currently possible to re-examine the female from the molecular analysis, this cannot be confirmed. It is also at least possible that the south-western clade is due to a non-coding copy of COI present in the genome in some south-western populations of one of the other species. Although the south-western clade and horned females are intriguing, we do not consider the evidence of a fourth species in Borneo as completely overwhelming yet, although it does seem likely.

It would be premature to draw any definite conclusion from these analyses, especially given the poor support values from ML (see Fig. 9), but they do suggest that four or possibly more, rather than three, species might be present in the material from Borneo. They also suggest that *H. borneensis* and *H. kelantanensis* may be the same species, although since no confirmed male sample of either species is included in the analyses, synonymising *H. borneensis* with *H. kelantanensis* would certainly be premature at this stage. Two (at least) of the species from our region of interest show rather high variability in the COI marker, and we suspect that this is also true for the Philippine *H. bakeri*, rather than that it is composed of two cryptic species. The bottom line here is that a critical mass of material is needed to make complete sense of this group in Borneo, Singapore and Peninsular Malaysia, whether morphological or molecular methods are used (ideally both would be used), and this critical mass has not yet been obtained.

Acknowledgements

The first author would like to thank the Sarawak Forestry Corporation and Sarawak Forest Department for granting permission to collect Odonata in Sarawak. The Timber Division of WTK Holdings Berhad allowed the first author to work in their timber concessions in the Gunung Melatai area and provided assistance on the ground at Gunung Melatai; Tuan Haji Madhan of the SFC helped make arrangements with WTK for the trip. Joanes Unggang allowed the first author to join the trip to the Kastima logging area. Last but far from least, the trip to Gunung Melatai was made possible by a grant from the International Dragonfly Fund.

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