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On the horns of a dilemma: toward a better understanding of the *Monacon* species (Hymenoptera: Perilampidae) of Borneo

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ABSTRACT

A new species of *Monacon* is described from Borneo based on digital images, COI sequences and X-ray microtomography. The natural history of this primary parasitoid is documented and its host, a pinhole borer or ambrosia beetle, is documented with digital images and a COI sequence. The X-ray microtomography revealed that the frontal horn that is characteristic of the genus *Monacon* is not simply a cuticular process, but is associated with tissues, and may have a sensory function.

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Introduction

Over the past 40 years, there has been virtually no improvement in our understanding of the taxonomy of the genus *Monacon* (Hymenoptera: Chalcidoidea) and species identifications must rely on Bouček (1980). His revision was hampered by scant material, most of it submitted by international foresters working in Africa and Southeast Asia. Twenty-six species were recognised, 17 of which were new. Of these, 5 species were based on single specimens, 4 on specimens from a single collection, and only 4 on multiple specimens from multiple localities. The revision is illustrated with a limited number of line drawings (and a few of the first SEMs) and we regard the keys and species accounts as very difficult to use, in part because some of the figures and captions are incorrectly associated.

All species of *Monacon* are best regarded as primary parasitoids of pinhole borers (Coleoptera: Curculionidae: Platypodinae) but the details of the life history and immature stages are known only for a single species from Indonesia (Darling and Roberts 1995). These data are hard to come by because of the cryptic nature of both the wasps and their hosts, and their close association with the heartwood of dead trees in tropical forests. Specimens of *Monacon* are rarely collected in Malaise and pan traps, and sweeping is generally ineffective because of the close association of *Monacon* adults with dead trees at the appropriate stage for attack by pinhole borers. Log emergence traps have been used with limited success, but the most productive approach is locating beetle-infested logs *in situ* by the characteristic frass tubes or sawdust.

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Supplemental data for this article can be accessed [here](#).

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Borneo is almost a blank slate with respect to *Monacon* species, which is remarkable given the extent and types of tropical forests that once covered the third largest island of the world. Of the 18 Indo-Australian species recorded by Bouček, only a single species is confidently recorded from Borneo, *M. spinifrons* (Cameron), type locality Kuching (Sarawak). Bouček also lists a single specimen of *M. productum* Waterston, type locality India, from Sabah. Recent ROM collections from Borneo total around 40 specimens and have been collected mainly in national parks and protected areas in Sarawak (Malaysia) and in East and West Kalimantan (Indonesia) and conservatively represent 8 species. There are also a few old Bornean specimens in other collections (BPBM, USNM). Finally, there is a remarkable series of 13 specimens, representing 5 species, from Gunung Buda, Sarawak (4°13'N 114°56'E) collected by Steve Heydon and Stella Fung (MT, 16-21.XI.1996, UCDC). Clearly, there is much more work that needs to be done on Bornean *Monacon*.

The purpose of this paper is to diagnose, illustrate and provide COI sequences (DNA 'barcodes') for an undescribed species of *Monacon* from Borneo and to briefly summarise aspects of its biology and host association. Our hope is to stimulate more work on these parasitoid wasps, which are involved in an intricate symbiosis involving pinhole borers, the tree species they attack and the fungi that provide the food (ambrosia) for the beetle larvae (Kirkendall et al. 2015). There are also possible economic implications because the blue stain fungi introduced by the beetles devalues timber (Beaver 1977), and as primary parasitoids *Monacon* species could limit the growth of beetle populations, particularly in log yards or log ponds where logs are accumulated prior to shipment for processing or export.

Many taxonomists gravitate to national parks or protected areas for fieldwork and collecting, regarding the surrounding local communities with their farming and agro-forestry practices as little more than waypoints or sources of local help. However, many of these communities provide a rich mosaic of land use that sustains high levels of biodiversity and provide access to trees of differing ages. The longhouse communities in Borneo are a case in point. Much of our work in Borneo has been focused on protected areas and primary forests, but these forests are difficult places to collect and study insects associated with weakened or fallen trees. Downed trees occur infrequently and randomly in the forests and need to be located before decomposition renders the logs unsuitable for xylo-mycetophagous beetles. Even if located quickly, the size and structural complexity of the downed trees make biological studies difficult. This is clearly a hit-or-miss approach. Another strategy is to rear insects from log sections in emergence cages, which requires long periods of time in the field or local collaborators to monitor future emergences.

Another approach is to work with communities surrounding the protected areas. In 2012, after collecting and setting Malaise traps in Batang Ai National Park, Sarawak we were invited to spend the Gawai holiday at the Iban longhouse at Nanga Delok, just outside the park. During lulls in the festivities, the environs around the longhouse were explored and a number of felled trees of various ages were found (Figure 1(a) – longhouse in upper left). One log had the telltale signs of ambrosia beetle attack, small piles of sawdust on the bark (Figure 1(b)) that led to tunnels into the heartwood (Figure 1(c)). Exploring the log and frass piles were *Monacon* females (Figure 1(d)). After the initial collections were made, the log was cut into about 5 cm sections (Figure 1(e)), which revealed the extent of the ambrosia beetle galleries and the blue stain fungi on which the



Figure 1. Fieldwork at Nanga Delok longhouse. (a) Cut log of *Baccaurea motleyana* behind the Iban longhouse. (b) Log with pinhole borer wood and frass piles (white patches). (c) Bark plug removed, tunnels into heartwood. (d) *Monacon* female, investigating sawdust and frass. (e) Cutting discs for log dissections. (f) Pinhole borer galleries and blue stain fungi in heartwood. (g) Pinhole borer larva and pupa. (h) Pinhole borer larva and adult dissected from heartwood. Note blue staining of heartwood in (g and h).

beetle larvae feed (Figure 1(f)). Subsequent dissections recovered larvae and adult beetles deep within the heartwood (Figure 1(g,h)). The felled tree was identified by the Iban as *rambai*, a native fruit tree that was healthy, but cut down 3 months previously because it was shading the *tanju*, or drying platform of the longhouse. Only as a result of spending time in the longhouse were we able to obtain a long series of specimens of *Monacon*, specimens of the host, and the name and age of the tree attacked.

We are confident that John LaSalle would have embraced this approach to fieldwork – and his outgoing personality would have made him a natural for celebrating Gawai at an Iban longhouse. We dedicate this new species of *Monacon* to John.

Methods

The new species is diagnosed in the context of Bouček (1980), using his terms for morphological features. A comprehensive morphological description is not provided, but rather, in accordance with Article 13.1.1. of the International Code of Zoological Nomenclature, a “description or definition that states in words characters that are purported to differentiate the taxon”. The diagnostic description provided herein is a clear intent to differentiate, by providing a summary of the characters that differentiate the new nominal taxon from related or similar taxa (Recommendation 13A).

Digital images of the *Monacon* species and its platypodine host were captured with a Keyence VHX-6000 digital microscope and cleaned up and optimised in Photoshop, and the high-resolution original images are archived in the Royal Ontario Museum’s online collection database at <https://collections.rom.on.ca>. These images can be accessed by searching for the ROME # at this URL.

X-ray microtomography (micro-CT scans) was undertaken at the Centre for Microscopy and Microanalysis, University of Western Australia. One specimen was stained overnight in I2E (1% iodine by weight in 100% ethanol) to improve contrast. The specimen was then rinsed and sealed in a micropipette in 100% ethanol for scanning. The specimen was scanned at 50 kV, 4 W using a Zeiss Versa 520 XRM running Scout and Scan software (v. 11.1.5707.17179). A total of 2001 projections were collected over 360°, each with 1 second exposure, 2X binning, LE1 filter and a 4X lens to achieve a voxel resolution of 3.953 µm. Raw data were reconstructed automatically through XMReconstructor (v11.1.5707.17179) using default settings. Data analysis and visualisation were then conducted in Drishti 2.6.5 (PC) and Drishti 2.6.4 (Mac) (Limaye 2012). Output from XMReconstructor (.txm) was imported into Drishti via Drishti Importer to generate a pvl.nc file. The 3D volume was cleaned in Drishti Paint (e.g. isolation of specimen from micropipette and ethanol, removal of dirt particles) and subsequently viewed and imaged in Drishti Renderer. The three-dimensional pdf image was generated following the protocol of Semple et al. (2019). Interactive micro-CT scans are provided as Supplemental Materials (SM).

DNA was extracted at the Laboratory of Molecular Systematics, ROM using a Qiagen DNeasy Blood & Tissue Kit (QIAGEN) following the manufacturer’s instructions and DNA was eluted with 50 µL of AE buffer. Each 25 µL PCR reaction consisted of 1 µL of template DNA, 18.89 µL ddH₂O, 0.56 µL dNTPs [10 mM], 0.05 µL Platinum Taq (Invitrogen), 1 µL [0.01 mM] each of the universal COI primers LCO1490 and HCO2198 (Folmer et al. 1994) and 2.5 µL 10X PCR buffer (Invitrogen). PCR thermo-cycling conditions were an initial hot start of 94°C for 1 min, 5 cycles of denaturation at

94°C for 30 s, annealing at 42°C for 40 s and extension at 72°C for 1 min, then 35 cycles of denaturation at 94°C for 30 s, annealing at 46°C for 40 s and extension at 72°C for 1 min, with a final extension at 72°C for 5 min. Three microliters of PCR products were combined with 3 µl loading dye and visualised using 1% agarose gel. Only amplicons with single, intense bands were sequenced. Before sequencing the remaining 23 µl of PCR product was treated with 0.5 µl of ExoSAP-IT (Applied Biosystems) and 1.5 µl ddH₂O and placed in a thermocycler under the following conditions: 37°C for 15 min, 80°C for 15 min, and then a 4°C hold. Each sequencing reaction consisted of 2 µl of PCR product along with 0.5 µl BIG DYE 3.1 reagent (Applied Biosystems, Inc), 0.5 µl LCO1490/HCO2198 primer, 5 µl ddH₂O and 2 µl 5X sequencing buffer (Invitrogen) and were then run on an ABI 3730 capillary sequencer (Applied Biosystems). Bioedit was used to trim primers, assemble and manually edit bidirectional contigs from raw trace files. COI sequences have been deposited in BOLD: The Barcode of Life Data System (<http://boldsystems.org/>).

Primers: LCO1490: 5'-gggtcaacaaatcataaagatatgg-3', HCO2198: 5'-taaacttcagggtgac-caaaaaatca-3'.

Museum acronyms

BPBM – USA, Hawaii, Honolulu, Bernice P. Bishop Museum.

NHMUK – UK, London, Natural History Museum.

ROME – Canada, Toronto, Royal Ontario Museum Entomology collection.

UCDC – USA, California, Davis, University of California, R.M. Bohart Museum of Entomology.

USNM – USA, Washington D.C., National Museum of Natural History, [formerly, United States National Museum]

Monacon gawai Darling (Figures 1(d), 2, 3, 4, SM1, SM2)

Type locality

Nanga Delok longhouse, Sri Aman Division, Sarawak (1° 13.998'N, 112° 01.252'E, 107 m).

Type material

Holotype Female (ROME176885), deposited at the Forest Research Centre, Sarawak Forestry Department, Kuching, 'MALAYSIA: Sarawak, Sri Aman Div., Nanga Delok longhouse, 1° 13.998'N, 112° 01.252'E, 107 m, 1 June 2012 DC Darling ROM 2012103; Ex. 3-month cut log *Baccaurea motleyana* with *Dinoplatypus pseudocupulatus* (Schedl)', imaged ROM 24 November 2017 and 31 October 2019. Thirty-five paratype females, 22 same data as Holotype: ROME179713 (BOLD COI sequence CDROM006-19, 411 bp); and 176834, 179714–17973 and 13 labelled 'MALAYSIA: Sarawak, Sri Aman Div., Nanga Talong longhouse, 1° 23.333'N, 111° 59.103'E, 246 m, 27 May 2018 DC Darling, N. Tatarnic ROM 2018526: Ex. durian log at mini-hydro dam, with ambrosia beetles (Platypodinae)': ROME179712 (BOLD COI sequence CDROM007-19, 431 bp) and ROME 179734 (BOLD COI sequence CDROM008-19, 430 bp), and ROM179735-17941, 179752, 179753 (X-Ray

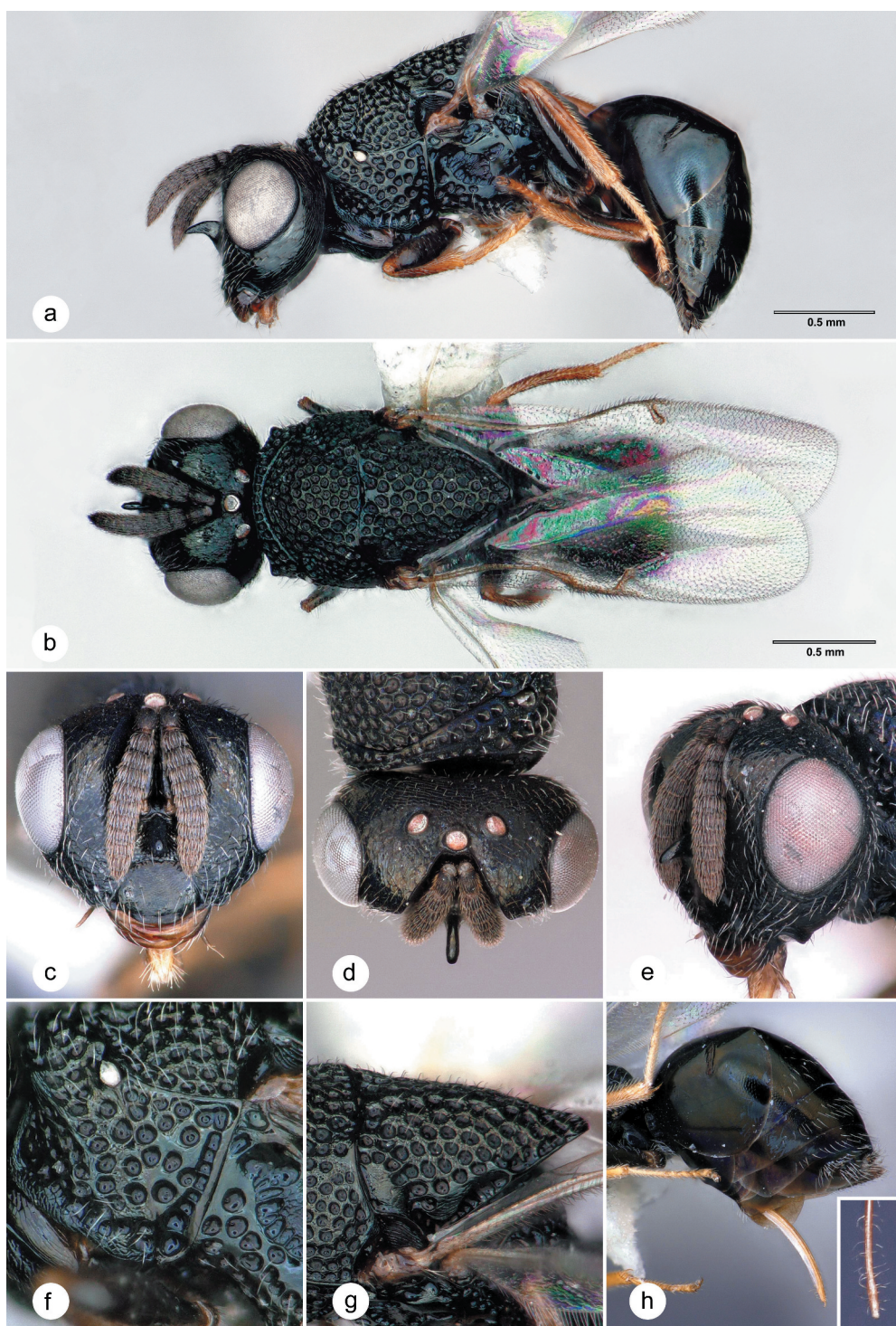


Figure 2. *Monacon gawai* n.sp. (a) Lateral habitus. (b) Dorsal habitus. (c) Head, frontal. (d) Head, dorsal. (e) Head, oblique. (f) Lateral pronotum and prepectus. (g) Scutellum, lateral view. (h) Metasoma and ovipositor, lateral view (Inset: apex of ovipositor, dorsal view). (a, b, f, g) Holotype, ROME176835. (c) Paratype, ROME179712. (d, e) Paratype, ROME139712. (h) Paratype, ROME179752.

microtomography). Paratypes deposited at Forest Research Centre, Sarawak Forestry Department, Kuching, ROME, NHMUK, and USNM.

Additional Material Examined

Malaysia (6 females): Borneo, Sarawak sw. Gunung Buda, 64 km S. Limbang, 4°13'N 114°56'E, 16–21.XI.1996 MT SL Heydon and S Fung; Indonesia (5 females): Sumatra, Aceh, Gunung Leuser Nat. Pk., Ketambe Res. Sta.: 9–21 September 1989. DC Darling, ROM 893089, 350 m, 3°41'N, 97°39'E. Malaise trap (ROME176871); and 31 January 1990. DC Darling. IIS 900003 (ROME176864); Indonesia: Borneo, West Kalimantan, Gunung Palung Nat. Pk., Cabang Panti Res. Sta., 15 JUN–15 August 1991. Darling, Ubaidillah, Sutrisno. IIS 910122, 100–400 m, 1°15'S, 110°5'E, Malaise trap (ROME176863, 176872, 176873).



Figure 3. *Monacon* species comparisons. (a) *M. modestum* Bouček. Holotype and labels (Insets, *Monacon gawai* n.sp. Above, fore wing (Paratype ROME179712); Below, lateral mesosoma (Paratype ROME179735)). (b and c) *Monacon gawai* n.sp., fore wing and venation. (b) Paratype female. (c) Female from Gunung Buda (Note: thickened band below marginal vein).

Diagnostic description

Females, slightly less than 3 mm in length. Black in colour, without iridescent reflections, except flagella, tegulae, trochanters, femora and tibiae brown, tibiae yellow. Wings hyaline, setose, type material without a thickened band below marginal vein (Figures 3(b), 4(b)).

Monacon gawai is one of the very few species in southeast Asia with a completely demarcated clypeus (Figure 3(c)) – the lateral sutures are distinct and the epistomal sulcus is deep and crenulate. The flat clypeus has very low and setose tubercles (*sensu* Bouček, 1980) near the lateral sutures and close to the anterior margin (Figure 3(c)). The clypeus, except for the tubercles, lacks setae and has very weak coriaceous sculpture, in contrast to the coarser sculpture on the rest of the face. The scrobal cavities are deep but restricted to the upper half of the face, convergent on the middle of the eye, with a distinct carina above (Figure 3(e)). The frontal horn is short in lateral view, less than one-half eye width, curved and triangular in lateral view (Figure 3(a)). The apex of the horn is rounded (Figure 3(b,d)).

Monacon gawai is most similar to *M. modestum* Bouček, and will run to this species in the key provided by Bouček (1980) who also notes that *M. modestum* is “especially distinctive because of its simple horn and relatively flat and fairly shiny lower face with the tubercles clearly indicated but very low and placed nearer the eye margin than in other known species”. This statement now needs to be modified to include *M. gawai*. And based on the images of the holotype of *M. modestum* (Figure 3(a), B.M. Type 5.2700), the following characters differentiate *M. gawai*: slightly smaller in size, length 3 mm versus 3.5 mm and more gracile in lateral habitus, the mesosoma is lower in profile, with the mesoscutum and scutellum weakly curved (mesoscutum strongly convex and scutellum almost flat in *M. modestum*) (Figures 2(a), 3(a) (inset), versus Figure 3(a)). In addition, the fore wing is lighter in colour in *M. gawai*, not infusate as in *M. modestum* (Figures 2(b), 3(a(inset),b,c) versus Figure 3(a)).

The only species of *Monacon* described from Sarawak is *M. spinifrons* (Cameron). Based on key and description in Bouček (1980), the drawing of the lateral view of the head (Waterston 1922, Fig. 17), and a specimen determined by Bouček, this species is regarded as distinct from both *M. modestum* and *M. gawai*. The horn of *M. spinifrons* is much broader at the base in lateral view, more triangular, and the clypeus is densely sculptured and setose.

Etymology

The specific epithet is a reference to Gawai Dayak, the annual harvest festival celebrated by the Dayaks of Borneo. The type material was collected in the vicinity of Iban longhouses, during or leading up to Gawai with the assistance of the Iban of Nanga Delok and Nanga Talong. *Terima kasih amai amai!*

Distribution

Monacon gawai is known only from Borneo. The type material is restricted to the specimens from the two longhouses in Sri Aman Division, Sarawak because COI sequences are only available from these two localities. These sequences, when aligned with ClustalW, had different bases at 4 of 411 sites, or a 99% similarity. COI sequences are not available for the specimens from Gunung Buda, Sarawak or Indonesia. In addition, these specimens have a thickened band below the marginal vein that is not found in any of the type

specimens (Figure 3(c) cf. Figure 3(b)). Otherwise, the specimens of *M. gawai* are morphologically very similar. *Monacon modestum* is not recorded from Borneo and is known from only three specimens, the holotype female (peninsular Malaysia) (Figure 3), and a female and male paratype from the Philippines (Mindanao).

Host Association

The holotype and 22 of the paratypes were collected in association with the ambrosia beetle *Dinoplatypus pseudocupulatus* (Schedl) (identification by Roger Beaver, Chiang Mai, Thailand). High-resolution digital images of a male (ROME179937) and female (ROME179376) are archived in the ROM's online collection. A COI sequence (BOLD CDR0M009-19, 696 bp) was obtained for ROME179938 and there is 98.3% similarity to a specimen of this species from Lambir NP (Sarawak) (GenBank Acc. KR261319 (Sarawak, Lambir NP)). The pinhole borers were associated with a fruit tree (*rambai*: *Baccaurea motleyana*, Phyllanthaceae), which was healthy but cut down 3 months before the collections were made. The paratypes from Nanga Talong were also associated with a fruit tree (durian, *Durio* species, Malvaceae), which was recently cut down during the construction of a mini-hydro dam.

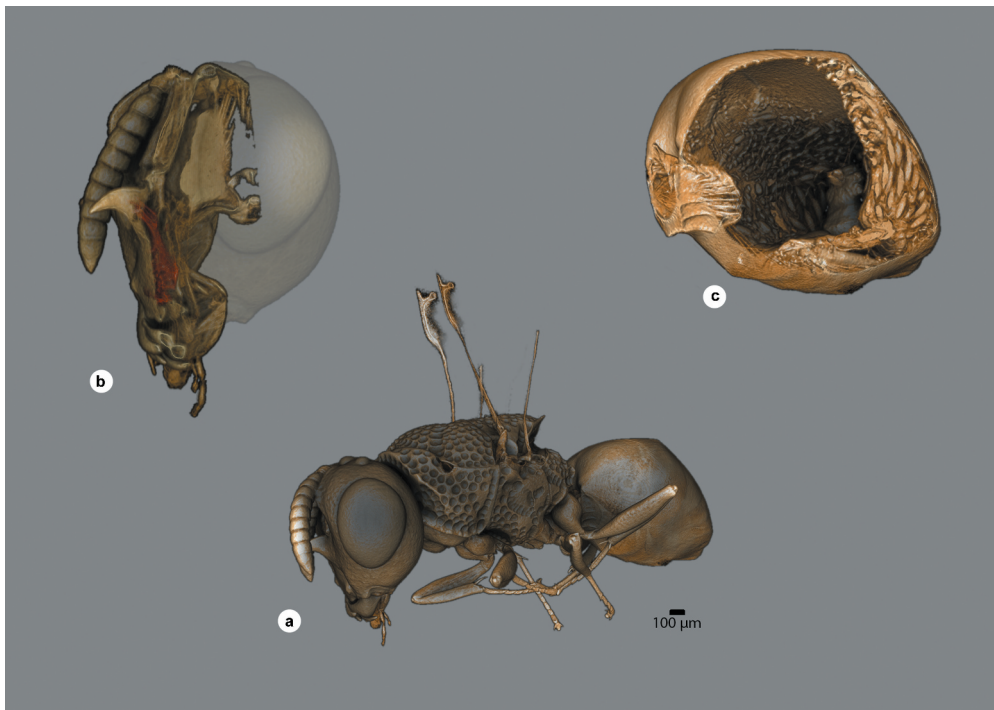


Figure 4. Micro-CT images of *Monacon gawai* n.sp. (ROME179753) (a) Lateral view of body. (b) Cut-away view of head, showing inner structure of horn. (c) Cross-section of abdomen with eggs. For interactive pdf see supplementary data.

Remarks

Monacon gawai is most closely related to *M. modestum*. Currently, *M. modestum* is poorly characterised in terms of morphological variation, geographic distribution, host associations, and there are no genetic data available. Until there are more collections from Borneo and peninsular Malaysia in particular it will not be possible to evaluate the hypothesis that *M. gawai* is a Borneo endemic. Should this species fall in synonymy, so be it, but the formal description of this species necessitates that this series of specimens, with paratypes distributed in numerous collections, and high-quality digital images and COI sequences archived at the ROM and BOLD, will have to be evaluated in future taxonomic studies of Southeast Asian *Monacon*.

X-ray microtomography provided novel insights into the internal structure of *Monacon* (Figure 4 and Supplemental Materials). The frontal horn is the most distinctive feature of all species of *Monacon*, and a horn on the supraclypeal area is unique to the genus and similarly developed in males and females. There has been little speculation on the function of the horn but Bouček (1980) suggested that the horn, the enlarged scrobal cavities and additional facial features “are apparently designed for the reception and protection of the antennae” and therefore associated with the emergence of adults from the galleries deep in the heartwood. It has been assumed that the horn was a cuticular process, but tomography reveals that there are tissues entering the horn and that these tissues also involve the inner surface of the clypeus (Figure 4(b), SM2). These could be glandular or sensory in function, which could suggest a role in host location. Females do not enter the galleries of the beetles but oviposit on the bark (Figure 1(d)) and the ovipositor is laterally compressed and has long setae toward the apex (Figure 2(h)-Inset). The first-instar or planidial larvae enter the galleries and locate the host (Darling and Roberts 1999). This is a risky strategy and may explain the large number of mature eggs in the abdomen of the female (Figure 4(c)). Also, striking was the size of the indirect flight muscles, in particular, the dorso-longitudinal muscles (SM Figure 4(a)). A well-developed flight mechanism might be expected for a genus of parasitoids that attack hosts with patchy distributions in both time and space.

Discussion

There has been much discussion in recent years about how to overcome the ‘taxonomic impediment’ in biology, and 10 years ago John La Salle noted that “taxonomists are still gathering morphological information and describing species as they have done for the last 250 years” (La Salle et al. 2009). Proposals have ranged from streamlining traditional practices using the internet (Godfray 2002) to a radical overhaul of existing practices by focusing almost exclusively on DNA barcodes for describing new species (Meierotto et al. 2019). DNA-based approaches, often grouped under the moniker of ‘turbo-taxonomy’, have been used to describe prodigious numbers of species in ‘hyperdiverse’ taxa such as braconid wasps (Butcher et al. 2012; Fernandez-Triana et al. 2014; Meierotto et al. 2019) and weevils (Riedel et al. 2013b). These studies all focus on barcoding specimens from only a subset of the geographic range of the taxon, from a single conservation area or country, and it remains to be seen if these studies can ‘scale up’ to provide a comprehensive understanding of the taxon across its range. More importantly, it

remains to be seen if these studies will stifle further study resulting in ‘orphan’ taxa that are totally neglected by the next generation of taxonomists.

John La Salle was an advocate for accelerating taxonomic discovery, noting that “describing species using traditional methods is very slow and tedious by nature” (La Salle et al. 2009). But rather than sidestepping morphology, they advocate for automatic character extraction from specimens and the development of a global natural history ‘metacollection’ (Balke et al. 2013). Ambitious goals indeed!

There are also changes that could be made to the time-consuming practice of taxonomic description. As suggested by Godfray (2002) and Riedel et al. (2013a), complete and standardised species descriptions, which include numerous characters that don’t serve to diagnose species, are time-consuming and of little utility, except perhaps in the rare cases of a comprehensive monographic revision of a putatively monophyletic taxon. In most cases, the next reviser will have to study the type material and additional specimens and not rely on the published descriptions. Concise and precise diagnoses based on morphology, geography, and natural history, and not simply DNA barcodes or other molecular characterisations, will promote interest and further study, which is the only way that taxonomists will be able to advance species discovery in poorly studied groups of insects.

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Disclosure statement

No potential conflict of interest was reported by the authors.

References

- Balke M, Schmidt S, Hausmann A, Toussaint EF, Bergsten J, Buffington M, Häuser CL, Kroupa A, Hagedorn G, Riedel A, et al. 2013. Biodiversity into your hands - a call for a virtual global natural history ‘metacollection’. *Front Zool.* 10(55):1–9. doi:10.1186/1742-9994-10-55.
- Beaver RA. 1977. Bark and ambrosia beetles in tropical forests. *Proc. Symp. forests pests diseases Southeast Asia*. No. 2 (Bogor): Biotrop Spec. Publ. p. 133–147.

- Bouček Z. 1980. A revision of the genus *Monacon* Waterston (Hymenoptera: Chalcidoidea: Perilampinae), parasites of ambrosia beetles (Coleoptera: Platypodidae). Bull Ent Res. 70:73–96. doi:[10.1017/S0007485300009792](https://doi.org/10.1017/S0007485300009792).
- Butcher BA, Smith MA, Sharkey MJ, Quicke DLJ. 2012. A turbo-taxonomic study of Thai *Aleiodes* (*Aleiodes*) and *Aleiodes* (*Arcaleiodes*) (Hymenoptera: Braconidae: Rogadinae) based largely on COI barcoded specimens, with rapid descriptions of 179 new species. Zootaxa. 3457:1–232.
- Darling DC, Roberts H. 1999. Life history and larval morphology of *Monacon* (Hymenoptera: Perilampidae), parasitoids of ambrosia beetles (Coleoptera: Platypodidae). Can J Zool. 77:1768–1782. doi:[10.1139/z99-155](https://doi.org/10.1139/z99-155).
- Fernandez-Triana J, Whitfield J, Rodriguez J, Smith M, Janzen D, Hajibabaei M, Burns J, Solis A, Brown J, Cardinal S, et al. 2014. Review of *Apanteles* sensu stricto (Hymenoptera, Braconidae, Microgastrinae) from Area de Conservación Guanacaste, northwestern Costa Rica, with keys to all described species from Mesoamerica. ZooKeys. 383:1–565.
- Folmer O, Black M, Hoeh W, Lutz R, Vrijenhoek R. 1994. DNA primers for amplification of mitochondrial cytochrome c oxidase subunit I from diverse metazoan invertebrates. Mol Mar Biol Biotech. 3:294–299.
- Godfray HCJ. 2002. Challenges for taxonomy. Nature. 417:17–19. doi:[10.1038/417017a](https://doi.org/10.1038/417017a).
- Kirkendall LR, Biedermann PHW, Jordal BH. 2015. Evolution and diversity of bark and ambrosia beetles. In: Vega FE, Hofstetter RW, editors. Bark Beetles. Biology and ecology of native and invasive species. London: Academic Press; p. 85–156. doi:[10.1016/B978-0-12-417156-5.00003-4](https://doi.org/10.1016/B978-0-12-417156-5.00003-4).
- La Salle J, Wheeler Q, Jackway P, Winterton S, Hobern D, Lovell D. 2009. Accelerating taxonomic discovery through automated character extraction. Zootaxa. 2217(1):43–55. doi:[10.11646/zootaxa.2217.1.3](https://doi.org/10.11646/zootaxa.2217.1.3).
- Limaye A. 2012. Drishti: a volume exploration and presentation tool. Proc. SPIE 8506, Developments in X-Ray Tomography VIII; San Diego, CA. p. 85060X.
- Meierotto S, Sharkey MJ, Janzen DH, Hallwachs W, Hebert PDN, Chapman EG, Smith MA. 2019. A revolutionary protocol to describe understudied hyperdiverse taxa and overcome the taxonomic impediment. Dtsch Entomol Z. 66:119–145. doi:[10.3897/dez.66.34683](https://doi.org/10.3897/dez.66.34683).
- Riedel A, Sagata K, Suhardjono YR, Tänzler R, Balke M. 2013a. Integrative taxonomy on the fast track - towards more sustainability in biodiversity research. Front Zool. 10(15):1–9. doi:[10.1186/1742-9994-10-15](https://doi.org/10.1186/1742-9994-10-15).
- Riedel A, Sagata K, Surbakti S, Tänzler R, Balke M. 2013b. One hundred and one new species of *Trigonopterus* weevils from New Guinea. ZooKeys. 280:1–150. doi:[10.3897/zookeys.280.3906](https://doi.org/10.3897/zookeys.280.3906).
- Semple TL, Peakall R, Tatarnic NJ. 2019. A comprehensive and user-friendly framework for 3D-data visualisation in invertebrates and other organisms. J Morph. 280(2):223–231. doi:[10.1002/jmor.20938](https://doi.org/10.1002/jmor.20938).
- Waterston J. 1922. On Chalcidoidea. (Mainly bred at Dehra Dun, U.P., from pests of Sal, Toon, Chir and Sundri). Indian For Rec. 9:51–94.