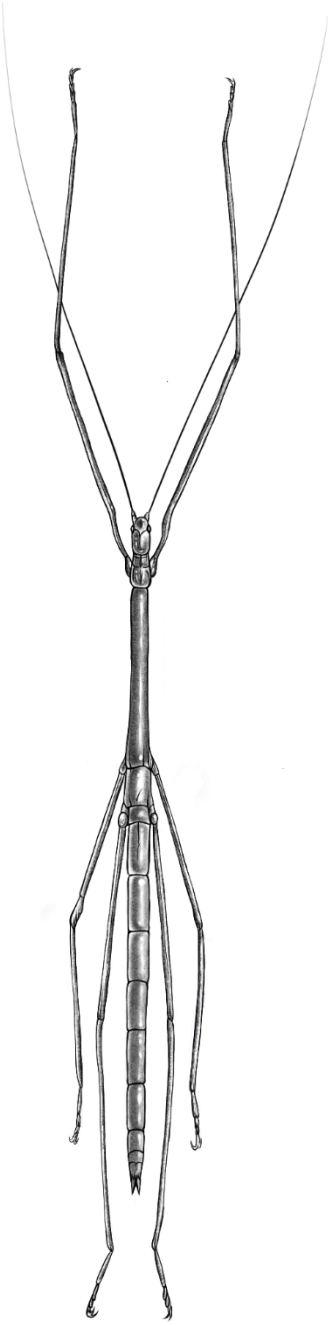
Printed ISSN 0966-0011
Online ISSN 1750-3329

PHASMID STUDIES

Volume 22

March 2026

Editor: Thies H. Büscher



Contents

Cover illustration: *Acacus sarawacus* (Westwood 1859) – drawing by S. Büscher, 2026

Phasmid Studies – Turning over a new leaf

Thies H. Büscher
Functional Morphology and Biomechanics, Kiel University, Am Botanischen Garten 1-9, 24118 Kiel, Germany.
tbuescher@zoologie.uni-kiel.de

Editorial

Considerable time has passed since the publication of the last volume of *Phasmid Studies* in February 2022. Therefore, I am particularly happy to see volume 22 completed and being published now.

Many things have changed in the meantime that circle around the aims and contents of *Phasmid Studies*. Ed Baker has stepped down from his role as executive Editor-in-Chief due to other commitments and I gladly agreed to take over. I would like to use this chance to thank both previous EiCs of the journal, Ed Baker and Phil Bragg, for their dedication over the years, as well as Judith Marshall and Paul Brock for their support. It is my pleasure to continue the editorial work for this journal. I have been a committee member of the PSG for a few years and work at Kiel University (Germany) where I study biomechanics and evolution of insects with particular focus on phasmids. As editor of different journals, such as *Physiological Entomology* (RES), *Zootaxa* and *Biodiversity Data Journal* I bring experience with publishing across different communities.

Phasmid Studies has changed over the years for many reasons. The dedication of PSG members results in high-quality articles in the PSG newsletter, phasmids receive growing attention in larger academic journals and the internet serves as a growing source of information on phasmids apart from print media and journal articles. Hence, the question might arise what role *Phasmid Studies* plays nowadays. My vision for this journal is to elevate the scientific study of stick and leaf insects by bridging professional research and enthusiast contributions. *Phasmid Studies* was conceived as a dedicated outlet for in-depth articles that go beyond the brevity of our newsletter. From its inception, the journal has championed longer, technical papers on all facets of phasmid biology—taxonomy, ecology, behaviour, captive rearing, and distribution—making complex topics accessible to all phasmid enthusiasts. Our strength is that it thrives on the unique perspectives of the PSG community, fostering exchanges that advance our understanding of these enigmatic insects. Central to this ethos is the enriching role of natural history data from enthusiasts, breeders, and non-professional entomologists. It is often the keen observations of PSG members—documenting rare matings, novel foodplants, or unexpected colour morphs in captivity—that fill critical gaps in the literature which are lacking in large-scale analyses of ecology and evolution and often remain anecdotal and undocumented. Such contributions, grounded in hands-on experience from phasmid enthusiasts, offer invaluable information on the natural history of phasmids.

We invite submissions that celebrate this synergy. Whether a taxonomic revision, breeding innovation, or field note synthesis, your work will find a home here.

- Thies H. Büscher, Kiel

Review of the Bornean members of the genus *Acacus* Brunner, 1907, with the description of two new species (Phasmida: Necrosciinae)

Philip E. Bragg
31 Parkhouse Road, Lower Pilsley, Chesterfield, Derbyshire, S45 8DG, U.K.
pbragg@aol.com

Abstract
The status of the genus *Acacus* Brunner, 1907 in Borneo is reviewed. Four species are found to occur in Borneo where the genus is widespread and commonly encountered. Two new species are described from Borneo: *Acacus inglisi* **n.sp**. and *Acacus vulgaris* **n.sp**. The two new species have been repeatedly misidentified as *A. sarawacus* (Westwood, 1859); there have been no genuine records under the name *sarawacus* since it was first described. The type species is actually relatively rare and appears restricted to a small area of Sarawak. *Acacus sapuani* Seow-Choen, 2016 is a new synonym of *A. sarawacus*. *Acacus sinkiebensis* (Wood-Mason, 1877) **stat. rev.**, from Sumatra, is found not to be a subspecies of *A. sarawacus* and is reinstated as a valid species. *Acacus rufipectus* Brunner, 1907, from Thailand, is considered to be wrongly placed in the genus. Keys are provided to the males, and to females, of the Bornean species. The Bornean species are all illustrated and distribution maps provided.

Key words
Phasmida, Necrosciinae, *Acacus inglisi* **n.sp.**, *Acacus sarawacus*, *Acacus vulgaris* **n.sp**., Borneo.

http://zoobank.org/urn:lsid:zoobank.org:pub:6A84E8FC-1CEF-4B36-A6FB-E50B872E9F9B

Introduction
Most of the work for this paper was done in 2005 –2008, most of the type specimens of the new species described here were labelled during that period, specimens in Bornean collections were examined and labelled in 2006. When this paper was almost completed I moved house and was without access to my collection, and without an office, until about 2020. In the meantime three new species of *Acacus* were described, one from Borneo and two from Sumatra; the species described from Borneo is actually a synonym of the type species. This paper was completed in 2022 but a delay in publication has allowed some additional data for specimens collected in 2022 –25 to have been added.

Acacus sarawacus (Westwood, 1859) is a wingless species of phasmid in the predominantly winged subfamily Necrosciinae. It is the type species of *Acacus* Brunner, 1907 and it was previously thought to have a widespread distribution within Borneo, and to occur elsewhere. However, re-examination of the type material has shown that the species has been misidentified by all authors since Westwood. The presence of two undescribed species of *Acacus* Brunner, 1907 was noted in *Phasmids of Borneo* (Bragg, 2001: 530); one of those species was subsequently described by Hennemann & Conle (2003). The second of my "undescribed species" is the true *A. sarawacus* (Westwood); the specimens previously referred to *sarawacus* are found to have been misidentified and comprise two species that are both described here as new. One of the new species has previously been recorded under the name *A. vulgaris* (Bragg, in Junker *et al*., 2008). A recently described species, *Acacus sapuani* Seow-Choen, 2016, is a synonym *A. sarawacus*. The Bornean species are treated in alphabetical order, and followed by some notes on some non-Bornean species.

The body length of all the examined specimens was measured to the nearest 0.5mm; Table 1 gives the full measurements for the longest and shortest specimens of each species, except in the case of *Acacus sinkiebensis* where measurements are taken from Wood-Mason's description have been converted from lines to millimetres and given to the nearest 0.1mm. Eggs were measured to the nearest 0.1mm using an eyepiece graticule; measurements exclude the opercular setae. Drawings were made using a binocular microscope fitted with a camera lucida. Microscope slides of the vomer were prepared as for the genitalia of Mantodea (Bragg, 2008: 193): cleared in potassium hydroxide and mounted in Euparal.

The following abbreviations are used: HT = Holotype, PT = Paratype, LT = Lectotype, PLT = Paralectotype, NP = National Park.

Specimens prefixed by the letters PEB- are individually numbered, these are in my own collection unless otherwise indicated. Phasmid specimens in Kinabalu Park Conservation Centre are individually numbered with the prefix SP/EPH (Sabah Parks, Entomology, Phasmid collection). Public collections are referred to mainly by the codens used in Arnett *et al*. (1993) and Bragg (2001), and private collections mainly by initials:

AJH – specimens from the collection of Allan Harman, these are now in BMNH.
BMNH – [= NHMUK] The Natural History Museum, London, U.K.
BORN – Borneensis, Universiti Malaysia Sabah, Kota Kinabalu, Sabah.
CLC – specimens from the collection of C.L. Chan, these are now in BMNH.
CUMZ – Cambridge University Museum of Zoology, Cambridge, U.K.
DCMD – Derby City Museum, Derby, U.K.
FH – specimens in the collection of Frank Hennemann (Bad Homburg, Germany).
KNP – Kinabalu National Park Conservation Centre, Sabah.
NHMN – Nottingham Natural History Museum, Nottingham, U.K.
NHMW – Naturhistorisches Museum Wien (Vienna), Austria.
NZSI – National Zoological Collection, Zoological Survey of India, Calcutta, India.
OXUM – [= OUMUK] Oxford University Museum, Oxford, U.K.
OZ – specimens in the collection of Oliver Zompro (Berlin, Germany).
PEB – specimens from the author's collection (Lower Pilsley, Derbys, U.K.)
PJ – specimens from the collection of Paul Jennings, these are now in BMNH.
SMSM – Sarawak Museum, Kuching, Sarawak, Malaysia.
SP/EPH – Sabah Parks, Entomology, Phasmid collection – see KNP.
ZSMC – Zoologische Staatssammlung, München, Germany.

Acacus Brunner, 1907

Acacus Brunner, 1907: 252; Günther, 1953: 558; Brock, 1996a: 87; Bragg, 2001: 530; Otte & Brock, 2005: 36 [for full list of references see Brock *et al.* (2022)].

Type species *Bacteria sarawaca* Westwood, 1859, by selection of Günther, 1938: 127.

Diagnosis of Bornean *Acacus*

Anareolatae: Lonchodidae: Necrosciinae. Apices of middle and hind tibiae without a sunken areole; antennae longer than fore legs. Body of both sexes of more or less uniform width; wingless; median segment shorter than metanotum; second abdominal segment of the female is longer than wide, that of the male is at least twice as long as wide*;* head flat (i.e. without a ridge, lobes or spines); anal segment of male more or less rounded; operculum of female bifurcate. Egg cylindrical, pointed at polar end.

Description of Bornean *Acacus*

Slender, stick-like, wingless, spineless. Fore legs compressed and incurving at the base. Antennae longer than fore legs. Hind legs reaching beyond, the end of the abdomen. Head flat, longer than wide, not ridged, or lobed, or spiny. Body granulose both dorsally and ventrally; setose. Head, body and legs lacking spines; medio-ventral carinae of femora with no more than a few tiny pointed tubercules. Apex of female's operculum bifurcate. Cerci of female do not project significantly beyond the end of the abdomen. Cerci of both sexes cylindrical, and simple, not toothed. Anal segment of male more or less rounded: not lobed or divided, with no more than a small notch in the posterior margin. Egg *c*apsule cylindrical with polar end conical. Capsule and operculum uniformly brown and rugulose or rugose; polar end with 3 short ridges. Operculum surrounded by a collar of long setae; opercular angle positive. Micropylar plate small, central, roughly oval.

Comments

Brunner described the genus in his Lonchodini, most of which have spines on the ventral carinae of the femora. This generic name is taken from the Greek ἀκακος – meaning guileless or harmless, presumably a reference to the absence of spines on the femora. The genus was transferred to Necrosciinae by Günther (1953: 558).

The type species, *A. sarawacus* (Westwood) was selected by Günther (1938: 127) although this was overlooked by Brock (1996: 87) who also selected *sarawacus*.

Brunner included three species in the genus but *Acacus buruensis* Brunner 1907 was synonymised with *Lamarchinus xiphias* (Westwood, 1859) by Günther (1934a: 79). *A. rufipectus* Brunner, 1907 from Thailand, is known only from the male; although I consider *rufipectus* to be wrongly placed in *Acacus*, it is unclear where it should be placed. One species later described in *Acacus*: *A. parvulus* Carl, 1913, was synonymised with *Parasipyloidea aenea* Redtenbacher, 1908 by Günther (1934b: 529, footnote).

Bacteria sinkiebensis Wood-Mason, 1877, from Sinkep Island (near Sumatra), was omitted from Brunner & Redtenbacher's monograph. Wood-Mason's species was synonymised with *A. sarawacus* by Günther (1938: 127); the status of this species is unclear because the type material of *sinkiebensis* is lost (Günther, 1938: 127) and *sarawacus* has been repeatedly misidentified.

Three new species have been described in recent years by Seow-Choen: *Acacus sapuani* Seow-Choen, 2016 from Borneo, and *Acacus sumatranus* Seow-Choen, 2018, and *Acacus indarungus* Seow-Choen, 2020, both from Sumatra.

Species of the genus *Acacus* are most likely to be confused with wingless *Lopaphus*, a number of which are known from West Malaysia, but from which they may be distinguished by the female operculum being bifurcate in *Acacus*, and by the male anal segment being bilobed in Lopaphus. *Anarchodes brocki* (Seow-Choen, 2016) occurs from 1500 –1800m on Mt Kinabalu and the female looks rather like a short legged *Acacus*, however, the male is very different and clearly does not belong in *Acacus*. There is also an undescribed phasmid from 2700m on Mt Kinabalu that, although superficially similar, clearly differs from *Acacus* in the form of the egg, the operculum of the female, and the anal segment of the male.

Key to *Acacus* of Borneo – females.

1. Anal segment of female not serrated, anterior half of operculum at most sparingly setose, posterior half without setae. .....*braggi* Hennemann & Conle.
- Anal segment of female serrated, operculum densely setose. ..... 2.
2. Head of female only 1.5 times longer than wide; second abdominal segment less than 1.5 times longer than wide. ..... 3.
- Head of female twice as long as wide; second abdominal segment twice as long as wide. .... *sarawacus* (Westwood).
3. Praeopercular organ a semicircular notch in the posterior margin of 7th sternite (fig. 1K). .....

..... *vulgaris* **n.sp.**

- Praeopercular organ a short raised longitudinal ridge on the posterior margin of 7th sternite (fig. 1E) .....*inglisi* **n.sp.**

Key to *Acacus* of Borneo – males.

1. Mid legs reaching to, or beyond apex of abdomen; body light or mid brown (with or without black stripe)..... 2.
- Mid legs not reaching to end of abdomen; body dark brown, black, dark green, or blue-black, legs often mottled. ..... 3.
2. Body pale brown with black longitudinal stripe on head and body, knee joints pale. .... *sarawacus* (Westwood).
- Body uniformly light brown, knee joints black. ..... *braggi* Hennemann & Conle.
3. Lateral margins of 9th tergite straight or smoothly curved; vomer with one point (figs. 2M & 12). ....v*ulgaris* **n.sp.**
- Lateral margins of 9th tergite distinctly angled (concave); vomer bispinose (figs. 2F & 13). ……...….*inglisi* **n.sp.**

Acacus braggi Hennemann & Conle, 2003 (figs. 1A–C, 2A–C, 3 & 5)

Acacus braggi Hennemann & Conle, 2003: 12, figs 1A–B (♀), 1C–D (♂), 1e –f (egg), 4 (♂), 5 (♀). 7 Holotype ♂ (ZSMC – FH 0324-1) Sarawak, Mt Serapi, 600m, 28.vii.1996. Paratypes: 3♀♀, 1♀nymph (ZSMC – FH 0324-2, FH 0324-3 to 5) Sarawak, Mt Serapi, 600m, 28.vii.1996; ♀ (PEB-528), ♂ (PEB-529), ♀ (PEB-530), ♂ (PEB-532) SARAWAK, Mt Serapi, 700m; P.E. Bragg, 27.vii.1991; ♀ (PEB-533), eggs (PEB-827) SARAWAK, Mt Serapi, 640m; P.E. Bragg, 12.viii.1989.

Material examined

3♀♀, 2♂♂, eggs PTs (all PEB specimens – data above).

♀ (OXUM) SARAWAK, Mt. Matang, vii.1903; Presented by Shelford, 1910; "doubtfully associated with 2♂♂".

Diagnosis of *braggi*

Male with mid legs reaching just beyond apex of abdomen; body and head plain light brown, knees dark. Female with anal segment not serrated, anterior half of operculum at most sparingly setose, posterior half without setae.

Female (figs. 1A–C & 3)

Colour uniformly mid brown. Head and second abdominal tergite with very few indistinct granules (the few present are easily overlooked); whole of thorax and median segment densely granulose, ventral and dorsal surfaces of thorax equally granulose; all abdominal sternites and tergites 3-10 without granules. Body length 93.0–101.0mm.

Head rectangular, width of epicranium just less than ¾ of the length. Pronotum one and a half times longer than wide. Mesonotum rectangular, 8.5 times longer than width at mid point; widening only very slightly at the posterior. Metanotum about twice as long as median segment. Second abdominal segment about as long as metanotum; 3rd about 5% longer than 2nd; 4th about 15% longer than 3rd; 4th and 5th of equal length; 6th – 9th decreasing in length; 10th as long as 9th (measured along the mid line). Apex of anal segment very slightly indented. Abdomen without setae except for a few on the ventral margins of tergites 8 –10. Operculum with deep incision. Cerci slender, cylindrical tapering to a point. The praeopercular organ very indistinct, two slight hollows each side of a small ridge on the mid line of the 7th sternite.

Legs long and slender. Hind tibiae reaching well beyond apex of abdomen. All legs with basal tarsomere longer than the combined length of tarsomeres 2 –5.

Male (figs. 2A –C & 3)
Whole insect mid brown except for the knee joints which are black. Thorax and median segment granulose; second abdominal tergite with a few rather indistinct granules. Body length 71–74mm.

Head almost rectangular, with epicranium slightly less than one and a half times longer than wide. Pronotum about one and a half times longer than wide. Mesonotum very slender, wider at anterior and posterior; about 17 times longer than width at mid point. Metanotum slightly more than twice as long a median segment. Abdomen slender, segments 8 –10 dilated. Anal segment with numerous small teeth ventrally. Cerci cylindrical, very slightly incurving at the apex. Vomer with a single spine (fig. 2C).

Legs very long and slender. Apices of the mid and hind femora with 4 –6 minute teeth on the medio-ventral carina. Mid legs reaching the end of the abdomen. Tarsi as in female.

Eggs (fig. 5)
Capsule mid to dark brown, rugose; length 4.4mm, width 1.6mm, height 1.8mm.

Comments

This species is known only from Mt Serapi (= Mt Matang) in north-west Sarawak. Measurements in table 1 are taken from my own material only; Hennemann & Conle's holotype is 68mm.

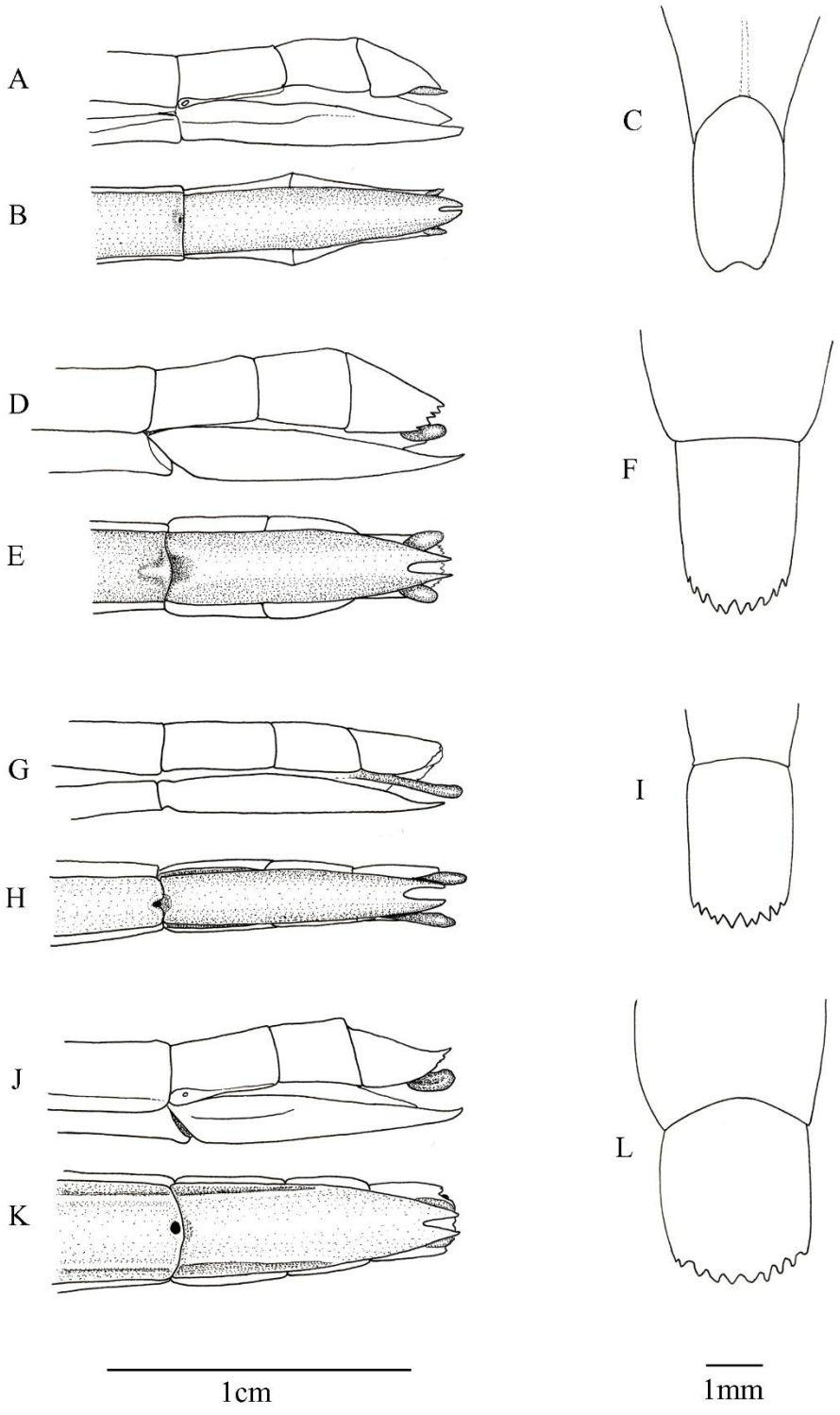


Figure 1. Apex of female abdomens, lateral, ventral and dorsal views. A–C. *Acacus braggi*; D–F. *A. inglisi*; G–I. *A. sarawacus*; J–L. *A. vulgaris*.

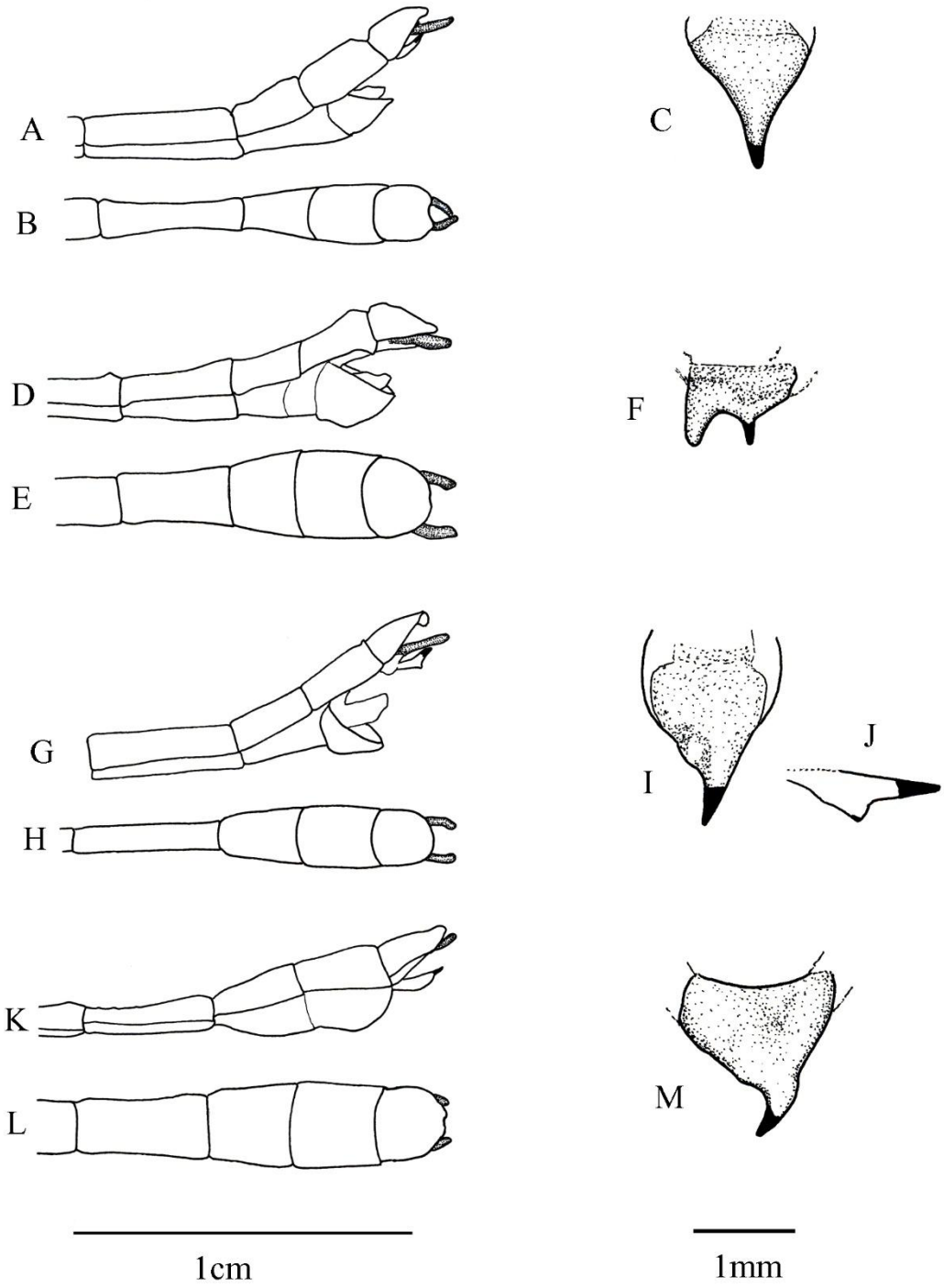


Figure 2. Apex of male abdomens, lateral, ventral view and dorsal view of vomer. A–C. *Acacus braggi*; D–F. *A. inglisi*; G–J. *A. sarawacus* (Fig. J = lateral view of vomer); K–M. *A. vulgaris*.

Acacus inglisi **n.sp.** (figs. 1D–F, 2D–F, 4, 6 & 12)

Bacteria sarawaca Westwood, 1859: 31 [in part only - ♀ PLT in OXUM, and ♂ "PLT" in BMNH].
Staelonchodes sarawacus; Kirby, 1904: 317 [BMNH specimen].
Acacus sarawacus [not Westwood, 1859]; Brunner, 1907: 252 [in part?]; Günther, 1943: 153; Bragg, 1992a: 301 [but not fig 9 (egg)]; Brock, 1997: 135, pl. 97M2 (♀); Bragg, 2001: 530 [in part, not fig 213 (egg)].
Acacus inglisi; Bragg, 2025: 86.

Holotype: ♂ (PEB-1662) Sarawak, Mt Santubong, 100m. P.E. Bragg, 31.vii.1992.

Paratypes: 24♂♂, 16♀♀

BORNEO:

♀ (OXUM) E. coll. (1830-1873) W.W. Saunders, Purchased and pres. '73 by Mrs F.W. Hope. ♂ (CUMZ) Shelford Oct. 20.1901. ♂ (CUMZ) [no further data].

SARAWAK:

1♀ [Paralectotype of *Bacteria sarawaca* Westwood, 1859] (OXUM, 563) [no locality specified] Wallace. E. coll. (1830-1873) W.W. Saunders, Purchased and pres. '73 by Mrs F.W. Hope. ♂ (BMNH – 56.44 "PLT") "*Sarawaca* pl. 25. fig. 1" "Sarawak, Borneo". ♀ (BMNH BM1931-570) C.J. Brooks, 1909, "*Acacus sarawacus* Westw. ♀ det. Klante, 1966". 2♀♀ (PEB-875; PEB-883) Bahagian Kuching [at least one ♀ is from Bengoh], P.E. Bragg, viii.1989. ♂ (PEB-2322) 2km E of Serian, Ranchang waterfall [= Ranchan]. P.E. Bragg, 09.xi.1994. ♀ (PEB-877) 3km west of Sri Aman. P.E. Bragg, 08.viii.1989. 3♂♂ (PEB-817; PEB-879; PEB-881) Bako NP. P.E. Bragg, 20.viii.1989. ♂ (PEB-873) Bako NP, 100m. P.E. Bragg, 01-01-1988. ♀ (BMNH BM1931-150) Bau. J.M. Bryan, 1-14, "*Acacus sarawacus* Westw. ♀ det. Klante, 1966". ♂ (PEB-878) Mt Santubong. P.E. Bragg, 18.viii.1989. 2♂♂ (PEB-1661; PEB-1663), 3♀♀ (PEB-1664; PEB-1665; PEB-1666) Mt Santubong, 100m P.E. Bragg, 31.vii.1992. ♀ (PEB-2317) Mt Santubong, 50-300m. P.E. Bragg, 21.x.1994. 2♂♂ (PJ) Mt Serapi. Paul Jennings, viii.1990. ♂ (PEB-1006) Mt Serapi, 30-240m. 26.vii.1991. 2♂♂ (PEB-869; PEB-882), ♀ (PEB-871) Mt Serapi, 30-240m. 13.viii.1990. Eggs (PEB-885; PEB-886) Mt Serapi, 30-240m. P.E. Bragg, 12.viii.1989. 2♂♂, 2♀♀, 2 Eggs (FH 0070-8 to 0070-11 & E) Mt. Serapi 600m. Hennemann & Conle 28.vii.1996. ♂ (PEB-876) Simunjan. P.E. Bragg, 16.viii.1991. 2♂♂ (AJH) Batu Niah. A. Harman & M. Salton, 1-30.xii.1980.

"SARAWAK & SABAH" [now believed to be only Sarawak]:

♀ (PEB-867) P.E. Bragg, viii.1990. ♀ (PEB-781; PEB-1450), ♂ (PEB-1452) ♂ (DCMD, PEB-1453) ♂ (NHMN, PEB-1451) captive reared, P.E. Bragg, 1992.

Other material (not types)

These specimens have not been re-examined since I misidentified them as *A. sarawacus* in 1992, but based on their locality they are very likely to be specimens of *A. inglisi*.

SARAWAK: Bahagian Kuching, ♀ (SMSM-521) P.E. Bragg, 1989. Kuching, ♂ (SMSM-251) 31.vii.1899; ♀ (SMSM-252) 09.xii.1899. Matang Road, ♂ (SMSM-249) 14.iv.1911; ♂ (SMSM-250) 30.xii.1910. Mt Santubong, ♀, ♂ (SFDK) P.E. Bragg, 31.vii.1992.

Diagnosis of *inglisi*

Male with mid legs not reaching to end of abdomen; body dark brown, black, dark green, or blue-black, legs often mottled; lateral margins of 9th tergite distinctly angled (concave); vomer bispinose. Female with anal segment serrated, operculum densely setose; praeopercular organ a short longitudinal ridge on the posterior margin of 7th sternite.

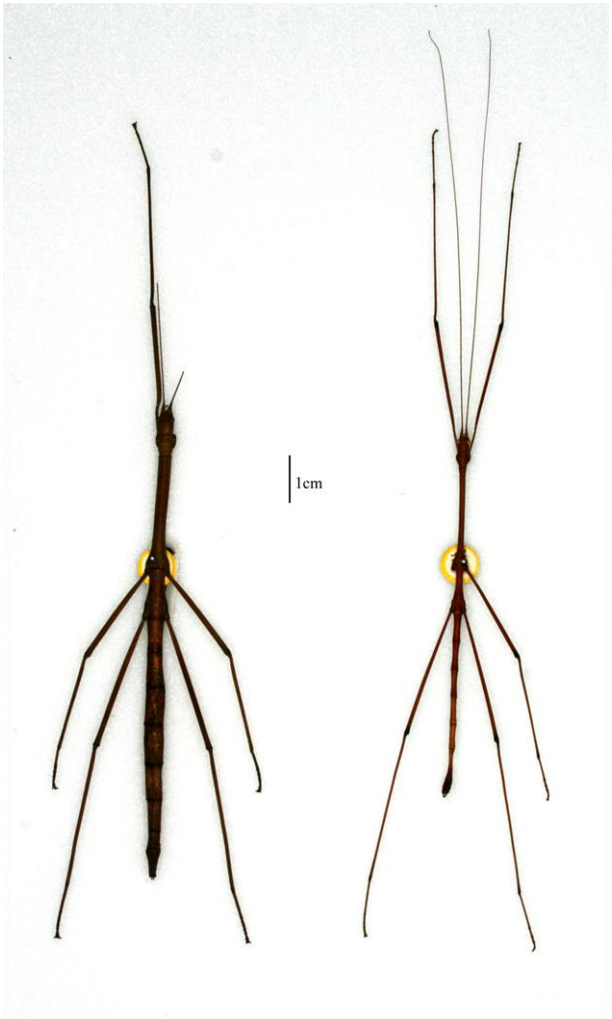


Figure 3. ♀PT & ♂PT of *Acacus braggi.*

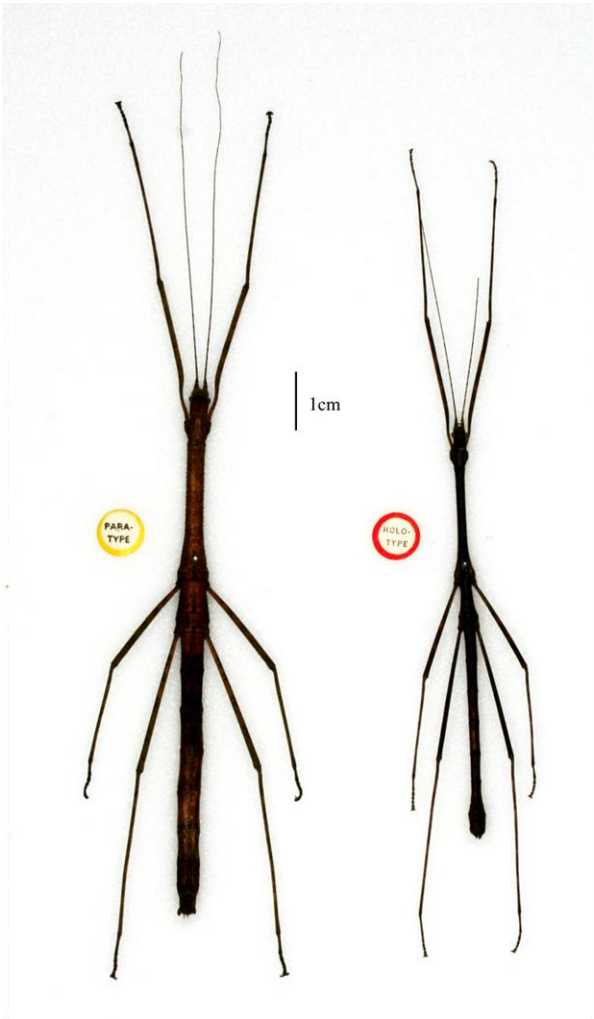


Figure 4. ♀PT & ♂HT of *Acacus inglisi.*

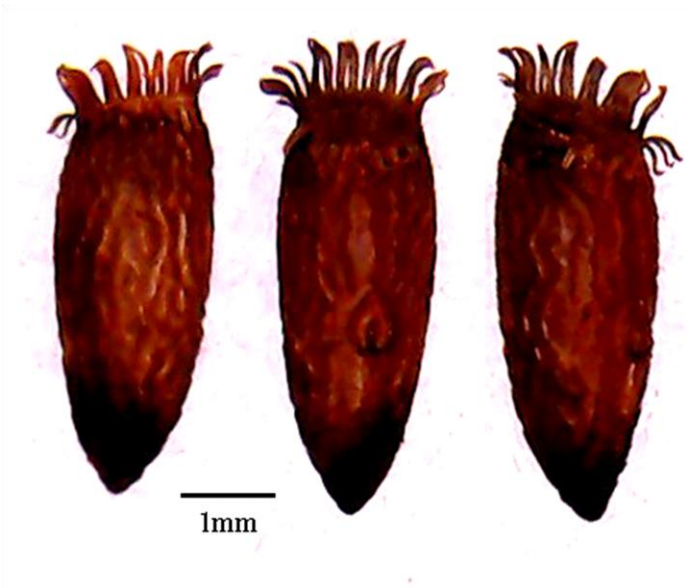


Figure 5. Eggs of *Acacus braggi.*

Figure 6. Eggs of *Acacus inglisi.*

Female (figs. 1D –F & 4)
Colour variable: from uniformly mid brown to cream, or black, lighter specimens may be speckled with dark brown or black; rarely dark specimens may have a broad pale stripe along the sides of the body. Head, prothorax and anterior of abdomen sparingly granulose; mesothorax and metathorax densely granulose, ventral and dorsal surfaces of thorax equally granulose; posterior half of abdomen without granules. Body length 75.5–93.5mm.

Head rectangular, width of epicranium ¾ of length. Pronotum one and a half times longer than wide. Mesonotum rectangular, 7.5 times longer than width at mid point; widening very slightly at the posterior. Metanotum about twice as long as median segment. Second abdominal segment slightly longer than metanotum; 3rd about 10% longer than 2nd; 4th about 10% longer than 3rd; 4th and 5th of equal length; 6th – 9th decreasing in length; 10th as long as 9th. Apex of anal segment usually with 12 sharp serrations (rarely 10 or 14). Abdominal tergites very sparingly setose, 9th & 10th notably setose. Anterior abdominal sternites sparingly setose, becoming increasingly setose towards posterior, 7th and operculum densely setose. Operculum with deep incision. Cerci short and broad. The praeopercular organ is a longitudinal ridge on the posterior margin, extending about one sixth of the way along the 7th sternite.

Legs long and slender. Hind tibiae reaching just beyond apex of abdomen. All legs with basal tarsomere shorter than the combined length of tarsomeres 2 –5.

Male (figs 2D –F, 4 & 12)
Colouration variable, usually dark brown, often with some dark olive green dorsally. Body length 60.0–70.0mm; Holotype 68.5mm.

Head rectangular, epicranium about one and a half times longer than wide. Pronotum about 1.75 times longer than wide. Mesonotum wider at anterior and posterior; about 12 times longer than width at mid point. Metanotum almost twice as long a median segment. Abdominal segments 2 –6 of about equal length, 7th about 30% shorter and widening at posterior; 8th widening to about twice as wide as 2 –6 and less than half their length; 9 –10 twice as wide as 2 –6, 9th half as long as 2nd, 10th about one third as long as 2nd. Anal segment with numerous small teeth ventrally. Cerci dilated, slightly laterally compressed. Vomer with two spines (figs. 2F & 12), the left process is almost central and heavily sclerotised (appears black), the right process is longer and broader but relatively weakly sclerotised (appears brown).

Mid legs not reaching the end of the abdomen, middle of hind tibiae about level with end of abdomen. Basal tarsomere of fore and hind legs about as long as combined length of tarsomeres 2 –5; shorter than combined length on mid legs.

Egg (fig. 6)

Capsule strongly rugose, mid to dark brown, *l*ength 5.6mm, width 2.0mm, height 2.1mm. The egg has a significantly larger diameter than other Bornean species of *Acacus*.

Etymology
Named after Paul Inglis who provided invaluable assistance with the collection of material during our 1992 collecting trip.

Comments
Darren Mann (OUMUK) has confirmed that the handwriting on the BMNH (56-44) specimen which had been labelled as a type of *sarawacus* is not Westwood's writing. The specimen has a locality label that is known to be in the hand of Charles Allen (A.R. Wallace's assistant), and it is known that such material was then purchased by the dealer Stevens. Brock *et al.* (2016) included this specimen as a type of Westwood's *sarawacus* although Westwood made no mention of a specimen in BMNH. Kirby (1904: 317) indicates a specimen in BMNH, but

not a type specimen. The specimen is of an age and collector consistent with it being available to Westwood, but the differences between this male and the male of *sarawacus* (illustrated by Westwood, and the species defined by the Lectotype) makes it unlikely that Westwood confused the two. I therefore consider it doubtful that this specimen is one of Westwood's types. The specimen has been marked as a type for many years and resulted in misidentifications by myself and, presumably, by other authors.

A few of my specimens were previously listed as from "Sarawak and Sabah" (Bragg, 2001: 531) because they were brought back to the UK alive, or reared in the UK from stock that was mixed together from Sarawak and from Sabah. These were designated as "PSG 124" on the Phasmid Study Group culture list in 1992, along with a second culture collected by Mel Herbert in Brunei (Bragg, 1992b). It is now clear, from the distribution of *inglisi* that the reared specimens (PEB-781, PEB-1450 to PEB-1453), and wild-caught (PEB-867) originated in Sarawak. The "second" culture reared by Mel Herbert was almost certainly *A. vulgaris*. Neither of the PSG 124 cultures were maintained beyond the third generation. At least one of the two specimens collected from "Bahagian Kuching" in 1989 was collected at Kampung Bengoh, but which one is not known.

Brock (1997: 135, pl. 97M2) illustrates a female from Mt Santubong with fairy typical colouration for this species. The colouration of the female is variable, ranging from sandy-pink to black; the majority are mid brown in colour. Most have uniform colouration but one dark brown specimen had a pale yellow stripe along the lateral surface of the body. Males show less variation, they are dark brown or black and may have some yellowish speckling especially on the abdomen.

The specimens in the Sarawak Museum and in the Sarawak Forestry Department that are excluded from the type series were previously identified as *sarawacus* and have not been re-examined, but they are all from localities where *inglisi* has been collected.

The known distribution of this species is limited to Sarawak (fig. 15). I initially had some doubts about the locality for the specimens from Niah collected by Allan Harman as they are the only ones from the eastern end of Sarawak, and I have collected *A. vulgaris* at Niah (and confirmed from specimens and by photographs taken in situ, and specimens collected in 2024); however, Allan Harman has assured me the data for his specimens is correct. *Acacus inglisi* is a common species in western Sarawak. References to *A. sarawacus* from Sarawak by Seow-Choen (2016 & 2018) almost certainly relate to *A. inglisi* although examination of all the specimens would be necessary to confirm this.

In captivity in the UK this species fed on *Pyracantha* sp., *Rosa canina*, *Rubus fruiticosus*, and *Rubus idaeus* (Bragg, 1992a: 302; Bragg, 2001: 21).

The bifurcate nature of the poculum of *inglisi* presumably allows it to fit either side of the ridge which forms the praeopercular organ of the female, although I did not examine the insects when they were mating. The asymmetry of the vomer would be consistent with males always wrapping their abdomen around the same side of the female.

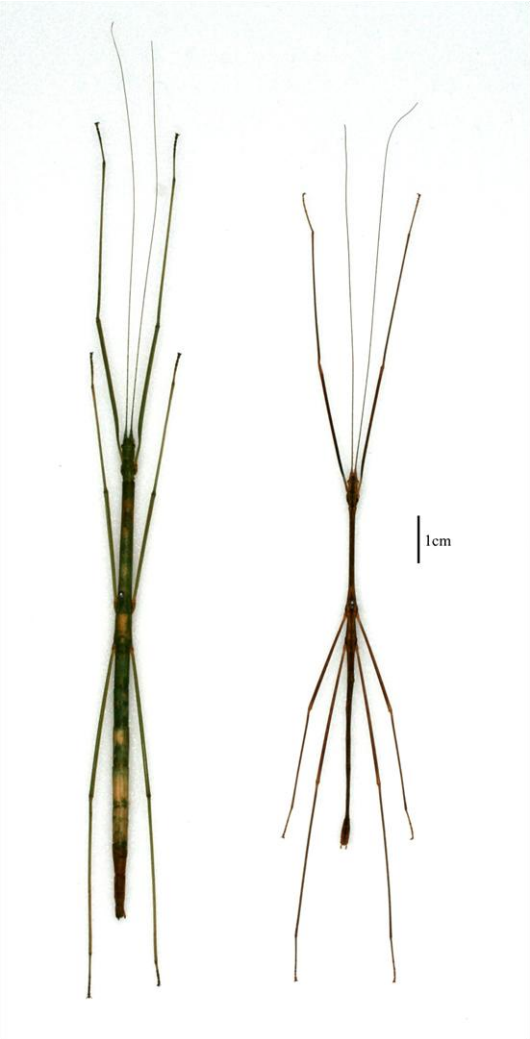


Figure 7. ♀ & ♂ of *Acacus sarawacus.*

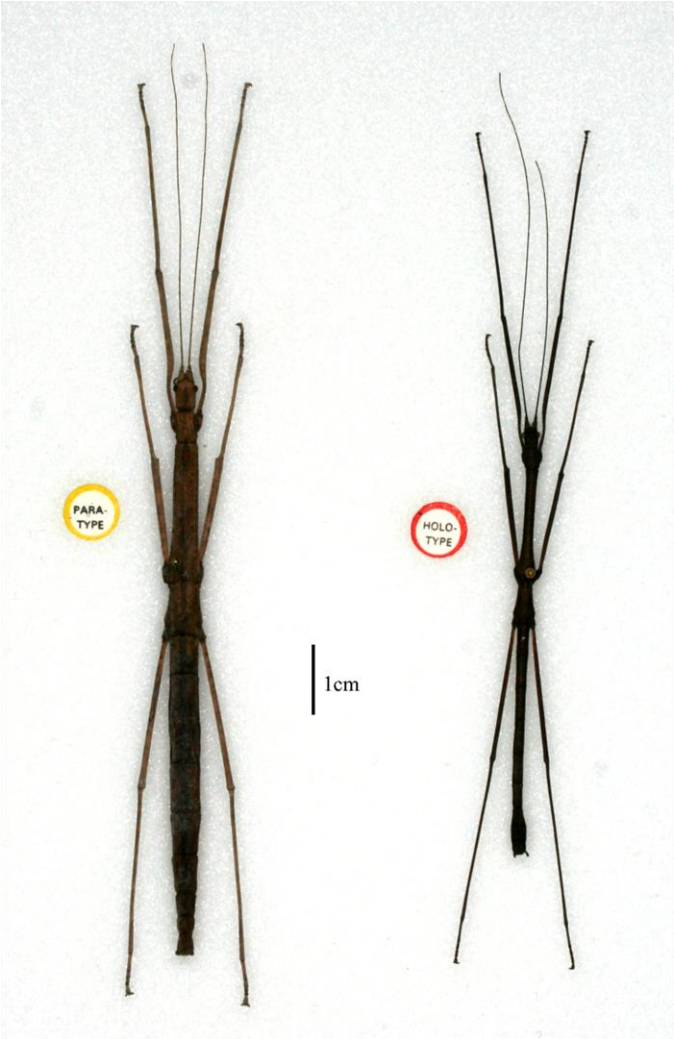


Figure 8. ♀PT & ♂HT of *Acacus vulgaris.*

Figure 9. Eggs of *Acacus sarawacus.*

Figure 10. Eggs of *Acacus vulgaris.*

Acacus sarawacus (Westwood, 1859) (figs. 1G –I, 2G –J, 7 & 9)

Bacteria sarawaca Westwood, 1859: 31, pl. 25.1(♂) & 25.2. Lectotype ♀ (OXUM, 563) Sarawak; Paralectotypes: 1♂, 1♀ (OXUM, Orth. 563) [The ♀ PLT in OXUM and ♂ in BMNH are not the same species as the lectotype – see *Acacus inglisi* n.sp.].
Staelonchodes sarawacus (Westwood); Kirby, 1904: 317 [in part – BMNH material mentioned by Kirby is not *sarawacus*].
Acacus sarawacus (Westwood); Brock, 1996: 87 [Lectotype selection]; Brock, 1999, figs 23a (♂), 23b-d (♀) [not fig 23e & not text]; Otte & Brock, 2005: 36.
[Not *Acacus sarawacus*; Günther, 1938: 127 – see *A. sinkiebensis*]
[Not *Acacus sarawacus*; Günther, 1943: 153 – see *A. vulgaris*]
[Not *Acacus sarawacus*; Brock *et al*, 2016: 193 – see below]
[Not *Acacus sarawacus* (Westwood) – all other authors – see comments on *inglisi* and *vulgaris*]
Acacus sapuani Seow-Choen, 2016: 17, figs 11 –18; Seow-Choen, 2017: 21. **New synonym.** Holotype ♀, Paratypes: 7♀♀, 8♂♂.

Material examined

BORNEO:

♂ (CUMZ) [no date, but probably c. 1900].

SARAWAK:

♀ LT, ♂ PLT (OXUM) Wallace. ♀ (CUMZ) Kuching. 16th August 1897 [A second label just reads "3"]. ♀ green form (PEB-2314) Mt. Santubong, 50 –300m. P.E. Bragg, 21.x.1994. ♀ green form (PEB-1005) Simunjan. P.E. Bragg, 16.viii.1991. ♂ (PEB-1655) Mt. Santubong, 700m. P.E. Bragg, 11.viii.1992. ♂ (PEB-1668) Mt. Santubong, 100m. P.E. Bragg, 31.vii.1992. 4♂♂ (PEB-2308, PEB-2309, PEB-2310, PEB-2311) ♀ brown form (PEB-2312) 2♀♀ green form (PEB-2313, PEB-2315) Mt. Santubong, 50-300m. P.E. Bragg, 21.x.1994. ♀ penultimate instar nymph, brown form (PEB-2316) Tarum (near Debak) P.E. Bragg, 25.x.1994.

Diagnosis of *sarawacus*

Male with mid legs reaching to apex of abdomen; body pale brown with black longitudinal stripe on head and body, knee joints pale. Female with anal segment serrated, operculum densely setose; head almost twice as long as wide; second abdominal segment twice as long as wide; body, head and legs uniformly coloured, either green or light brown.

Female (figs. 1G –I & 7)
Whole insect uniformly mid green or uniformly mid brown. Head, thorax and anterior of abdomen sparingly granulose; ventral surface less granulose than dorsal surface. Adult length 100 –113mm, full measurements of my specimens are given in Table 1; the lectotype is only 99mm in length but the end of the abdomen has been distorted, originally it must have been longer than 99mm. The CUMZ specimen is unusually long at 113mm. My female nymph has a length of 79mm.

Head more than 1.6 times longer than wide; almost rectangular. Pronotum rectangular, about 1.75 times longer than wide. Mesonotum widening very slightly at the posterior, 10 times longer than width of the mid point. Metanotum about 60% of the combined metanotum and median segment. Abdominal segments 2-6 of equal length, at least twice as long as wide; 7th slightly shorter and narrowing, 8th half as long as 2 –6, 9th & 10th shorter than 8th. Anal segment terminating in about ten sharp equal sized serrations (fig 1I). Operculum densely setose, apex with deep incision. Cerci cylindrical, straight, only very slightly clubbed. Praeopercular organ a small semicircular pit.

Legs long and slender, hind tibiae reaching well beyond apex of abdomen. Basal tarsomere of mid and hind legs about as long as tarsomeres 2 –5 combined, longer on fore legs.

Male (figs. 2G –J & 7)
Body and legs light to mid brown with a black stripe running the full length of the dorsal surface of the head and body, and with a black stripe along the side of the body. Leg joints notably paler than the rest of the legs. Body length 69 –79mm.

Head about twice as long as wide. Pronotum about 1.75 times longer than wide. Mesonotum very slender, wider at anterior and posterior; about 20 times longer than width at mid point. Metanotum almost twice as long a median segment. Abdomen slender, segments 8 –10 dilated. Anal segment with numerous small teeth ventrally. Cerci cylindrical, very slightly incurving at the apex. Vomer with a single spine, and a ventrally projecting tubercule on the right (fig. 2J). Mid legs reaching the end of the abdomen. Tarsi as in female.

Egg (fig. 9)
Capsule rugulose, light brown, length 4.7mm, width 1.5mm, height 1.5mm.

Comments

In his catalogue of species from Peninsular Malaysia and Singapore, Brock (1996: 87) correctly selected the female illustrated by Westwood (1859: pl. 25 fig 2) as the lectotype of *sarawacus* but failed to notice that the female paralectotype is a different species (see *A. inglisi*). The female paralectotype is one of the two widespread species that have been treated as *sarawacus* by all authors since Westwood's original description (including Bragg, 1992a, 1992b, & 2001). The confusion is, at least partly, due to a male in BMNH that was labelled as a syntype of *Bacteria sarawaca*. Westwood (1859) does not mention material in BMNH, and Kirby (1904: 317) indicates only non-type material of *sarawaca* in BMNH. Although Kirby was correct in not listing type material in BMNH, his catalogue entry presumably relates to this specimen because there are no specimens of the true *sarawacus* in BMNH. This specimen was incorrectly listed as a type by Brock *et al.* (2016: 193): the specimen is clearly different from the OXUM male paralectotype (see also comments above on *Acacus inglisi*).

Acacus sarawacus has been recorded from Singapore by Seow-Choen and by Brock, although photographs published by both authors (e.g. Seow-Choen *et al*, 1994b: 93; Seow-Choen *et al*., 1994c: fig page 12*;* Seow-Choen, 2005: 25) are clearly not the same species as the lectotype of *sarawacus*. My own specimen of *Acacus* from Singapore was collected as a nymph and died immediately after becoming adult, as a result it cannot be reliably identified but is clearly not *sarawacus* or *braggi*; the general appearance is consistent with both *inglisi* and *vulgaris.*

Bacteria sinkiebensis Wood-Mason, from Sinkep Island, near Sumatra was synonymised with *sarawacus* by Günther (1938), and recently listed as a subspecies of *sarawacus* by Seow-Choen (2020), but the type material cannot be traced; the measurements given by Wood-Mason disagree with those of *sarawacus* so the synonym rejected as is invalid (see additional notes on *sinkiebensis* below). Brunner (1907: 252) recorded *sarawacus* from the Moluccas in addition to Borneo but examination of photographs of his material in NHMW shows it was misidentified: it is clearly not *sarawacus*; the identity of the Moluccan material is not known. Brock's illustration (1997: plate 97M2) of a female from Santubong is clearly not *sarawacus*: the locality and general appearance agrees with *Acacus inglisi*.

The species *sarawacus*, as represented by the lectotype, is comparatively rare and is only known from western Sarawak (fig. 15). *Acacus sapuani*, unmistakeably the same species as the lectotype of *sarawacus,* was described from Bako National Park in western Sarawak.

This species seems to lose its legs easily: two of my seven females have lost one leg, one has three missing; one of the six males has one leg missing and another has three missing. Although the three-legged specimens probably lost some or all after capture, the female from Simunjan was photographed in situ with only five legs. One female has only four tarsomeres on the right mid leg, right hind leg, and left fore leg, indicating that

the legs may have been lost and regenerated; three other females, and one male each have one four-segmented tarsus.

The green and the brown females both occur at Mt Santubong. The original colours of the CUMZ specimen and the lectotype are unknown.

Figure 11. Female *Acacus vulgaris* laying eggs in vermiculite tray.

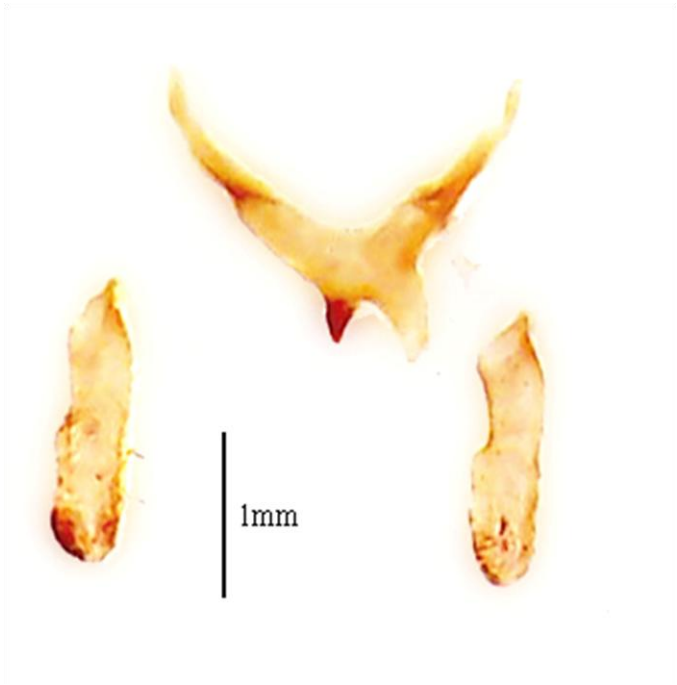


Figure 12. Vomer (dorsal view) and cerci of *Acacus inglisi.*

Figure 13. Vomer (dorsal view) and cerci of *Acacus vulgaris.*

Figure 12. Male *Acacus vulgaris* – Crocker Range NP.

Acacus vulgaris **n.sp.** (figs. 1J –L, 2K –M, 8, 10, 11, 13 & 14)

Acacus sarawacus; Günther, 1943: 153; Hausleithner, 1991: 221; Bragg, 1994: figure on page 240 (♀); Bragg, 2001: 530 [in part], fig 213 (egg); Blüthgen *et al*., 2006: 37; [Brunner, 1907: 252 – in part?]; Seow-Choen, 2017: 23.

Acacus vulgaris; Junker *et al*. 2008: 449, Table 1; Bragg, 2025: 86; Bragg *et al*. 2026: 22 & 23.

Holotype: ♂ (PEB-3606) Sabah, Crocker Range, Kota Kinabalu-Tanbunan road, N005º 46' 03" E116º 20' 38". P.E. Bragg. 09.xii.2006.

Paratypes: 90♂♂, 54♀♀

BORNEO:

♂ (BMNH 94-138) "Borneo".

BRUNEI:

♀ (OXUM) "Brunei". Capt. Waterstradt. Van. der Poll. Coll. Bought Jansen, 1909. 1909, 583. ♂ (OXUM) "Brunei". Capt. Waterstradt. Van. der Poll. Coll. Bought Jansen, 1909. 1909, 459. ♀(FH 0070-1) Badas, near Seria, "Pitcher Plant Walk". Hennemann & Herbert 7.viii.1994. 4♂♂, 2♀♀ (FH 0070-2 to 7) Badas, ex Zucht F1-Generation. F. Hennemann vii.1995. ♂ (OZ, PHA 10176) leg. F.Hennemann, vii.1995, reared by F. Hennemann xii.1995. ♂ (PEB-2319), ♀ (PEB-2320) Rampayoh, waterfall trail. P.E. Bragg, 03.xi.1994. ♂ (PEB-868) Temburong District, Bukit Belalong, 910m. P.E. Bragg, 10.viii.1991. ♂ (PEB-2318) Teraja, waterfall trail. P.E. Bragg, 03.xi.1994.

KALIMANTAN:

♀ (PEB-1983) Kalimantan Tengah, Sungai Ratu Miri Logging Camp. P.E. Bragg, 22.viii.1993.

SABAH:

♂ (KNP, SP/EPH/00661) Crocker Range Park. Sinail D. 02-12.iv.2004. ♂ (KNP, SP/EPH/01154) Crocker Range Park. Yusilie Kumin. 03.ix.2005. ♂ (KNP, SP/EPH/01174) Crocker Range Park. Johnny Lepidin. 03.ix.2005. ♀ (KNP, SP/EPH/00686) Crocker Range Park. Yusilie K. 02-12.iv.2004. 2♂♂ (KNP, SP/EPH/01143; KNP, SP/EPH/01142), ♀ (KNP, SP/EPH/01147) Crocker Range Park, 900m. Yusilie Kumin. 26.v.2005. 3♂♂ (PEB-3615, PEB-3616, PEB-3617) Crocker Range Park, near Kenningau, N005º 23' 59" E116º 06' 10". P.E. Bragg. 25.xii.2006. 4♀♀ with eggs (PEB-3753, PEB-3761, PEB-3762, PEB-3763) ♂ (PEB-3764) Crocker Range Park, near Kenningau, N005º 23' 59" E116º 06' 10". Collected as nymphs by P.E. Bragg 25.xii.2006, and reared to adult in UK on Eucalyptus, raspberry and bramble. ♀ (KNP, SP/EPH/00685) Tmn Banjaran Croker, 900m. Yusilie Kumin. 09-19.viii.2004. ♂(OXUM) Danum valley, Danum 1. At night, D.J. Mann, 07.xi.2005. ♀(CUMZ) Danum valley. T2 VC. J.L. Snaddon, iii.2006. 3♂♂ ♀ (FRCS) Keningau, Ulu Bagam. Momin B., John L.Y & Willibrord J. 15-17.iv.2006. 4♂♂ (PEB-496; PEB-872; PEB-874; PEB-880), 2♀♀(PEB-870; PEB-887), eggs (PEB-884) Mt Kinabalu NP, near HQ, 1580m. P.E. Bragg, 30.vii.1990. 2♂, 2♀ (AJH) Kinabalu N.P. A. Harman & M. Salton, 26.ix-15.xi.1983. ♂ (KNP, SP/EPH/00653) Kinabalu Park, Silau Silau Trail. P.E. Bragg. 21.viii.2001. ♀ (KNP, SP/EPH/00666) Kinabalu Park, Silau Silau Trail. Johnny L. 06.vi.2002. ♂ (KNP, SP/EPH/00652) Kinabalu Park, Silau Silau Trail, 1450m. Wahimah S.04.vi.2003. 3♂♂ (KNP, SP/EPH/00650; KNP, SP/EPH/00649; KNP, SP/EPH/00656) Kinabalu Park, Silau Silau Trail, 1450m. Johnny L. 04.vi.2003. ♂ (KNP, SP/EPH/00655) Kinabalu Park, Silau Silau Trail, 1450m. Benedict B. 04.vi.2003. ♂ (KNP, SP/EPH/00658) Kinabalu Park, Silau Silau Trail, 1450m. Johnny L. 06.vi.2002. ♀ (KNP, SP/EPH/00674) Kinabalu Park, Silau Silau Trail, 1450m. Nancy J. 04.vi.2003. ♀ (CLC) Kinabalu Silau Silau Trail, 5200ft. C.L. Chan, K.M. Wong & Jamal Hassim, June 1994. 2♂♂ (KNP, SP/EPH/00657; KNP, SP/EPH/00648) Kinabalu Park HQ. Johnny L. 17.x.2002. ♂ (KNP, SP/EPH/00651) Kinabalu Park HQ. Yusilie K. 17.x.2002. ♀ (KNP, SP/EPH/00669) Kinabalu Park HQ. Sinail D. 10.iv.2002.

♀ (KNP, SP/EPH/00673) Kinabalu Park HQ, 1450-1600m. Johnny L. 05.v.2004. ♀ (KNP, SP/EPH/00670) Kinabalu Park HQ, 1450-1600m. Yusilie K. 03.iii.2004. ♂ (KNP, SP/EPH/00647), ♀ (KNP, SP/EPH/00672) Kinabalu Park H.Q., 1400-1600m. Yusilie K. 05.v.2004. ♂ (KNP, SP/EPH/00646) Kinabalu Park H.Q., 1400-1600m. Sinial D. 05.v.2004. ♂ (KNP, SP/EPH/00659) Kinabalu Park HQ 1400-1500m. Sinial D. 06-07.viii.2003. ♂ (KNP, SP/EPH/00654) Kinabalu Park HQ, 1500m. Wahimah S. 06.vi.2002. ♀ (KNP, SP/EPH/00675) Kinabalu Park HQ, 1500m. Nancy J. 06.vi.2002. ♀ (KNP, SP/EPH/00671) Kinabalu Park HQ, 1500m. Yusilie K. 06.vi.2002. ♀, 2♂♂ (CLC) Kinabalu N.P. c. 5200ft. C.L. Chan & A. Phillips, 05.ii.1986. ♀, ♂ (CLC) Kinabalu N.P. c. 5200ft. C.L. Chan & V.K. Lo, 24.iv.1982. ♀ ♂ (CLC) Kinabalu N.P. c. 5200ft. C.L. Chan & L. Chin, 19.ix.1981. 2♂♂ (CLC) Kinabalu N.P. c. 5200ft. C.L. Chan & K.F. Ki, 10.x.1981. ♂ (CLC) Kinabalu N.P. c. 5200ft. C.L. Chan, 09.x.1982; *Staelonchodes sarawaca* (Westwood). 2♂♂ (CLC) Kinabalu N.P. c. 5200ft. C.L. Chan & M.Y. Chan, 30.iv.1986. 2♂♂ (CLC) Kinabalu N.P. c. 5200ft. C.L. Chan & M.Y. Chan, 01.v.1986. 2♀♀, 3♂♂ (PJ) Kinabalu N.P. c. 5200ft. Paul Jennings, vii.1990. ♀ + egg (BMNH BM1982-387) Kinabalu NP, 5200ft. A. Harman, 10-19.i.1981. 4♂♂, 2♀♀ (FH 0070-12 to 17) Mt. Kinabalu Park, near Head Quarters, Silau-Silau Trail, 1550 m. leg. Hennemann & Conle 4-8.viii.1996. ♂ (KNP, SP/EPH/00660) Eksplorasi PHQ T.K. Yusilie K. 07.vii.2004. 2♀♀ (KNP, SP/EPH/00681; KNP, SP/EPH/00680) Eksplorasi PHQ T.K. Yusilie Kumin. 03.v.2004. ♀ (KNP, SP/EPH/00687) K. Kinabalu, Pulau Gaya. Sinial D. 15.x.1998. ♂ (CLC) Maliau Basin, Gunung Lotung, 500m. W. Wong, 18-20.iv.1988. ♀ (FRCS) Mile 69, Lungmanison ground.1. Jaunis. 23.ix.1969. ♀ (CLC) Penampang. C.L. Chan & L. Chin, 04.ii.1982; *Staelonchodes sarawacus* (Westwood). 2♂♂ (FRCS) Penampang Sugud. Momin B., John L.Y & Willibrord J. 10-14.iv.2006. ♂ 3♀♀ (FRCS) Ranau, Jalan Mamut. Momin B., John L.Y & Willibrord J. 20-24.iv.2006. ♂ (CLC) Ranau, Tenompok Forest Reserve, Lower Montane Forest, 4800ft. Sulaiman Talip, 30.vi.1994. ♂ (KNP, SP/EPH/00665) Sayap, 1000m. Patric. 18.ii.1993. ♂ (FRCS) Sepilok Aroebtum *[sic]*. Dius. 23.xi.1977. ♂ (CLC) Sepilok. C.L. Chan, 25.ix.1982. ♀ (KNP, SP/EPH/00688) Mt. Silam (B). Sinial D. 12.ix.1995. ♀, ♂ (CLC) Mt. Silam. W.W.W. Wong, 1986. ♂ ♀ (FRCS) Sook. Momin, Zaina & John. 10-13.vii.2005. ♂ (KNP, SP/EPH/00663) Tawau Hill Park. 300m. Johnny L. 25.ix.2002. ♀ (KNP, SP/EPH/00683) Tawau Hill Park. 300m. Johnny L. 23.ix.2002. ♂ (KNP, SP/EPH/01049) Tawau Hill Park. 300m. Yusilie K. 28.viii.2004. ♀ (KNP, SP/EPH/01271) Tawau Hill Park. 300m. Yusilie Kumin. 12-17.i.2006. ♂ (KNP, SP/EPH/01266) Tawau Hill Park. 300m. Johnny Lapidin. 12-17.i.2006. 8♂♂ 4♀♀ (FRCS) Telupid, H.S. Tawai. Ento. Staff. vi-vii.1994 [one male lacks the abdomen]. ♂ (FRCS) Telupid S'kan, Tawai F. Res. Ento. Staff. 1-13.ix.1994. ♂ (KNP, SP/EPH/00664) Telupid, Imbak, Ekspidisi, 150-300m. Sinail Dunsul. 12-16.v.2004. 2♂♂ 2♀♀ (FRCS) Tenom, Ulu Kallang. Momin B., Richard L.A. & Willibrord J. v.2004. ♂ (KNP, SP/EPH/00662) Tenom, Melalap, Kg Samlnling. Dolois S. 26-30.i.2004. ♀ (KNP, SP/EPH/00684) Trus Madi ekspidisi. Maklarin L. 02.xii.2001. ♀ (AJH) Ulu Dusun. AJE Harman & M. Salton, 18.viii.1979. ♀ (AJH) Ulu Dusun. A. Harman & M. Salton, 22.viii.1979.

SARAWAK:

♀ (BMNH 87-14) "Sarawak". B. Low. ♀ (BMNH 95-202) Borneo, Baram. ♀ (SMSM) Lambir Hills N.P. #8-4.3, Robert Junker, 04.iii.2006 "Lonchodinae ?". ♀ (PEB-1635) Niah NP. P.E. Bragg, 17.viii.1992. ♀ + egg (BMNH BM1982-387) Batu Niah. A. Harman, xi-xii.1980. ♀ (PEB-2321) Tarum (near Debak). P.E. Bragg, 05.xi.1994. ♀ (PEB-495); eggs (PEB-1055 – removed from body of PEB-495) Mt Serapi. P. E. Bragg, 13.viii.1990.

Other material (not types)

The following are excluded as types because they have not been re-examined, are too immature, or lack any locality data.

BRUNEI: ♂ (BMKB, PEB-993), ♀ (BMKB, PEB-992) Temburong District, Bukit Belalong, 910m. P.E. Bragg, 10.viii.1991 [labelled as *A. sarawacus*].

SABAH: Kinabalu Park, HQ area: several immature specimens in KNP.

NO DATA: ♂ (OXUM).

Specimens have been collected or recorded from the following localities since the description of the species was completed; some additional specimens were not collected, but were identified in the field and released. These records are included on the distribution map. Some specimens have since been deposited in KNP and FRCS.

SARAWAK, Niah National Park. ♀ (PEB-4178) P.E. Bragg, 23.vi.2024; ♀ (PEB-4180) P.E. Bragg, 24.vi.2024.

SABAH, Mt. Silam. ♀ (PEB-4061) P.E. Bragg, 09.x.2022.

SABAH, Kawag Gibong Forest Reserve. ♀ (PEB-4074) P.E. Bragg, 12.x.2022.

SABAH, Sepilok RDC. ♀ (PEB-4139) P.E. Bragg, 26.xi.2023.

SABAH, Kinabalu Park, HQ area, Silau-Silau trail, lower end. ♀ (PEB-4152) P.E. Bragg, 03.xii.2023 [deposited in KNP].

SABAH, Crocker Range Park, Ulu Kimanis substation. ♀ (PEB-4199) ♂ (PEB-4198) P.E. Bragg, 29.vi.2024 [deposited in KNP].

SABAH, Crocker Range Park, Melalap substation. ♀ (PEB-4204) ♂ (PEB-4205) P.E. Bragg, 30.vi.2024 [deposited in KNP].

SABAH, Crocker Range Park, Gunung Alab substation. ♀ (PEB-4220) ♂ (PEB-4221) P.E. Bragg, 02.vii.2024 [deposited in KNP].

SABAH, Tawai FR. ♀ (PEB-4239) P.E. Bragg, 08-09.vii.2024 [deposited in FRCS].

SABAH, Crocker Range Park HQ (near Keninau). 1♀n [*in situ* only] P.E. Bragg, 16.ii.2025.

SABAH, Tawau Hills National Park. ♀ (PEB-4283), ♂ (PEB-4284) P.E. Bragg, 19.xi.2025.

Diagnosis of *vulgaris*

Male with mid legs not reaching to end of abdomen; body dark brown, black, dark green, or blue-black, legs often mottled; lateral margins of 9th tergite straight or smoothly curved; vomer with one point. Female with anal segment serrated; operculum densely setose; praeopercular organ a semicircular notch in the posterior margin of 7th sternite.

Female (figs. 1J –L, 8 & 11)
Colour usually more or less uniformly mid or dark brown, lighter individuals may have some dark granules. Head, prothorax and abdomen sparingly granulose; mesothorax and metathorax densely granulose, ventral and dorsal surfaces of thorax equally granulose; posterior half of abdomen rugulose. Body length 64.5–95.0mm.

Head rectangular, width of epicranium ¾ of length. Pronotum one and a half times longer than wide. Mesonotum rectangular, of uniform width, about 5.5 times longer than width. Metanotum about 1.3 times longer than median segment. Second abdominal segment slightly longer than metanotum; 3rd about 10% longer than 2nd; 4th about 10% longer than 3rd; 4th and 5th of equal length; 6th–9th decreasing in length; 10th as long as 9th. Anal segment usually with about 10 sharp serrations; the number varies from about 8–12 and some may be blunt rather than sharp. Abdominal tergites very sparingly setose, 9th & 10th notably setose. Abdominal sternites densely setose along the mid line, 7th and operculum densely setose across the whole width. Operculum with deep incision. Cerci short and broad. The praeopercular organ is a deep semi-circular indentation on the posterior margin of the 7th sternite.

Legs long and slender. Hind tibiae reaching just to apex of abdomen. All legs with basal tarsomere shorter than the combined length of tarsomeres 2 –5.

Male (figs. 2L –M, 8, 13 & 14)
Colouration usually almost uniformly dark to very-dark brown, occasionally with a reddish tinge to the middle and hind legs, and often with pale "knee" joints. Head and prothorax sparingly granulose; mesothorax and metathorax densely granulose, ventral and dorsal surfaces of thorax equally granulose; abdominal tergites decreasingly granulose: 1 –3 moderately, 4 –5 very sparingly granulose; posterior half of abdomen rugulose. Body length 52.5–75.0mm; Holotype 60.0mm.

Head rectangular, epicranium about one and a half times longer than wide. Pronotum almost twice as long as wide. Mesonotum wider at anterior and posterior; about 12 times longer than width at mid point. Metanotum almost twice as long a median segment. Abdominal segments 2 –5 of about equal length, 6th about 15% shorter than 2nd, 7th about 30% shorter than 2nd and widening slightly at posterior; 8th widening to about 1.5 times as wide as 2 –6; 8th and 9th each half as long as 2nd; 10th slightly shorter than 9th. Lateral margin of 9th tergite more or less straight. Anal segment slightly indented, with numerous small teeth ventrally. Cerci cylindrical. Vomer broad, with a single spine (figs. 2M & 13).

Mid legs not reaching the end of the abdomen, middle of hind tibiae about level with end of abdomen. Basal tarsomere of fore and hind legs about as long as combined length of tarsomeres 2 –5; shorter than combined length on mid legs.

Egg (fig. 10)
Capsule light to mid-brown, rugose, length 5.6mm, width 1.7mm, height 1.7mm. The length of eggs is quite variable (three eggs varied from 4.7 –5.7mm) but diameter seems fairly consistent.

Comments

The colouration of the female is less variable that that of *inglisi*, ranging from mid brown to black. The end of the male's abdomen is slightly less dilated than *inglisi*.

At my request, Frank Hennemann examined Günther's (1943: 153) female specimen of "*sarawacus*" in RMNH and has confirmed that it is this species. Two specimens from the collection of C.L. Chan had been labelled *Staelonchodes sarawacus* (Westwood) by Chan.

The species varies in size and my two female specimens from around Kinabalu Park HQ (68 –69mm) are slightly smaller than those from elsewhere (70 –94mm). Although my smallest males are from Kinabalu, the variation (55 –66mm) is not dissimilar from some lowland areas; the largest male from Kinabalu is not much smaller than my largest Bornean specimen (70mm, from Teraja waterfall trail, Brunei).

Blüthgen (2006: 37) records it from Danum Valley (as *sarawacus*), but found in feeding tests that it would not feed on *Mallotus miquelianus, Macaranga hypoleuca, Spatholobus* spp., *Parashorea malaanonan,* or *Dryobalanops lanceolata*. Junker *et al.* (2008) record it from Lambir Hills and in feeding tests it did eat (in order of mass eaten): *Shorea smithiana, Pseuduvaria nervosa, Horsfieldia pallidicaula, Dryobalanops lanceolata, Macaranga beccariana, Koilodepas laevigatum,* and *Mallotus wrayi.* The differing results for *Dryobalanops lanceolata* could be due to leaves of different ages being tested.

In captivity in the UK the nymphs collected in the Crocker Range Park on 25.xii.2006 fed on *Rosa canina*, *Rubus fruiticosus*, *Rubus idaeus,* and *Eucalyptus gunnii*. The females subsequently laid eggs in a tray of damp Vermiculite (fig. 11) but their egg laying behaviour in the wild is unknown; it is possible that eggs are laid in crevices in tree bark or in moss on trees rather than in soil.

It is possible that the specimen from "Mt Serapi, Sarawak" (♀ PEB-495 and eggs PEB-1055 removed from its body) has been mislabelled. A number of specimens of *Acacus* were brought back to the UK alive in 1990 from Sarawak and from Sabah and were housed in the same cage; the specimen could be from Mt Kinabalu. However, this species has also been found at Tarum in Western Sarawak and in Kalimnatan Tengah so obviously has a wide distribution (fig. 15). My illustration and measurements of the egg of "*sarawacus*" (Bragg, 1992, and 2001) are of *vulgaris.*

Some specimens are excluded from the type series: those in BMKB have not been examined since they were collected and misidentified as *sarawacus* in 1991, but they are from the same locality as material in the type series; the OXUM specimen lacks any data; there are a number of immature specimens in KNP which are presumably this species (based on their locality). References to *A. sarawacus* from Sabah by Seow-Choen (e.g. 2016) probably relate to *A. vulgaris* rather than *A. inglisi.*

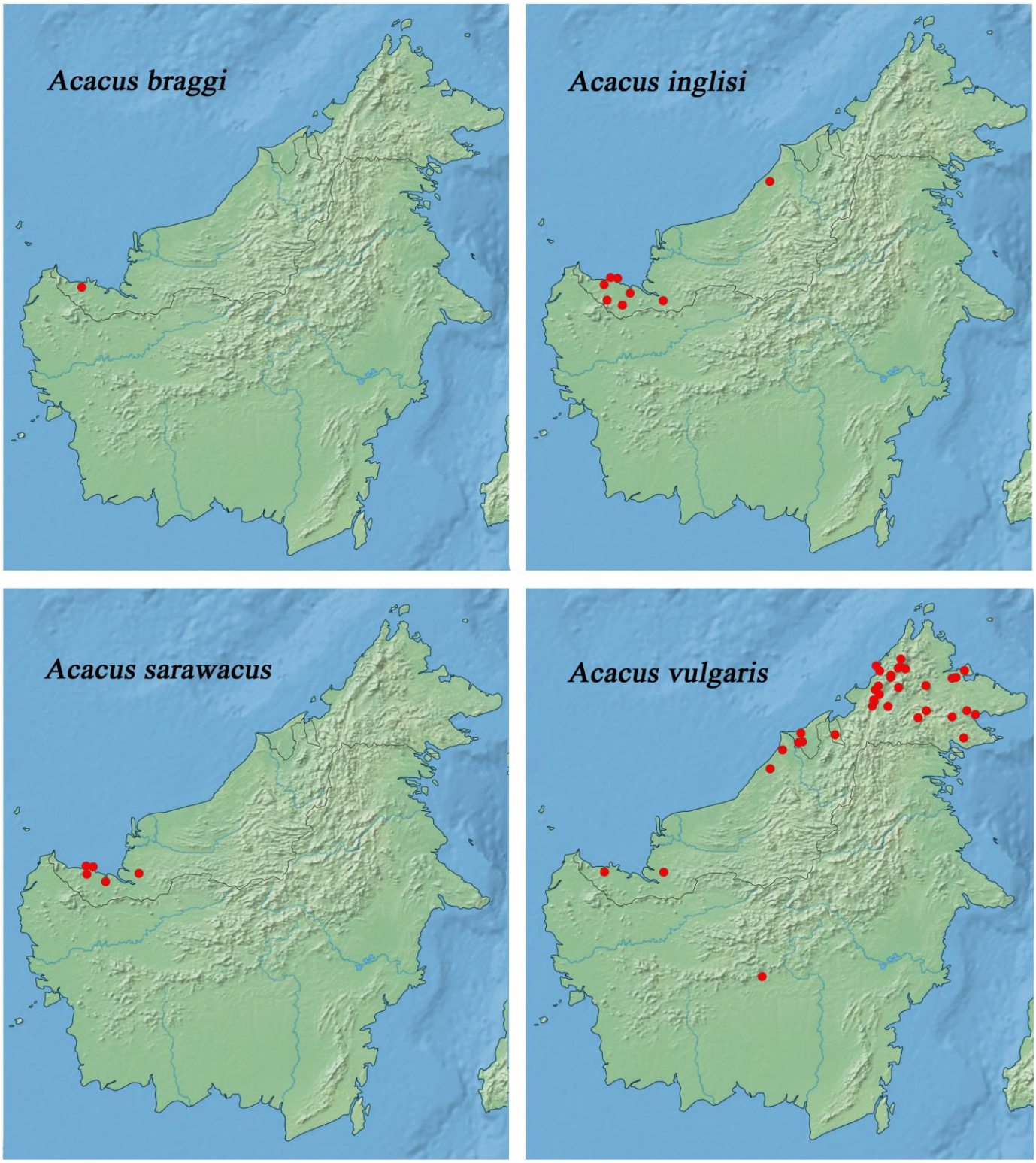


Figure 13. Distribution maps of Bornean *Acacus* spp.

Acacus from outside Borneo

The genus has been recorded from several islands other than Borneo: Moluccas, Singapore, and Sumatra; it has also been recorded from Thailand. The status of the records from Thailand, Moluccas and Singapore requires further investigation.

Acacus sinkiebensis Wood-Mason, 1877, stat. rev.

*Bacteria sinkiebensi*s Wood-Mason, 1877: 343. Syntypes: 1♀, 1♂ (NZSI) Sumatra, Sinkep Island [specimens lost according to Günther, 1938: 127]; Mukherjee & Sirinivasan, 2013: 28 consider the two specimens in NZSI to be the syntypes.

Staelonchodes sinkiebensis (Wood-Mason); Kirby 1904: 317.

Acacus sarawacus Günther, 1938: 127 [not *sarawacus* Westwood, 1859]; Seow-Choen, 2018: 14 [but the figures are not *sinkiebensis*].

Acacus sarawacus sinkiebensis Seow-Choen, 2020: 70.

Diagnosis: Combined length of the metanotum & median segment clearly more than 10% of body length in male, about 10% in female; both sexes with pronotum more than 5% of body length.

Wood-Mason's description of this species is extremely brief: "Differs from *B. sarawaca*, Westw. ♂ ♀ chiefly in the relative proportions of the different parts of the body." He then gave measurements of the two sexes. Wood-Mason's measurements were given in inches and lines; these have been converted to millimetres (using 1 line = 2.22mm) and are given in Table 1. The species was named after Sinkib Island, which appears to be an alternative spelling, or misspelling for Sinkep Island that is off the N.E. coast of Sumatra.

Günther synonymised the species, based on a female specimen from the type locality. He stated that it agreed perfectly with Westwood's illustration and description. Seow-Choen (2020) treated *sinkiebensis* as a subspecies of *sarawacus*. However, Wood-Mason's measurements do not agree with any other species of *Acacus*; the length of the mesonotum and median segment is too great compared with the body length for any species other than *A. braggi* (21% too large in both sexes when compared to *sarawacus*). The pronotum of *sinkiebensis* is 20-30% too large when compared to *braggi*. Examination of photographs of the male and female specimens in NZSI show the female is much too robust to be *sarawacus* and too granulose to be *braggi*; the male is too robust to be either of these species. It is therefore unjustifiable to treat *sinkiebensis* as either a synonym or a subspecies of *sarawacus*. Unfortunately, the photographs available to me are not detailed enough to be certain of excluding *inglisi* and *vulgaris*, but the apex to the abdomen of the female does not appear to be serrated so *sinkiebensis* seems to be distinct from all the Bornean species. The illustrations in Seow-Choen (2018: 14 –15) are not *sinkiebensis*, and not from Sumatra.

Maluku islands

The Maluku islands, formally known as the Molucca islands, are a large group of Indonesian islands which spread over a wide area. Brunner (1907: 252) recorded *Acacus sarawacus* from the Moluccas in addition to Borneo, but examination of photographs of his material in NHMW shows it was misidentified; although it is clearly not sarawacus, the identity of the Maluku material is not known.

Singapore

"Acacus species (possibly new)" Seow-Choen *et al*., 1994c: 12 & fig.

Acacus sarawacus Seow-Choen *et al.*, 1994a: 9; Seow-Choen *et al.*, 1994b: 93 fig (♀ & ♂); Brock, 1999: 47, 23e (egg)*;* Seow-Choen, 2000: 11, pl. 17a-b (♂), 17c-d (♀), 17e (egg); Seow-Choen, 2005: 25 & 4 figs. [not *sarawacus* Westwood]; Seow-Choen, 2018, fig. 1 (& figs 2A-F ?).

My material: Singapore, Nee Soon Swamp Forest, ♀ (PEB-1512) 25.vii.1992.

Records of *Acacus sarawacus* from Singapore, largely by Brock and Seow-Choen, are somewhat inconclusive. The illustrations given by these authors are clearly not *sarawacus* (except Brock, 1999: figs 23a-d which were taken from Westwood's publication) but are inadequate to distinguish between *inglisi* and *vulgaris*. My single specimen is in poor condition, having apparently shed its skin shortly before dying; it is not possible to be certain to which species it belongs. It is probably *A. inglisi* but could be A. vulgaris; it is clearly not *A. sarawacus* or *A. braggi*. Other specimens I collected in 1992 were deposited in Singapore, labelled as *A. sarawacus*, at the time of collection but I have not had the opportunity to re-examine them.

Seow-Choen *et al.* (1994: 93) state that material [of their *sarawacus*] from "Singapore differs from those found in Borneo only by being about a third to half as large". However the size range for Singapore specimens of "female: 88 –91mm" given by Seow-Choen (2000: 11) falls well within the range shown by *vulgaris* (females 68 –94mm); Seow-Choen's males (72 –75mm) are at the larger end of the range shown by *vulgaris* (55 –75mm). When discussing Bornean material Seow-Choen (2000: 11) states "There are two forms there. The lowland form is similar in size to the Singapore specimens, whereas the form from Mount Kinabalu is much smaller in size". In fact *A. inglisi* fall within the size range of *vulgaris*, so size cannot be used to distinguish the species. Generally the lowland specimens tend to be larger than those from higher altitudes but with the large number of specimens of *vulgaris* that I have examined there does not appear to be any discontinuity in the size. Seow-Choen (2000: 11) records three foodplants found in South East Asia: *Lithocarpus ewyckii, Psidium guajava, Rubus moluccanus* but it is not clear if this relates to the species in Singapore, or a species from Borneo. Seow-Choen (2018) states that figure 1 is from Singapore but does not state the origin of the material in the other photographs.

Sumatra

Three species are associated with Sumatra.

1. *Acacus indarungus* Seow-Choen, 2020: 64. The bifurcate anal segment of the female distinguishes this from the other species in the genus.
2. *Acacus sinkiebensis* (Wood-Mason, 1877) is discussed above.
3. *Acacus sumatranus* Seow-Choen, 2018: 16, figs 3-4. This is superficially similar to *A. inglisi* and *A. vulgaris* but the females may be distinguished by the anal segment which is not serrated in *sumatranus* but is in the two Bornean species.

Thailand

Acacus rufipectus Brunner, 1907: 252; Brock, 1998: 54; Otte & Brock, 2005: 36. Holotype ♂ (NHMW) Western Thailand.

This species is known only from the holotype. The description, and a photograph of the holotype, suggests that it does not belong in *Acacus*. Brunner's description of thickened legs and transverse carinae on the thorax leads shows this species differs considerably from the Bornean species and is clear that this species does not belong in the same genus. Frank Hennemann (personal communication, August 2005) has examined the specimen and agrees with this view. The correct generic position is unknown.

Distribution of *Acacus* in Borneo

The genus is recorded from Borneo, Singapore, Sumatra and Thailand. However, *A. rufipectus* Brunner, 1907 from Thailand clearly does not belong in *Acacus*. The absence of the genus from mainland Malaysia raises the possibility that the genus may have been introduced to Singapore. It is known that various insects, including phasmids, were being reared by Shelford when he was Curator of the Sarawak Museum and that this included some non-Bornean species (Shelford, 1916: 154); it is therefore possible that some live Bornean species were exchanged with Singapore and subsequently escaped or were released.

The known distribution of the Bornean species (fig. 15) is limited because the material examined has been largely limited to Sarawak and Sabah. *Acacus braggi* is only known from Mt. Serapi in Kubuh National Park. *Acacus sarawacus* is only known from within a 70km radius of Kuching at the western end of Sarawak. *Acacus inglisi* is known from the western end of Sarawak and Niah National Park in eastern Sarawak. *Acacus vulgaris* has the most widespread distribution, occurring in Brunei, Kalimantan, Sabah, Sarawak, and also from the small island of Pulau Gaya near Kota Kinabalu.

Disposition of type specimens

The holotypes of the two new species, along with a female of each species will be deposited in BMNH[1], as will a pair of *A. sarawacus*. The type specimens from C.L. Chan's collection have been deposited in BMNH, as have the type specimens from the collection of Paul Jennings. I intend to distribute some of my own paratypes to SMSM, FRCS, and Kinabalu Park Conservation Centre so that each has male and female representatives of both species. Paratypes of *Acacus inglisi* have recently been deposited as follows: PEB-1661 & PEB-1666 in BORN, and PEB-1663 in OXUM. Robert Junker's specimen of *A. vulgaris* was deposited in SMSM in January 2024. Other paratypes will be distributed to other museums when the opportunity arises.

[1][Editor remark: for comments on deposited specimens at NHMUK/=BMNH see *Editorial Remarks*, p. 50]

Summary

There are four species of *Acacus* recognised from Borneo. At least two species are endemic to Borneo: *A. braggi* Hennemann & Conle, and *A. sarawacus* (Westwood); both seem to have quite a restricted distribution. *Acacus sarawacus* has been misidentified by all authors since it was originally described and A. *sapuani* Seow-Choen, 2016 is a junior synonym. *Acacus sinkiebensis* (Wood-Mason, 1877) which has previously been synonymised with *sarawacus* by Günther (1938) and listed as a subspecies of *sarawacus* by Seow-Choen (2020) seems to be a valid species and is distinct from the Bornean fauna. The remaining species: *A. inglisi* **n.sp.** and *A. vulgaris* **n.sp.** both occur in Borneo and are the two most common species in the genus. The species that occurs in Singapore is probably either *inglisi* or *vulgaris* but specimens need to be examined to confirm which.

Acknowledgements

Thanks to Frank Hennemann (Germany) for providing photographs of material in NHMW and RMNH; to Tushar Mukherjee for photographs of *Acacus sinkiebensis*; to C.L. Chan, Paul Jennings, Frank Hennemann, Oliver Zompro, Alan Harman, Robert Junker, & Nico Blüthgen (Universität Würzburg) for the loan of material; to Darren Mann (OUMNH) for checking Westwood's handwriting and for the loan of material; to George Beccaloni (previously NHMUK) and Judith Marshall (NHMUK), William Foster (CUMZ), Chey Vun

Khen (previously FRCS), Arthur Chung (FRCS), Maklarin bin Lakim (Kinabalu Park) for access to the collections. I am also grateful to the late Abang Hamid (Sarawak Forestry Department), Chey Vun Khen, and Maklarin bin Lakim for giving me permission to collect phasmids during my visits to Sarawak & Sabah from 1987-2006. The material collected at Kuala Belalong in 1991 was collected as part of the RGS/UBD expedition. Specimens collected in Sarawak in 2024 were collected under permit SFC.810-461(2024)-009; those from Sabah in 2022-2025 were collected under SaBC Access Licences JKM/MBS.1000-2/2JLD.14(101), JKM/MBS.1000-2/2JLD.17(159), and JKM/MBS.1000-2/2/1JLD.1(52).

References

Arnett, R.H., Samuelson, G.A. & Nishida, G.M. 1993. The insect and spider collections of the world. [second edition] Sandhill Crane Press, Gainesville, Florida.

Blüthgen, N., Metzner, A. & Ruf, D. 2006 Food plant selection by stick insects (Phasmida) in a Bornean rain forest. Journal of Tropical Ecology, **22**: 35–40.

Bragg, P.E. 1992a. Phasmida from Bako National Park. Sarawak Museum Journal, **43**(64): 295–319.

Bragg, P.E. 1992b. New Additions to the species list. Phasmid Study Group Newsletter, **50**: 5.

Bragg, P.E. 1994. Stick insects pp. 240 –241. In: Earl of Cranbrook & Edwards, D.S. Belalong – a tropical rainforest. The Royal Geographical Society & Sun Tree Publishing, UK & Singapore.

Bragg, P.E. 2001. Phasmids of Borneo. Natural History Publications (Borneo), Kota Kinabalu.

Bragg, P.E. 2008. Praying mantids from the 'Gladiator' Expedition to the Brandberg Massif, Namibia, in 2002 (Insecta: Mantodea). Entomologist 's Monthly Magazine, **144**: 173–179.

Bragg, P.E. 2025. A Review of The Cockroaches, Mantids and Phasmids from Niah National Park, Sarawak (Insecta: Blattodea, Mantodea, & Phasmida). The Sarawak Museum Journal, **89**(110): 73–92.

Bragg, P.E., Japir, R. & Dg. Fazrinah, A.D. 2026 Cockroaches, mantids and phasmids from Tawai Forest Reserve, Sabah (Insecta: Blattodea, Mantodea and Phasmida). Sepilok Bulletin, **35**: 19–35.

Brock, P.D. 1996. Catalogue to stick and leaf-insects (Insecta: Phasmida) associated with Peninsular Malaysia and Singapore. Malayan Nature Journal, **49**(2): 83–102.

Brock, P.D. 1997. Magnificent Malaysian insects. Bulletin of the Amateur Entomologists' Society, **56**(413): 135 –136, pl. 97M & 97N.

Brock, P.D. 1998. Catalogue of type specimens of stick- and leaf-insects in the Naturhistorisches Museum Wien (Insecta: Phasmida). Naturhistorisches Museum Wien, Austria.

Brock, P.D. 1999. Stick and leaf insects of peninsular Malaysia and Singapore. Malaysian Nature Society, Kuala Lumpur.

Brock, P.D., Büscher, T. & Baker, E. 2022. Phasmida Species File Online. Version 5.0/5.0.http://Phasmida.SpeciesFile.org.

Brock, P.D., Marshall, J.A., Beccaloni, G.W. & Harman, A.J.E. 2016. The types of Phasmida in the Natural History Museum, London, UK. Zootaxa, 4179 (2): 151–208.

Brunner von Wattenwyl, K. 1907. Die Insektenfamilie der Phasmiden. Vol. **2**. Leipzig.

Carl, J. 1913. Phasmides nouveaux ou peu connus du Muséum de Genève. Revue Suisse de Zoologie, **21**(1): 1–56, pl. 1.

Günther, K. 1934a. Phasmoïden von den Talaud-Inseln und von der Insel Morotai, mit kritischen Bemerkungen über einzelne Arten und einem zoogeographischen Anhang. Sitzungberichte der Gesellschaft naturforschender Freunde, pp. 75–94.

Günther, K. 1934b. Phasmoiden und Forficuliden von Java, den Kleinen Sundainseln und Nordaustralien. Revue Suisse de Zoologie, **41**: 525–537.

Günther, K. 1938. Neue und weinig bekannte Phasmoiden aus dem Indian Museum Calcutta. Records of the Indian Museum, **40**: 123–141.

Günther, K. 1943. Die Phasmoïden (Orthoptera) der "Borneo-expedition Dr. Nieuwenhuis" aus dem Stromgebiet des oberen Mahakam. Eos Madrid, **19**: 149–172.

Günther, K. 1953. Über die taxonomische Gliederung und die geographische Verbreitung der Insektenordnung der Phasmatodea. Beiträge zur Entomologie, **3**(5): 541–563.

Hausleithner, B. 1991. Eine Phasmidenausbeute aus dem Gebiet des Mount Kinabalu, Borneo (Phasmatodea). Nachrichten des Entomologischen Vereins Apollo, Frankfurt, N.F. **11**(4): 217–236.

Hennemann F.H. & Conle, O. 2003. Notes on rarely known Phasmatodea from Sarawak with the description of two new species and studies on the genus *Gargantuiodea* Redtenbacher, 1908. Mitteilungen der München Entomologische Gesellschaft, **93**: 11–24.

Junker, R., Itioka, T., Bragg, P.E. & Blüthgen, N. 2008. Feeding preferences of phasmids (Insecta: Phasmida) in a Bornean dipterocarp forest. Raffles Bulletin of Zoology, **56**(2): 445–452.

Kirby, W.F. 1904. A synonymic Catalogue of Orthoptera. Vol. **1**. London.

Mukherjee, T.K. & Sirinivasan, G. 2013. Type specimens of phasmids in the National Zoological Survey of India collection (NZSI), Kolkata, India (Insecta: Phasmida). Phasmid Studies, **18**: 24–33.

Otte D. & Brock, P.D. 2005. Phasmida Species File, catalog of stick and leaf insects of the world. Insect Diversity Association, Philadelphia.

Seow-Choen, F. 2000. An illustrated guide to the stick and leaf insects of peninsular Malaysia and Singapore. Natural History Publications (Borneo), Kota Kinabalu.

Seow-Choen, F. 2005. Phasmids of Peninsular Malaysia and Singapore. Natural History Publications (Borneo), Kota Kinabalu.

Seow-Choen, F. 2016. A Taxonomic Guide to the Stick Insects of Borneo. Volume 1. Natural History Publications (Borneo), Kota Kinabalu.

Seow-Choen, F. 2017. Observations on Stick Insects from Mount Kinabalu featured in A taxonomic guide to stick insects of Borneo including Emendations. The Sabah Society Journal, 33: 1–30.

Seow-Choen, F. 2018. A Taxonomic Guide to the Stick Insects of Sumatra. Volume 1. Natural History Publications (Borneo), Kota Kinabalu.

Seow-Choen, F. 2020. A Taxonomic Guide to the Stick Insects of Sumatra. Volume 2. Natural History Publications (Borneo), Kota Kinabalu.

Seow-Choen, F., Brock, P.D. & Seow-En, I. 1994a. An introduction to the stick and leaf-insects of Singapore. Malayan Naturalist, **48**: 7–11.

Seow-Choen, F. Seow-En, I. & Seow-An, S. 1994b. Nature's mimics. Nature Malaysiana, **19**(3): 89–96.

Seow-Choen, F., Brock, P.D. & Seow-En, I. 1994c. The Stick Insects of Singapore. Singapore Scientist, **70**: 10–14.

Shelford, R.W. 1916. A Naturalist in Borneo. T. Fisher Unwin, Ltd. London. [1985 reprint, Oxford University Press].

Westwood, J.O. 1859. Catalogue of the Orthopterous Insects in the Collection of British Museum. Part I: Phasmidae. London.

Wood-Mason, J. 1877. Notes on Phasmidae. Journal of the Asiatic Society of Bengal, **46**(4): 342–352, pl. 2–3.

***Acacus* spp.**	*braggi*		*inglisi* **n.sp.**		*sarawacus*		*sinkibensis*		*vulgaris* **n.sp.**	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
Body length	71-74	93-101	60-70	75.5-93.5	69-79	100-105	71	93.2	52.5-75	64.5-95
Antennae	>76-88	78-?	57-66	>37-66	75-83	89->91	63.2	69.3	>41.5-69	44-c.64
Head	3	5	3-3.5	4.5-5	3-3.5	4.5	3.9	5.6	3-3.5	4-5.5
Pronotum	3	4-4.5	3	4.5	3-3.5	4.5	3.9	5.6	3-3.5	4-5.5
Mesonotum	19-21	23-25	17-18.5	19-23.5	20.5-23	27	19.4	23.9	14.5-20	15.5-25
Metanotum	6-6.5	7	5	4.5-6	4.5-5	5	8.9	9.4	4-5	4-5.5
Median segment	2.5	4	2.5-3	3-3.5	2.5-3	3-3.5			2-3	2.5-3.5
Fore femur	29-27.5	28-29	19-22	20-23	24-26	28-29	-	-	16.5-23.5	17.5-25
Fore tibia	32-30	29	20-24	20-23.5	26-29	31-32	-	-	18-24.5	17-27.5
Fore tarsus	12	12-12.5	6.5-7	7.5-8	7.5-8	9.5	-	-	6-7.5	6-8
Mid femur	21	21	14-16	15-17.5	18-20	22-22.5	-	-	13-17.5	13-19
Mid tibia	23-22	19-20.5	14.5-17	14-16	18.5-21	22-22.5	-	-	13-17.5	13-18.5
Mid tarsus	9	9	5.5	6-6.5	6-6.5	7	-	-	5-6	4.5-6
Hind femur	28-27	28.5-29.5	19.5-23	20-24	25-28	30	-	-	18-25.5	18-26
Hind tibia	33-32	29-30.5	22.5-28	21.5-25.5	28-33	33-34	-	-	20-26.5	20-28
Hind tarsus	13	12	7	7-7.5	8-8.5	9.5	-	-	6-7	6-7.5

Table 1. Measurements (mm) of Bornean *Acacus* species taken from the longest and shortest specimens and measurements of *Acacus sinkibensis* from Wood-Mason's description (converted from lines to mm).

The giant walking stick (*Megaphasma denticrus*) feeding on eastern cedar (*Juniperus virginiana*)

Mark Janowiecki
City of New Orleans Mosquito, Termite, and Rodent Control Board, 2700 Leon C. Simon Dr., New Orleans, Louisiana, United States
mark.janowiecki@nola.gov

Abstract
Megaphasma denticrus (Stål) is the largest U.S. stick insect and is commonly found across the central portion of the country. Previously, it has been reported to feed on oak, elm, mesquite, hackberry, grasses, and grape vines. In both Arkansas and Texas, U.S., I found young nymphs of this species commonly, and exclusively, on eastern cedar (*Juniperus virginiana* Linnaeus). Following this discovery, I tested whether *M. denticrus* can complete its lifecycle exclusively on eastern cedar foliage and how this diet impacted body size and fecundity compared to a diet of rose leaves. I found that *M. denticrus* can be successfully reared on eastern cedar. However, females reared on exclusively eastern cedar were smaller than those reared on exclusively rose and laid smaller eggs. Male body size was unaffected by diet. Despite the size and fecundity decrease, *M. denticrus* nymphs may still be commonly found on eastern cedar either because these stick insects switch host plants in nature over the course their lifecycle, or the benefit of increased camouflage outweighs the impact on size and fecundity.

Key words
Giant walking stick, eastern cedar, diet, host plant

Introduction
In the United States, there are 47 native phasmid species belonging to *Diapheromera* (9), *Manomera* (3), *Megaphasma* (1), *Pseudosermyle* (7), *Sermyle* (2), *Parabacillus* (2), *Haplopus* (1), *Anisomorpha* (2), and *Timema* (20) (de Luna, 2022). Of these, *Megaphasma denticrus* (Stål), the giant walking stick, is the largest with colourful adults reaching 15cm long (Arment, 2006). This species is found in the central U.S. from New Mexico to Alabama and north to Iowa and Indiana (de Luna, 2022).

Many stick insects feed on angiosperm plant foliage, particularly oak and various grasses. *M. denticrus* has previously been reported to feed on oak, elm, hackberry, mesquite, grasses, and grape vines (Helfer, 1987; Arment, 2006; Maginnis *et al*., 2008). In an elm-mesquite forest, Wilkins and Breland (1951) surveyed different plants and found a majority of *M. denticrus* adults on elm (75%) while they were found less commonly on other angiosperms such as mesquite, hackberry, and gum elastic, and the gymnosperm cedar. Despite finding stick insects on cedar, the authors did not test survival on any food sources in their study. In general, angiosperm foliage is a more common host plant for insects than gymnosperm foliage, but there are exceptions. Evergreen gymnosperms typically have increased chemical defences, thus reducing the diversity of herbivorous insects that can feed on them. For example, of the thousands of known leaf miner species, a recent checklist found only 133 species in North America and Europe produced leaf mines on gymnosperms (Chen *et al*., 2022). Within Phasmida, few species consume gymnosperm foliage. *Timema*, the sister group to all remaining phasmids, contains species that specialize on different pine and fir species, of which *T. coffmani* feeds on Utah juniper, *Juniperus osteosperma, T. ritensis* feeds on alligator juniper *(J. deppeana*), and *T. nevadense* feeds on California juniper (*J. californica*) (Sandoval and Vickery, 1999; Arment, 2006), but few other stick insect species specialize on angiosperms.

Following the discovery of young *M. denticrus* nymphs feeding on eastern cedar, *Juniperus virginiana* Linnaeus, my objectives were to determine whether eastern cedar is a suitable host plant and compare the development on this plant to individuals under this author's standard phasmid rearing conditions on rose leaves.

Figure 1. *Megaphasma denticrus* nymph feeding on cedar plant in Bexar County, Texas, U.S. (photo by Rob Michaelson, used with permission).

Materials and Methods

Young nymphs (3rd - 4th instar) of *M. denticrus* were observed in an oak-hickory forest at Mount Kessler Park in Fayetteville, Arkansas, U.S. at night on June 2, 2014. At the top of a young ~2m tall eastern cedar tree, a stick insect was noticed as it was exposed, halfway through its moulting process. Further investigation of the eastern cedar tree yielded several additional nymphs. Nymphs were collected using a beat sheet in the general area but despite checking a wide variety of foliage along the hiking trail, nymphs were only found on eastern cedar trees. Later, nymphs were also collected in Medina County, Texas, U.S. during a Texas A&M University Department of Entomology EntoBlitz on April 23, 2016. There are also several pictures of *M. denticrus* nymphs on cedar plants on BugGuide (bugguide.net) posted by Rob Michaelson in Bexar County, Texas, U.S. (Figure 1, BugGuide photo#914675), Jeff Gruber in Comal County Texas, U.S. (BugGuide photo#1494997), and Gacko in Somerville County, Texas, U.S. (BugGuide photo#1869867).

To determine whether eastern cedar was a suitable host plant for *M. denticrus* to complete its lifecycle, nymphs collected in Medina County, Texas, U.S. were raised in captivity feeding on rose (*Rosa* hybrid 'Knock Out') and cedar foliage to adulthood and eggs were collected. These eggs were incubated along with the stick insect frass in plastic containers with holes punched in the lid maintained at room temperature (~18–24°C). The eggs hatched in the spring of 2018, approximately two years after they were laid. The hatchlings were divided randomly into two groups and provided ad libitum either exclusively eastern cedar or exclusively rose foliage in containers of water to maintain leaf quality. The foliage was replaced weekly throughout the season. In the fall of 2018, survival was assessed for each group as whether individuals survived to adulthood and laid eggs. Growth measurements (body length, femur length, and pronotum length) were taken for adult males and females from both food choices. In total, I measured 51 individuals with 10-16 individuals per sex for each food choice. As an approximate fecundity, the egg weight was compared between females provided both food

choices. Normality of each variable was determined with Shapiro-Wilk tests and means were compared between experimental groups with t-tests run in R v-4.1.3 (R Core Team, 2022).

Results and Discussion

Under captive rearing conditions, *M. denticrus* survived to adulthood and laid eggs when fed either eastern cedar or rose foliage. The two-year incubation time occurred in all subsequent generations but may be a result of the egg storage conditions. No cold temperatures were required to break the diapause; eggs were maintained at room temperature (~18–24°C) year-round. This species requires a tall aquarium (>30cm) for successful moulting as they are a relatively large species.

Female stick insects fed rose had larger body length ($P = 0.00017$), middle femur length ($P = 0.00018$), and pronotum length ($P = 0.0056$, Figure 2). However, males were not significantly different in any of these size metrics ($P > 0.05$) (Figure 2). Females fed rose laid larger eggs than those fed eastern cedar ($P = 0.011$, Figure 2). Females from this study fed eastern cedar (average length of 10.3cm) were below the range previously reported for field collected adults: 11.2–11.5cm (Wilkins and Breland, 1951) and 10.5–13.5cm *(Maginnis et al*., 2008); however, individuals in this study fed rose (average length of 11.63cm) were within these ranges. Males were smaller (average length of 8.9cm) than those collected by Wilkins and Breland (1951): 9.9–13.8cm and Maginnis *et al*. (2008): 9.0–12.5cm. These differences are likely caused by food type or food quality limitations in captivity since foliage was only replaced weekly.

Overall, I found that *M. denticrus* was able to complete a generation on eastern cedar and laid viable eggs. However, there was a sex-specific diet-dependent size difference where female size and egg weight was decreased when fed eastern cedar rather than rose, while male size was not affected. This may indicate that while the male body size is more evolutionarily stable, since it likely conducts the searching behaviour to find a mate, the female body size may be more adaptable to increase size when presented a richer food source with more available nutrients. In a study observing *M. denticrus* mating behaviours, Maginnis *et al*. (2008) found mate preference was opportunistic, not favouring the larger males but the first male discovered. This is likely because of their more dispersed lifestyle in tree canopies. Conversely, species known to live in higher densities, such as those in large numbers on isolated shrubs, generally have less sexual dimorphism because females select for larger males (Sivinski, 1978).

Despite eastern cedar being an inferior food choice for *M. denticrus* females, this species was exclusively found on cedar trees in my survey in Arkansas. However, this sampling only occurred in the spring and found immature nymphs. Nymphs are more camouflaged in cedar foliage (Figure 1) than adults who transform from mottled green nymphs to tan adults with colourful patches. It is possible that over the course of the growing season, these stick insects switch host plants from initially more camouflaged hosts (cedar) to later more nutritious and less camouflaged hosts (rose, oak, elm, etc.). This may explain Wilkins and Breland (1951) finding most adults in their study on elm and only a small number on cedar. Another possible explanation for *M. denticrus* in the current study exclusively found on an inferior food choice is simply the benefit of increased camouflage. This level of protection from predators may outweigh the impact on size and fecundity and select for individuals feeding on cedar. Future studies testing the choice between cedar and other tree species or more extensive sampling in areas with known *M. denticrus* throughout the season may shed light into the natural habits and food usages in nature of this species.

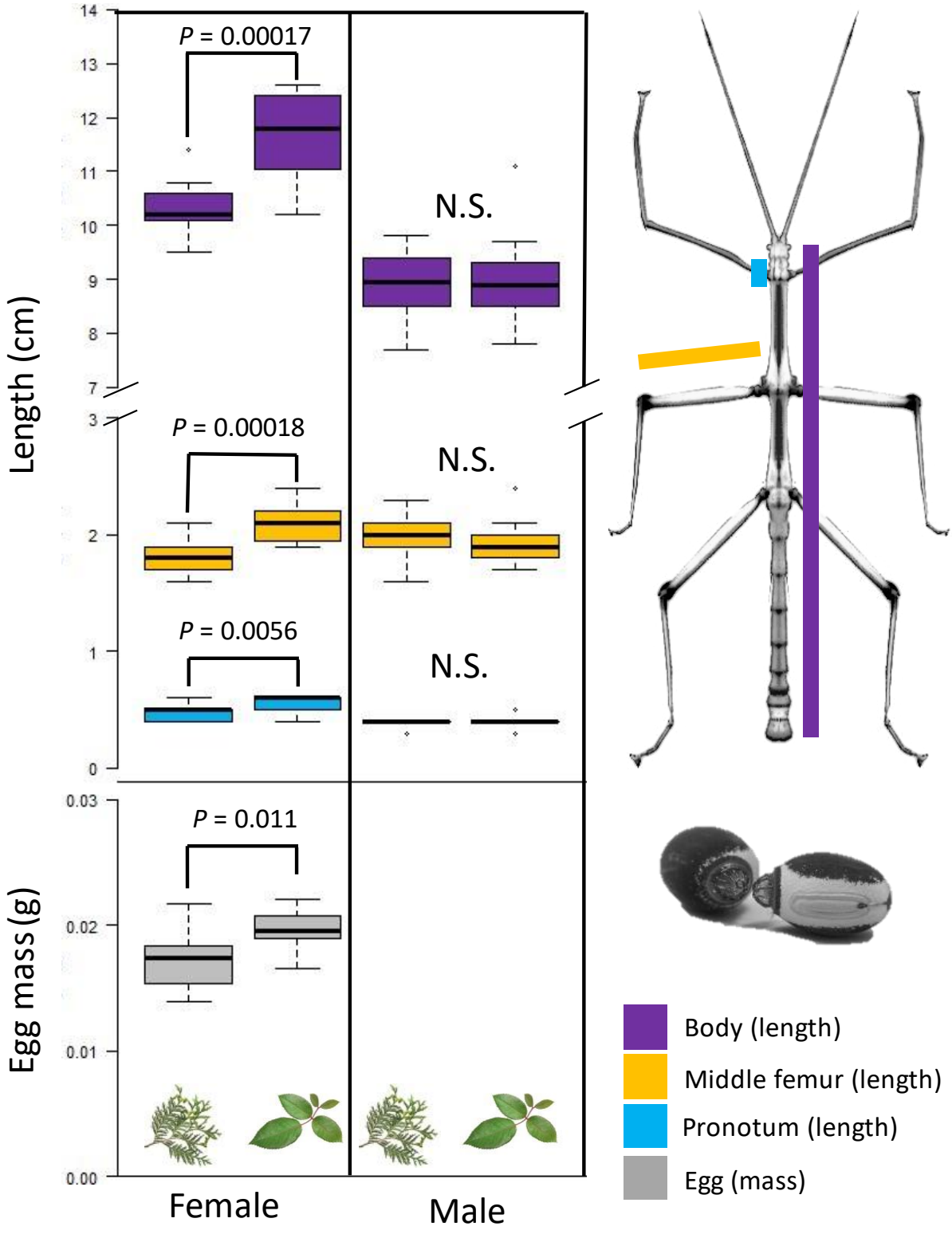


Figure 2. Comparison of body length measurements for male and female *Megaphasma denticrus* fed either eastern cedar (*Juniperus virginiana*) or rose (*Rosa*) foliage.

Conclusion

This study confirms that eastern cedar is a suitable food source for the giant walking stick, *M. denticrus*. Insects reared in captivity survived on this gymnosperm foliage and laid viable eggs. However, females fed eastern cedar were smaller and laid smaller eggs than females fed rose. Male body size was unaffected by food type. The discrepancy of finding nymphs of *M. denticrus* in the field predominately on eastern cedar may indicate they switch food sources over their lifecycle or that the increased camouflage is worth the decreased size and fecundity.

Acknowledgements

I wish to thank Amber Tripodi and Clinton Trammel for their help and encouragement. I also thank Derek Hennen for inviting me into the field the first night I discovered the moulting stick insect on the cedar tree. Thanks to Jaclyn Martin and two anonymous reviewers for editing this manuscript.

References

Arment, C. 2006. Stick insects of the continental United States and Canada, species and early studies. Coachwhip Publications, Landisville, Pennsylvania.

Chen, T., Dai, X. & Eiseman, C. 2022. A checklist of gymnosperm-feeding leafminers (Arthopoda, Insecta) in North America and Europe. Biodiversity Data Journal, **10**: e91313.

de Luna, M. 2022. Checklist of stick insects (Insecta: Phasmatodea) of North America, with three new records for Nuevo León, México. Phasmid Studies, **21**: 90–105.

Helfer, J.R. 1987. How to know the grasshoppers, crickets, cockroaches and their allies. Dover Publications, Inc., New York.

Maginnis, T.L., Cool, C.L. & Muniz, J.L. 2008. Some observations on the mating behavior of the giant walking stick, *Megaphasma dentricus*. Texas Journal of Science, **60**: 57–62.

R Core Team. 2022. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Sandoval, C.P. & Vickery, V.R. 1999. *Timema coffmani* (Phasmatoptera: Timematodea) a new species from Arizona and description of the female of *Timema ritensis*. Journal of Orthoptera Research, **8**: 49–52.

Sivinski, J. 1978. Intrasexual aggression in the stick insects *Diapheromera veliei* and *D. covilleae* and sexual dimorphism in the Phasmatodea. Psyche, **85**: 395–405.

Wilkins, O.P. & Breland, O.P. 1951. Notes on the giant walking stick, *Megaphasma dentricrus*. Texas Journal of Science, **3**: 305–310.

Exploring Bergerard's methodology: comparison of intersex *Carausius morosus* obtained from incubating eggs at elevated temperatures

Benjamin D. Moate
5 Winsford Grove, Great Sutton, Ellesmere Port, Cheshire, CH66 4XL, U.K.
bdmoate@gmail.com

Abstract
In this paper the experimental method of Bergerard is revisited, using simple modern equipment readily available to amateur phasmid enthusiasts. The resulting intersex gynandromorphs are presented and compared. Results on the impact of the methodology on egg viability and gestation period are discussed.

Key words
Gynandromorph, incubation experiment, embryonic development, masculinisation

Introduction
The occasional spontaneous appearance of gynandromorph or intersex phasmids has been previously reported and studied by a range of both amateur enthusiasts and the scientific community (Bergerard, 1962; Clark, 1977; Pijnacker and Ferwerda, 1980; Brock *et al*., 2018). Generally, two forms of gynandromorph are encountered; mosaic gynandromorphs and intersex gynandromorphs. The former typically present with different parts of an individual displaying distinctly male and female body characteristics, often split laterally. In contrast, intersex gynandromorphs, typically arising within parthenogenetic populations, present individuals that are somewhere between the male–female dimorphism for the given species.

Due to the naturally low frequency of occurrence of gynandromorphs, most previous studies focus on individual specimens, with only a handful of studies having examined multiple living gynandromorphs side by side. One such study was the 1962 paper by French entomologist Joseph Bergerard who reported on the effects of elevated temperatures on eggs of *Carausius morosus* (Bergerard, 1962). According to Bergerard, incubating eggs at higher than normal temperatures, 30°C, for a period of 30 days during the early embryonic phase of development, led to the production of intersex individuals. Further, Bergerard reported that as the duration of exposure to elevated temperatures increased, so too did the masculinisation of the resulting intersexes. It is curious that since Bergerard's remarkable paper, few other investigators have reported similar experiments. Thyme (2014) reported on the appearance of apparent males in cultures of *Pulchriphyllium giganteum*, possibly linked to elevated temperatures from a heat mat and outlined possible future experiments. Updates from Thyme's website indicate males continue to appear in his *Pulchriphyllium giganteum* cultures (www.phyllium.dk, September 2023), though it must be noted that bisexual cultures of *Pulchriphyllium giganteum* were, at least anecdotally, introduced in Europe at about the time of Thyme's original report.

Nevertheless, intersex gynandromorphs of *C. morosus* have been consistently reported intermittently in hobbyist cultures; see Moate (2020) for a review of recent reports. Bergerard (1962) included black and white photographs to illustrate the range of intersexes that resulted from his experiments and indeed most individual gynandromorphs reported by hobbyists appear nominally similar to the "males" in Bergerard's figures. Having had two gynandromorph *C. morosus* males spontaneously appear in the author's own cultures in 2020 (see Moate, 2020, and 2021), the present author elected to attempt Bergerard's method to facilitate a more direct

comparison of any resulting intersex specimens with those occurring in hobbyist cultures. The results of these experiments are reported in the present paper.

Whilst adventurous phasmid enthusiasts may well hope that the method could yield a "true" male, capable of mating and creating a bisexual culture, unfortunately current scientific understanding would seem to insist this is quite impossible. Biologically, this is because even if a gynandromorph male capable of spermatogenesis were to result, the chromosomes of the sperm would all be expected to be identical to the ovule and would thus lead to only females arising from any fertilisation, being identical to those produced by parthenogenesis (Bergerard, 1962).

However, the production of a fertile male was not the goal of the present work. *C. morosus* already reproduce well enough without giving them any additional avenues by which to procreate! Rather, the main aim of the present study was to determine if results similar to those of Bergerard could be readily obtained with unsophisticated equipment readily available to hobbyists. More generally, the aim of the present study was to observe, photograph, compare, and preserve any intersex specimens that resulted, particularly in relation to specimens that spontaneously appeared in the authors' own cultures and those reported elsewhere.

Ethical considerations

Before undertaking any experimentation involving animals it is appropriate to consider the ethical aspects. In this study ethical considerations were structured around the recommendations of the Nuffield Council on Bioethics (2005). In the present work the methodology involved taking (unfertilised) eggs of *C. morosus* and exposing them to temperatures around 30°C. The first two morally relevant features specified by Nuffield Council on Bioethics (2005) were considered to be of low bearing. Specifically, the eggs and developing embryos were not expected to possess sentience, nor be capable of higher cognitive capacities. The third and fourth features, the capacity to flourish and sociability, were both expected to be largely unaffected – there is no evidence from previous gynandromorphs that their existence is significantly impaired from these perspectives. The final feature, possession of a life, may initially be of low consequence – the fate of the eggs in the absence of the experiment would likely be for them to be discarded/destroyed anyway. This could arguably be balanced by such a fate being no worse than the likely fate of millions of eggs laid in the wild every year; due to environmental pressures and predation.

Of course, if the methodology was successful, the impacts of the experiment on any insects raised from the eggs should also be considered. In the present study this was done from the perspectives of (i) considering the likelihood of suffering and (ii) by considering the three R's of Nuffield Council on Bioethics (2005). In respect of (i), previous reports on gynandromorphs were examined (see references above) and none reported any observable suffering of the individuals reported. As stated above, the biological impacts of the experiments were expected to be that the individuals would not be able to reproduce. It was considered unlikely that any intersexes arising from the experiments would have any awareness of this fact however, and additionally phasmids generally don't show any maternal instincts towards their eggs or young. Finally, regarding (ii) the principles of the 3 R's were considered; refinement, replacement, and reduction. In the present study, based on Bergerard (1962), the methodology was already well refined and involved only one dependent variable – temperature. Replacement was not a viable option as it would prevent the aims of the work from being achieved. Reduction was incorporated into the experiments. The number of eggs exposed to the elevated temperatures was kept to a minimum and selected by considering possible impacts to egg viability and likely success rates of gynandromorph production. In summary, the experiment was considered to be highly unlikely to inflict any suffering perceivable to the insects involved and steps were taken to restrict the experiment to the minimum that would support the aims to be achieved.

Experimental method and equipment

Randomised control trial

Eggs of *C. morosus* were sourced from two adult colonies, one raised in an East facing room, the other in a West facing room in the same domestic residence. Both colonies were fed on bramble and both kept in similar enclosures and cared for in the same way. Bergerard was quite specific when stating that gynandromorphs arose when freshly laid eggs were exposed to higher temperatures. Therefore, at the start of the experiment, both colonies were cleaned out completely, removing and destroying all eggs and replacing the kitchen towel lining at the bottom of the cage.

Three days (72 hours) later, on 14th August 2020, 30 eggs were collected from each colony and pooled to form a single group of 60 eggs. The reasoning here was that at least some eggs would likely be "freshly laid", whist the oldest would only be three days old at the most. After mixing the eggs to randomise them, eggs were then drawn at random, separating the 60 eggs into three separate batches of 20 eggs each; a control group and two trial groups, thus forming the basis of a randomised control trial. Each batch of eggs were placed in identical, small plastic horticultural saucers, see Figure 1, with each saucer being cleaned using ordinary detergent prior to use.

Figure 1. The randomised control trial; the control group (top left), trial group one (bottom) and trial group two (top right). Each group consisted of 20 freshly collected *C. morosus* ova.

Incubation and experimental setup

The experimental setup for all three groups was completed on the same day. The control group was simply placed in an empty "Cricket box" and labelled. This Cricket box was of the type that locusts and crickets are sold in by UK reptile dealers and pet stores. These boxes have copious ventilation holes already punctured in the sides, and no additional ventilation was added. The control group was placed in an East facing room and incubated in the author's usual manner for non-fussy phasmids. Daytime temperatures during incubation typically varied between 18°C and 24°C for the control group, measured by a digital thermometer.

In contrast, both trial groups were placed in a poultry incubator, which provided the elevated temperatures. The incubator was activated on the same day that the eggs were collected. The poultry incubator was of the HHD brand widely available online, was low cost, had programmable temperature settings, was equipped with an integral fan, and is shown in Figure 2. The incubator was of plastic construction with a semi-tinted upper, this reduced the intensity of light entering the incubator whilst still permitting viewing of the contents inside. The temperature in the poultry incubator was set to 31.2°C. Whilst slightly higher than the 30°C specified by Bergerard, this temperature was selected in the present experiments simply to give a bit of lee-way; to account for slight temperature fluctuations inside the incubator associated with the heater switching on and off, as well as to account for any inaccuracies of the built in thermometer itself. An independent digital thermometer was placed inside the poultry incubator, alongside the eggs, throughout incubation to enable constant double checking and monitoring of the temperature inside the incubator. The independent thermometer provided temperature readings to 1 decimal place and from simple testing, seemed accurate to within a degree of other thermometers in the author's possession. The independent thermometer also provided humidity readings in percent. Throughout the duration of incubating both trial groups at elevated temperatures, the temperature in the poultry incubator varied between 30.9°C and 31.5°C according to the independent thermometer. The incubator was never switched off during the period of incubation to ensure temperatures remained near stable, day and night, throughout the duration of the experiment.

Figure 2. The poultry incubator used in the experiments, with trial group one and two inside, along with the independent thermometer.

Eggs in the control and both trial groups were sprayed with tap water twice a week, every Tuesday and every Friday in the early evening and this was the only source of moisture to the eggs throughout incubation. When the eggs were sprayed, the independent thermometer showed humidity readings in the poultry incubator increased from the usual 40% to around 70% for an hour or so before falling back to the pre-spraying level.

The first trial group was incubated for a total of 30 continuous days, the same duration as used by Bergerard, whilst the second trial group was incubated for a total of 50 continuous days. After their respective periods of incubation in the poultry incubator, trial groups were removed from the incubator and placed in separate identical Cricket boxes, labelled, and transferred to the same room as the control group. Both the base and lid of the trial group boxes were labelled to prevent any accidental mix ups when spraying or examining the eggs. The trial groups were then incubated alongside the control group and treat in an identical manner.

Results

After approximately three months of incubation, eggs in the control group began to hatch. Of the two trial groups, only eggs from trial group one produced any nymphs; three in total, though these emerged sometime after those in the control group. Table 1 presents the dates and numbers of eggs hatching from both the control group and trial group one. Table 1 shows the bulk of hatchings within the control group were clustered between 90 and 100 days after collection, though one "stray" emerged over a month later. In contrast, the three eggs that hatched from trial group 1 did not began to hatch until over two months later than the bulk of those in the control group. Table 1 shows the three eggs that hatched in trial group one emerged over a shorter absolute period than those in the control group, though trial group one hatchings were much more sporadic in nature compared to the clustered hatching of the control group.

Table 1. Date and number of *C. morosus* hatching from the control group and trial group one. Eggs were collected 14/08/2020.

Hatching date	Days after collection	Control group	Trial group one	Author's Accession number
13/11/2020	91	2		
14/11/2020	92	4		
15/11/2020	93	2		
16/11/2020	94	1		
17/11/2020	95	2		
18/11/2020	96	1		
20/11/2020	98	1		
28/12/2020	136	1		
20/01/2021	159		1	BM-3-CM-G
04/02/2021	174		1	BM-4-CM-G
26/02/2021	196		1	BM-5-CM-G

As the eggs hatched, those arising from the control group were placed in a small commercial cage of the Small Pal Pens brand and offered bramble as the foodplant. Nymphs arising from trial group one were placed in a separate, identical Small Pal Pens cage and also offered bramble. All nymphs from both groups accepted the foodplant with no mortality in either group. The 14 nymphs arising from the control group reached adulthood after around four months and as expected, were all females.

Intersex gynandromorphs

In contrast to the control group, all three nymphs arising from trial group one were intersexes; producing three adult gynandromorphs of varying masculinity – confirmation that Bergerard's method can indeed be readily reproduced. The three intersex males resulting from trial group one are shown in Figure 3, alongside one of the adult females from the control group (far right). The intersexes reached adulthood more quickly than their female counterparts from the control group with all males taking around three months from hatching to reach adulthood. As the intention in this experiment was to preserve any resulting gynandromorphs each intersex was designated an accession number. The accession numbers are shown in Table 1 and are used hereafter to aid clarity when referring to the different specimens. The first intersex to hatch, specimen BM-3-CM-G, moulted into adulthood on 14th April 2021 and was a mostly-male specimen. The second intersex (BM-4-CM-G) reached adulthood by 8th May 2021 and was a female-like intersex from outward appearance. The third intersex (BM-5-CM-G) was adult by the 18th May 2021 and was a male-like intersex, being similar to the first though not quite as male. Photographs were taken as each intersex reached adulthood and outward appearances were sufficiently different to enable ongoing visual identification of each individual within the colony (see Figures 3 to 5).

After reaching adulthood, the intersex males were placed in a cage with some adult females for a few weeks to determine if any mating took place; none was observed. In terms of behaviour, the intersex males seemed typical of any other phasmid, dividing their time between eating and resting, with no unusual behaviour observed. After a few weeks, the intersexes were photographed by the author and then posted to Paul D. Brock for additional high resolution photographing and preservation.

Figure 3. The resulting three intersex males from trial group one, showing from left to right; a mostly-male intersex, a male-like intersex, and a female-like intersex. A normal adult female is shown on the far right for comparison.

Taxonomic differences of intersex specimens

This first gynandromorph, BM-3-CM-G, being a mostly-male intersex, did not exhibit any curvature in its abdomen and was slightly longer than the other intersexes obtained from trial group one, with a body length of approximately 58 mm. The longer length of this male and the absence of any curvature in the abdomen can be discerned in Figure 3 (left most male). Curvature in intersex abdomens is often reported for "male" *C. morosus* occurring spontaneously in hobbyist cultures (see Moate, 2020 & 2021, and references there-in). Higher resolution photographs of this male are provided in the left panels of Figure 4. The terminal abdominal segments of this specimen appeared almost completely male, see Figure 4a to 4c, though lacked the characteristic ventral bump often seen in male phasmids associated with the poculum. The terminal abdominal segments of this specimen are consistent with those illustrated by Clark (1977), which also show no discernible poculum. This may suggest even mostly-male intersexes of *C. morosus* lack any internal male genitalia. This specimen possessed the usual red colouration of the ventral prothorax often reported in intersex males of *C. morosus* and lacked any red colouration on the inside of the femur of the fore legs, see Figure 4d. Absence of red colouration on the inside of the fore legs has been reported for other intersex males among hobbyist cultures (again see Clark, 1977).

In contrast to the first gynandromorph, the second intersex specimen BM-4-CM-G was a female-like intersex and was the least male-like intersex produced in these experiments, despite being incubated under identical conditions as part of the same trial group. Comparison of the first (BM-3-CM-G) and second (BM-4-CM-G) intersexes shows the extent of the gradient in masculinity exhibited by these specimens, see Figure 4. Figure 4e to 4g shows the terminal abdominal segments of this female-like intersex and show several interesting features on the ventral surface of the cuticle. It was not possible to confirm from simple observation what these features were, though they appeared to be female genitalia exposed by the absence of a normal operculum. Figure 4f and 4g show a small black protrusion was present on the 8th sternum, this may correspond to a diminished or underdeveloped operculum. A larger green protrusion can be seen in Figure 4f and 4g on the 9th sternum, this may correspond to incomplete internal genitalia. Figure 4h shows the second gynandromorph showed very little of the red coloration on the ventral prothorax and clearly displayed red markings on the inside of the femurs on the fore legs. As most phasmid breeders will know, this later feature is typical of females of *C. morosus*.

In comparison to these two extremes, the third gynandromorph BM-5-CM-G was most similar to the first. The third gynandromorph was a male-like intersex, being slightly shorter than the first and displaying some curvature in the abdomen, see Figure 3 (second from left). This intersex male also displayed strong red colouration on the ventral prothorax with no red colouration on the inside femur of the fore legs, see Figure 5a. As with the second gynandromorph, this third intersex male showed a small black protrusion on the 8th sternum, see Figure 5b, though lacked any further protrusions on the 9th sternum.

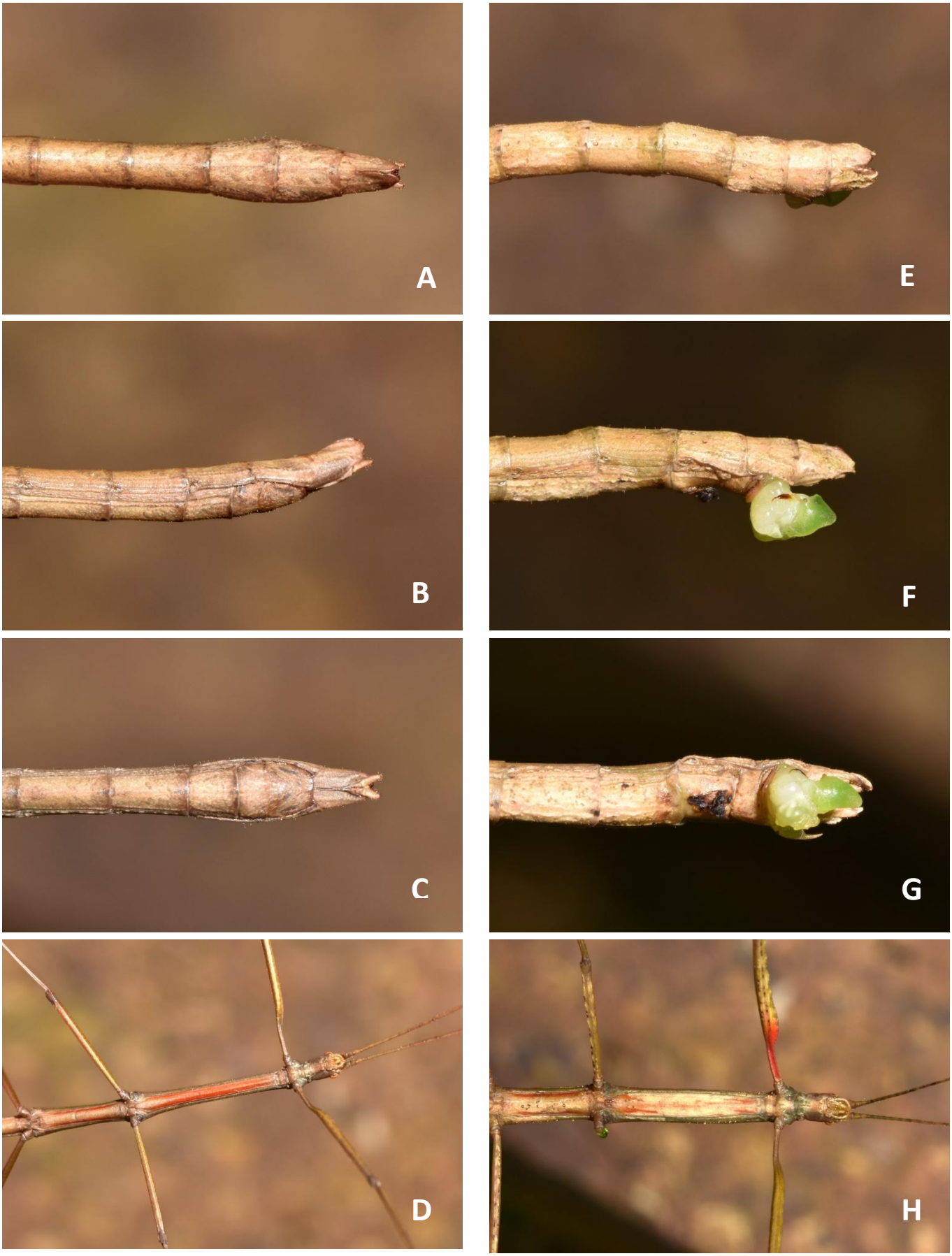


Figure 4. Comparison of two individual *C. morosus* gynandromorphs from trial group one, a mostly-male intersex (left panels) and a female-like intersex (right panels). **BM-3-CM-G** end of abdomen: **A** dorsal, **B** lateral, **C** ventral views, and **D** ventral head and thorax. **BM-4-CM-G** end of abdomen: **E** dorsal, **F** lateral, **G** ventral views, and **H** ventral head and thorax. Photos by Paul D. Brock.

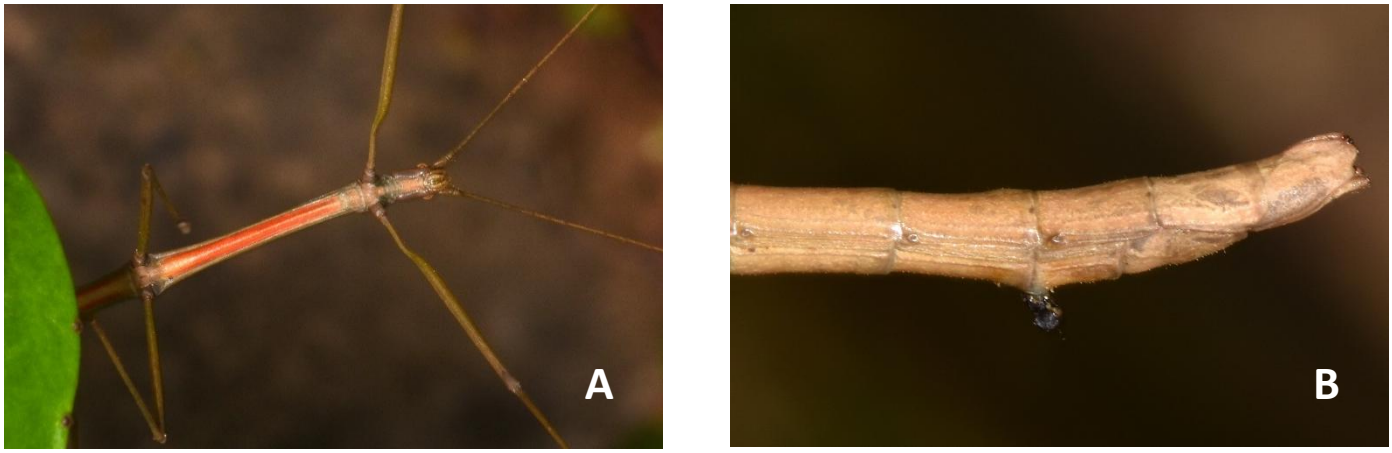


Figure 5. The third *C. morosus* gynandromorph from trial group one, a male-like intersex. **BM-5-CM-G**: **A** ventral head and thorax and **B** lateral view end of abdomen. Photos by Paul D. Brock.

Discussion

The results of this simple experiment have shown that intersex males of *C. morosus* can be readily generated following Bergerard's approach without the need for sophisticated equipment or professional laboratories. Whilst this experiment was successful in recreating the results of Bergerard (1962), only 3 intersexes were reared and a significant feature of this first attempt was the low viability of the eggs exposed to elevated temperatures. Given the hatch rate of trial group one was just 15%, and that of trial group two was 0%, presumably the extended period of constant elevated temperatures dried the eggs out and the frequency of spraying was insufficient to prevent this. If the experiment were repeated, the eggs could instead be placed on a more moisture retentive medium, such as damp sand, and the eggs sprayed daily rather than twice weekly, as was the case here.

Another more puzzling feature of the results from trial group one was the extended gestation period before hatching commenced (see Table 1), despite the trial group eggs being incubated either at higher temperatures, or under identical conditions to the control group after the period of elevated temperatures had ended. It is not clear from the current experiment what caused this. It's possible it was related to the low viability/dehydration of the eggs and that this extra gestation period was required for rehydrating the eggs that eventually hatched. Or possibly the extended gestation resulted as the trial group eggs had experienced such a large shift in the incubation temperature, from over 30°C down to around 20°C. Bergerard (1962) did not detail any impacts on viability or gestation period of the eggs in his experiments.

In common with the results of Bergerard (1962), the intersexes produced in this experiment displayed a spread in masculinity. It is possible that in the present experiment this was caused by some of the eggs already being up to three days old when the elevated temperatures were applied, having already started to develop as females. Certainly the spread of masculinity here is consistent with that observed in intersex males of *C. morosus* that spontaneously appear in hobbyist cultures (see Moate, 2020 and Moate, 2021). This reinforces the notion that at least some intersexes that spontaneously occur in hobbyist cultures are the result of unintended exposure to elevated temperatures for eggs of varying ages. An alternative explanation for the range of masculinity observed in the present experiment may be that some eggs were simply closer to the heater in the poultry incubator and thus different eggs experienced different temperatures. The independent thermometer placed within the poultry incubator would seem to dampen that idea however, instead supporting that the integral fan was efficient at distributing the heat within the incubator.

The success of this methodology with *C. morosus* raises the question of whether it would also yield male-like intersexes for other phasmid species. Intersex males have been reported for other species amongst hobbyist cultures, e.g. Deschandol (1989), so future experiments could apply Bergerard's methodology to a range of parthenogenetic phasmid species to determine if masculinised intersexes result. One factor to consider with such experiments would be the duration of exposure to elevated temperatures required – presumably this varies with the normal incubation period of the species in question, so may need to be longer than 30 days for some species.

Acknowledgements

The author would like to thank Paul D. Brock for photographing and preserving the intersex specimens that resulted from these experiments and for his guidance with the manuscript.

References

Bergerard, J. 1962. La partenogénesis en los fásmidos. Endeavour, 21: 137–143.

Brock, P.D., Lee, M., Morgan-Richards, M. & Trewick, S.A. 2018. Missing stickman found: the first male of the parthenogentic New Zealand phasmid genus *Acanthoxyla* Uvarov, 1944 discovered in the United Kingdom. Atropos, **60**: 16–23.

Clark, J.T. 1977. A male of the stick insect *Caraursius morosus* Sinety (Phasmida, Phasmatidae). Entomologists Monthly Magazine, **112**: 139–143.

Deschandol, A. 1989. Males of *Carausius morosus* and *Sipyloidea sipylus*. PSG Newsletter, **38**: 3.

Moate, B.D. 2020. A Gynandromorph Male of *Carausius morosus*. PSG Newsletter, **145**: 8–10.

Moate, B.D. 2021. Further Notes on Gynandromorph *Carausius morosus*: A pregnant gynandromorph and comparison of two males. PSG Newsletter, **147**: 18–21.

Nuffield Council on Bioethics. 2005. The ethics of research involving animals. Nuffield Council on Bioethics, London.

Pijnacker, L.P. & Ferwerda, M.A. 1980. Sex chromosomes and origin of males and sex mosaics of the parthenogenetic stick insect *Carausius morosus*. Chromosoma, **79**(1): 105–114.

Thyme, P. 2014. *Phyllium giganteum* PSG72 Sexual Reproduction? PSG Newsletter, **132**: 18–19.

Notes on colour variation in *Entoria ishigakiensis* Shiraki, 1935 (Phasmatodea: Phasmatidae)

Tomoki Sumikawa
Gunma Insect World, 460–1 Tsurugaya, Nisato-chô, Kiryu-shi, Gunma, 376–0132 Japan
sumi_t0603@icloud.com

Kohei Watanabe
Ishikawa Insect Museum, Inu–3, Yawata-machi, Hakusan-shi, Ishikawa, 920–2113 Japan
koutarouhigasi@yahoo.co.jp

Wataru Yoshida
Kohama, Taketomi-chô, Okinawa, 907–1221 Japan

Abstract
An unusual variation of a female *Entoria ishigakiensis* Shiraki, 1935 with white speckles was observed during captive rearing conditions in Japan.

Key words
Female, museum, rearing, stick insects.

Introduction
Entoria ishigakiensis Shiraki, 1935 (Phasmatidae) is a large insect species widely distributed in Japan (Ishigaki-jima, Iriomote-jima, Taketomi-jima, Kuro-shima, Kohama-jima, and Hateruma-jima Islands) and Taiwan (Ichikawa, 2013, 2016). This species is found along forest edges, in bushes around fields, woodland and parks. This species is polyphagous and feeds on *Hibiscus* spp., *Mallotus japonicus*, *Castanopsis* spp., *Rubus* spp., and Pteridophytes (Ichikawa, 2016) and is known to reproduce sexually (Okada, 1999). Female *E. ishigakiensis* have green, brown, or greenish-brown intermediate body colour (Ichikawa, 2016; Figs. 4–6). The ventral surface and the area around the legs are sometimes reddish purple to black; there are no other conspicuous patterns on the body.

We found an *E. ishigakiensis* with irregular white speckles on its body and legs under rearing conditions. In this report, we describe the appearance of this specimen as well as the rearing environment in which it was discovered.

Methods
We kept early to mid-instar nymphs, mid to late-instar nymphs and adults in cages of 33 × 33 × 45 cm and 43 × 40 × 90 cm (Fig. 1), respectively. These cages were made of a wooden frame with screen door mesh on the top and four sides and a door for the maintenance and replacement of food plants. In each cage, approximately 100–200 individuals were kept. In summer, the insects were reared at 25 °C using air conditioners, but the air conditioners were switched off from 17:00 to 08:00 JST every day. As a result, the temperature after sunset and before sunrise was very high and reached up to 38 °C. In winter, the heating system with hot water circulation was always under operation, and the room temperature rose to over 20 °C on sunny days. However, on most days, the temperature fell below 20 °C up to a minimum of 17 °C. The insects were fed *Photinia glabra* × *P. serratifolia*, *Lithocarpus edulis*, and *Quercus salicina* throughout the year and *Rosa multiflora*, *Cerasus jamasakura*, *Q. serrata*, and *Q. crispula* from spring to autumn. We changed the food plants every

three days or sooner if they were dwindling or dying faster. We changed the water when the food plants were changed or when the water was dirty or low. We sprayed tap water twice a day on dry days and once on humid days. We have been rearing *E. ishigakiensis* using this method for more than 10 years in Ishikawa Insect Museum.

During the process of rearing by the aforementioned method, a female late-instar nymph, with abnormal white speckles on its green body, was found on 21 December 2020. We kept it individually and continued observation. The nymph moulted on 21 January 2021 (Fig. 2) and reached adult (Fig. 3) on 22 February 2021. As the nymph grew, the white speckled pattern decreased. This individual was born through sexual reproduction.

Figures 1–2. 1, Rearing cage of middle- to late-instar nymphs and adults; 2, last-instar nymph of *Entoria ishigakiensis*.

Results and Discussion

Description of the adult female: the white speckled pattern is absent from the antennae and head and is only slightly visible on the lateral margins of the prothorax. On the mesothorax and metathorax, it appears on the lateral margins and most of the dorsal and ventral surfaces. Speckles are also observed on the abdomen; more pronounced in the fourth and fifth terga of the abdomen and the epiproct, where it turns white. The size and density of the white speckles on the body varies greatly on the dorsal surface but is almost the same on the

ventral surface, especially the thorax. This pattern is also observed on the legs. The tip of each tarsus is black and the rest of it is mostly white. In addition, white and green areas appear alternately on the tibia and femur, forming bands, but white areas do not appear in the tibia and femur of the right foreleg and left hind leg. Although there is some similarity between the speckles on the left and right sides of the body, the pattern is not perfectly symmetrical.

To our knowledge, this is the first report of a white speckled colour pattern in Japanese stick insects including *E. ishigakiensis*. This colour variation appears to be very rare, as we found only one such case from more than 10,000 individuals that we have reared and observed. Some species of stick insect show colour polymorphism such as *Libethra rabdota* (Westwood, 1859) (Gutiérrez-Valencia *et al*., 2017), but the variation in this species is not that wide. Speckled specimens of phasmids occur in culture stocks of various species and some species in the wild are likely to employ such colour forms, regardless of which country they occur. Other species have a speckled body as typical, such as the blue-spotted *Channia bayai* Seow-Choen, 2016 from Sabah. The reason for the appearance of this speckled pattern in *E. ishigakiensis* may simply be to blend in and better match its surroundings, but it is unknown in the genus *Entoria* and further research is required to clarify these factors.

Acknowledgements

We would like to thank Paul Brock and Thies Büscher for critically reading the manuscript and Masato Hayashi for providing literature.

References

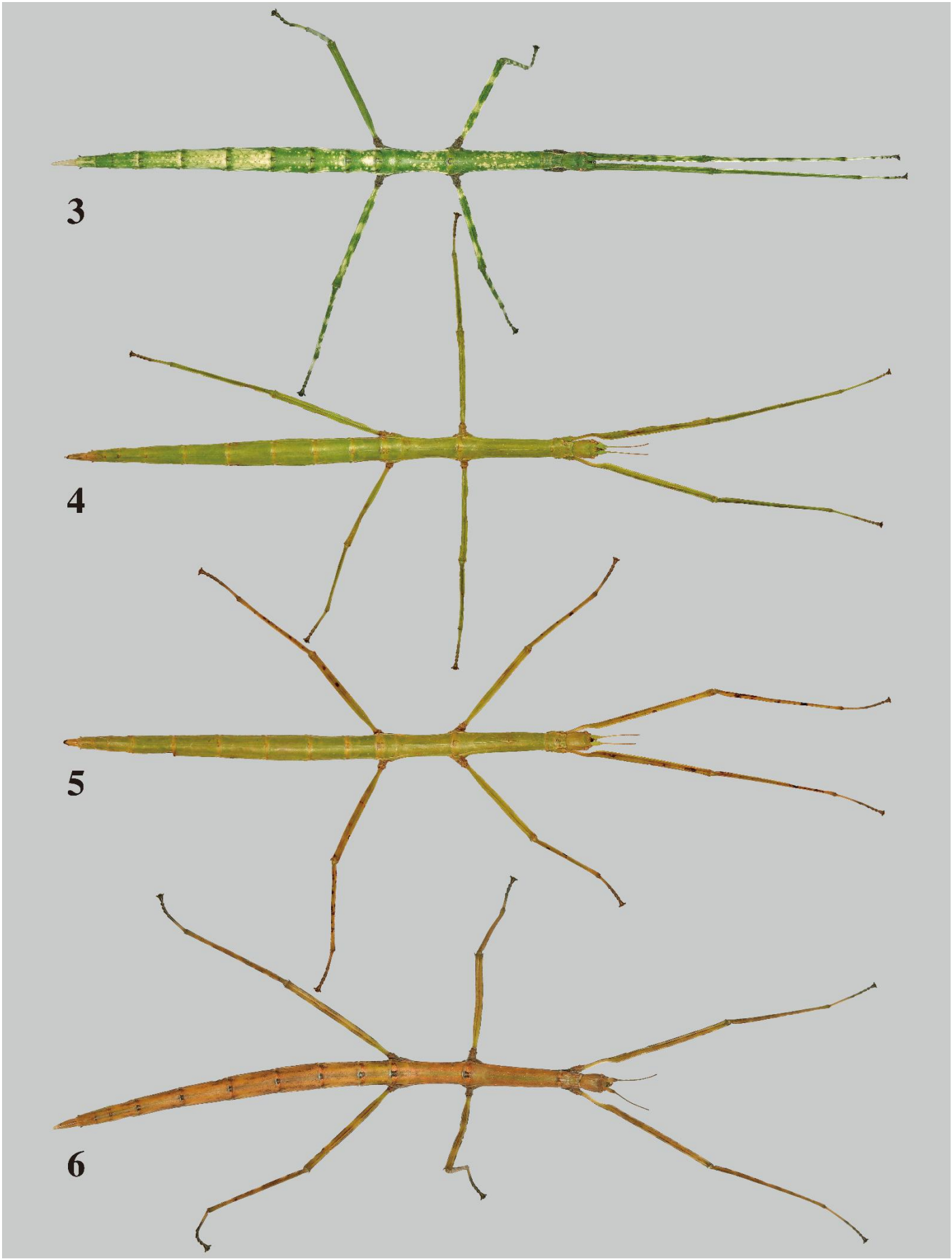
Gutiérrez-Valencia, J., Gutiérrez, Y. & Dias, L.G. 2017. Species delimitation in the crypsis-defended and polymorphic stick insects of the genus *Libethra* (Phasmatodea, Diapheromeridae). Zoologica Scripta, **46**: 693–705.

Ichikawa, A. 2013. [Taxonomic report of Phasmatodea.] Battarigisu, **151**: 14–15. (In Japanese.)

Ichikawa, A. 2016. Phasmatodea. pp. 187–196, pls. 11–34. In: Orthopterological Society of Japan (ed.). The Standard of Polyneoptera in Japan. Gakken Plus, Tokyo. (In Japanese.)

Okada, M. 1999. [All About Stick Insects.] Tombow Publishing, Osaka. (In Japanese.)

Shiraki, T. 1935. Orthoptera of the Japanese empire (part IV) Phasmidae. Memoirs of the Faculty of Science and Agriculture, Taihoku Imperial University, **14**: 23–88, pls. IV–X.



Figures 3–6. Colour variation in *Entoria ishigakiensis*. 3, white speckled colour pattern; 4, green; 5, greenish-brown intermediate; 6, brown.

Editorial Remarks

Thies H. Büscher
Functional Morphology and Biomechanics, Kiel University, Am Botanischen Garten 1-9, 24118 Kiel, Germany.
tbuescher@zoologie.uni-kiel.de

Submission

Submissions and pre-submission enquiries are welcome. Please, use the following contact address: phasmidstudies@phasmidstudygroup.org
Instructions for authors are listed on the PSG webpage (phasmidstudygroup.org). Contributions are welcome from both members of the PSG and non-members.

Peer-review

All submissions to this journal undergo peer review by independent experts in the relevant field to ensure the scientific quality, validity, and originality of the published work. Authors might be asked to revise their manuscripts based on their feedback.

Phasmatodea vs. Phasmida

The ordinal name for stick and leaf insects is subject to debates. As there is no regulation for ordinal names by the code of the International Commission on Zoological Nomenclature there are two coexisting names for this clade: Phasmida Leach, 1815 and Phasmatodea Jacobson & Bianchi, 1902. Arguments for Phasmida follow age priority (as this name was published as the first in 1815) and traditional use, whereas Phasmatodea is favoured due to grammar correctness, conformity with modern nomenclatural standards for stability of ordinal names and the predominance in recent publications. Authors are free to choose which one to use in *Phasmid Studies*.

Nomenclatural acts

The validity of nomenclatural acts in *Phasmid Studies* articles is ensured in accordance with the code of the ICZN (International Commission on Zoological Nomenclature; Article 8.1–8.5). *Phasmid Studies* is published under the ISSN 0966-0011 (printed) and ISSN 750-3329 (online). Electronic copies of Phasmid Studies are deposited in the following libraries: British Library, U.K.; Hope Library, Oxford University Museum of Natural History, UK; Nottingham University Library, UK.; Naturhistorisches Museum Wien, Austria; Nationaal Natuurhistorische Museum, Leiden, The Netherlands. Nomenclatural acts are furthermore registered in ZooBank (ZooBank.org).

Current format

Phasmid Studies is published with *Open Access* with no costs for authors and readers. It is produced in hybrid format. Printed and online versions are identical. The online version can be downloaded for free from the PSG webpage.

NHMUK type specimens

Type specimens donated to the NHMUK will receive two additional labels: 1) acquisition number and 2) a unique barcode label. When the types have been received at NHMUK these labels will be included in the PSF (phasmida.speciesfile.org).