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First discovery of the mangrove ant *Pheidole sexspinosa* Mayr, 1870 (Formicidae: Myrmicinae) from the Oriental region, with redescriptions of the worker, queen and male

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Abstract. The ant species *Pheidole sexspinosa* Mayr, 1870 is re-described based on colony series and individual specimens collected from various mangroves in Singapore; the worker, queen, and male, including male genitalia, are described. The recognition of *P. sexspinosa* in Singapore constitutes the species' first discovery in the Oriental region. *Pheidole sexspinosa* was previously thought to be restricted to Oceania, but our findings suggest a much broader geographic distribution including continental Asia. COI partial sequences from the Singapore specimens are almost identical (100% cover, 99% identity) to those from Palau (Micronesia) specimens, which were identified as *P. sexspinosa* and registered in GenBank. The Singapore populations of *P. sexspinosa* were found nesting in a decayed stem of a *Rhizophora* L. (Rhizophoraceae) tree, and in cable roots of *Excoecaria agallocha* L. (Euphorbiaceae). The apparent wide distribution of *P. sexspinosa* may be attributed to long distance dispersal of rotten logs and branches, and viviparous seeds of mangrove trees carrying queens or queen-right colonies by seasonal circulatory currents, or human-mediated dispersal.

Key words. insect, mangrove habitat, new geographic distribution, Oceanian species

INTRODUCTION

The genus *Pheidolacanthinus* was established by F. Smith (1865) for *Pheidolacanthinus armatus* (junior synonym of *Pheidole quadrispinosa*); it was subsequently demoted to a subgenus of *Pheidole* by Forel (1900). Emery (1921) divided the subgenus "*Pheidolacanthinus*" into three species groups, i.e., *P. quadrispinosa* F. Smith, 1865 (Australasia and Austro-Malaya), *P. cervicornis* Emery, 1900 (New Guinea), and *P. quadricuspis* Emery, 1900 (Indo-Malaya) groups. The *Pheidole quadrispinosa* group included *P. sexspinosa* Mayr, 1870 and its extant subspecies: *biroi* Emery, 1900, and *fuscescens* Emery, 1900.

The monophyly of *Pheidole sexspinosa* and its close relatives (*P.sexspinosa* subsp. *biroi* and a few undetermined species or local populations) was highly supported by Economo et al. (2015). Therefore, this monophyletic group is hereafter referred to as the *P. sexspinosa* group.

According to Economo et al. (2015) and AntMaps (http://antmaps.org/), the *P. sexspinosa* group, including *P. sexspinosa* subsp. *fuscescens* Emery, 1900, which was not examined in Economo et al. (2015), is known from the Oceanian realm including New Guinea (Holt et al., 2013), but has not yet been recorded from the west of the Lydekker Line.

However, we recently recognised multiple populations of the *P. sexspinosa* group in Singapore, far from its known range. In the present paper, we confirm the identity of these populations based on DNA barcoding and morphological examination, make necessary taxonomic treatments, and give some relevant biological notes.

MATERIAL AND METHODS

Material examined. Multiple colony series with major and minor workers that agree with the species diagnosis of *Pheidole sexspinosa* were first discovered in the Zoological Reference Collection (ZRC) at the Lee Kong Chian Natural History Museum (LKCNHM). These colonies had been collected from mangrove habitats in a few localities north of Singapore during the 1970s. Then, in the course of our recent field surveys in Singapore (for details, see under "Taxonomic Accounts"), fresh material was collected for DNA barcoding and morphological examination.

Type images of the following species and subspecies given in AntWeb v.7.27.2 were examined:

Pheidole sexspinosa Mayr, 1870 – syntype, major, CASENT0919761, Tuvalu, Oceania, only part of head and thorax being intact.

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"*Pheidole sexspinosa* subsp. *adamsoni* Wilson & Taylor, 1967" (junior synonym of *P. sexspinosa*) – cotype, major, CASENT0249104, Marquesas Is.; cotype, major, LACMENT182082, Marquesas Is.

Pheidole sexspinosa subsp. *biroi* Emery, 1900 – syntype, major, CASENT0904306, New Guinea; syntype, minor, CASENT0904307, New Guinea.

Morphological examination and imaging. Morphological observations of the body were made using an Olympus SZX16 stereomicroscope, while measurements were made using micrometers on the same microscope. Measurements of the type images given in AntWeb v.7.27.2 were made using ImageJ 1.52c (Schneider et al., 2012; available at http://imagej.nih.gov/ij). Genitalia of one male preserved in 80% ethanol were slide-mounted by following the preparation done by Yamada & Eguchi (2017), and examined with a Nikon Eclipse E600 microscope.

Morphological terminology of male external genitalia largely follows Boudinot (2013).

The following parts of bodies were measured, and then the indices were calculated (see also Eguchi et al., 2016). Measurements are given in mm.

HL maximum length of head capsule excluding the mandibles, measured in full-face view in a straight line from the midpoint of posterior head margin to anterior clypeal margin. If anterior clypeal margin and/or posterior margin of head are concave, the straight line is drawn between the midpoints of transverse lines spanning the anterior-most and/or posterior-most points of the head, respectively.
HW maximum width of head capsule, excluding eyes.
OL ocellus length, measured as diameter of major axis of median ocellus in frontal view (queen and male).
OED ocellus-eye distance, maximum distance between lateral ocellus and compound eye (male only).
SL maximum length of antennal scape, excluding the basal condylar bulb.
PmW1 maximum width of promesonotum measured at the bottom in anterodorsal view (for both major and minor).
PmW2 maximum width of promesonotum measured between the apices of pronotal spines in dorsal view (for both major and minor).
PmL length of promesonotum measured from the midpoint of anterior margin of pronotal collar to the midpoint of a transverse line spanning the posterior-most points of mesonotal spines, in dorsal view.
MSW maximum width of mesoscutum in dorsal view (queen and male only).
ML mesosomal length, measured from the midpoint of anterior margin of pronotal collar to the midpoint of a transverse line spanning the posterior-most points of metapleuron in dorsal view.
HFL length of hind femur, measured from the distal margin of the trochanter to the apex of femur.
PtL petiolar length measured in lateral view, from the anterodorsal-most point of petiolar peduncle to the posterodorsal corner of the petiole.
PtW maximum width of petiolar node in dorsal view.
PPtL length of postpetiolar tergite, excluding helcium, measured in lateral view from the anteroventral corner to posterodorsal corner of the tergite.
PPtW maximum width of postpetiole in dorsal view.
CI cephalic index, HW/HL × 100
SI scape index, SL/HW × 100
PmI promesonotal index, PmL/PmW2 × 100
MI mesosomal index, ML/PW × 100 (major and minor); ML/MSW × 100 (queen and male)
PtI1 petiolar index 1, PtL/PPtL × 100
PtI2 petiolar index 2, PtW/PPtW × 100
HFI hind femur index, HFL/HW × 100

Source images for focus stacking were taken using a Lumix DMC GX8 digital camera, attached to a Nikon AZ100 stereomicroscope (for major, minor, and male bodies, excluding male genitalia) and a Nikon Eclipse E600 microscope (for male genitalia). Focus-stacked images were produced using Helicon Focus Pro 6.8.0 (Helicon Soft Ltd., http://www.heliconsoft.com/), and improved with the retouching function of the same software. Colour balance and contrast were adjusted using GIMP 2.8 (The GIMP Development Team, http://www.gimp.org). A dealate queen was imaged with a Dun Inc. ™ Passport II macrophotography imaging system, using a Canon MP-E 65 mm lens. Focus-stacked images of the queen were produced using Zerene Stacker (Zerene Systems LLC, http://zerenesystems.com/cms/stacker). The final images were annotated, and scale bars added using Adobe® Photoshop CS6.

DNA barcoding. DNA extraction, PCR amplification, and sequencing of cytochrome oxidase subunit I (COI) for two minor workers (colony: ZRC_ENT00007290) were performed by following Satria et al. (2015). In addition, DNA extraction for an alate queen (ZRC_BDP0017401) was performed using QuickExtract™ DNA extraction solution (Kranzfelder et al., 2016); the extract was used as template for subsequent COI barcoding. PCR amplification and next generation sequencing were performed following the procedures described in Wang et al. (2018).

Successful barcodes were checked for contamination and identities against the GenBank (NCBI) nucleotide database (Benson et al., 2013), using the online NCBI Basic Local Alignment Search Tool (BLAST) ver. 2.6.0+ (Altschul et al., 1990) under default parameters in *Megablast* (word size: 28).

RESULTS AND DISCUSSION

The COI sequences of the Singaporean populations (GenBank accession numbers: MH726208 – 726210) were nearly identical (100% cover, 99% identity) to those obtained from Palau and identified by Economo et al. (2015) as *P. sexspinosa* (GenBank accession numbers: KJ141794.1, EF518404.1; det.: Economo et al., 2015; loc.: Ngardmau, Palau), and also closely matched (100% cover, 96% identity) to that of

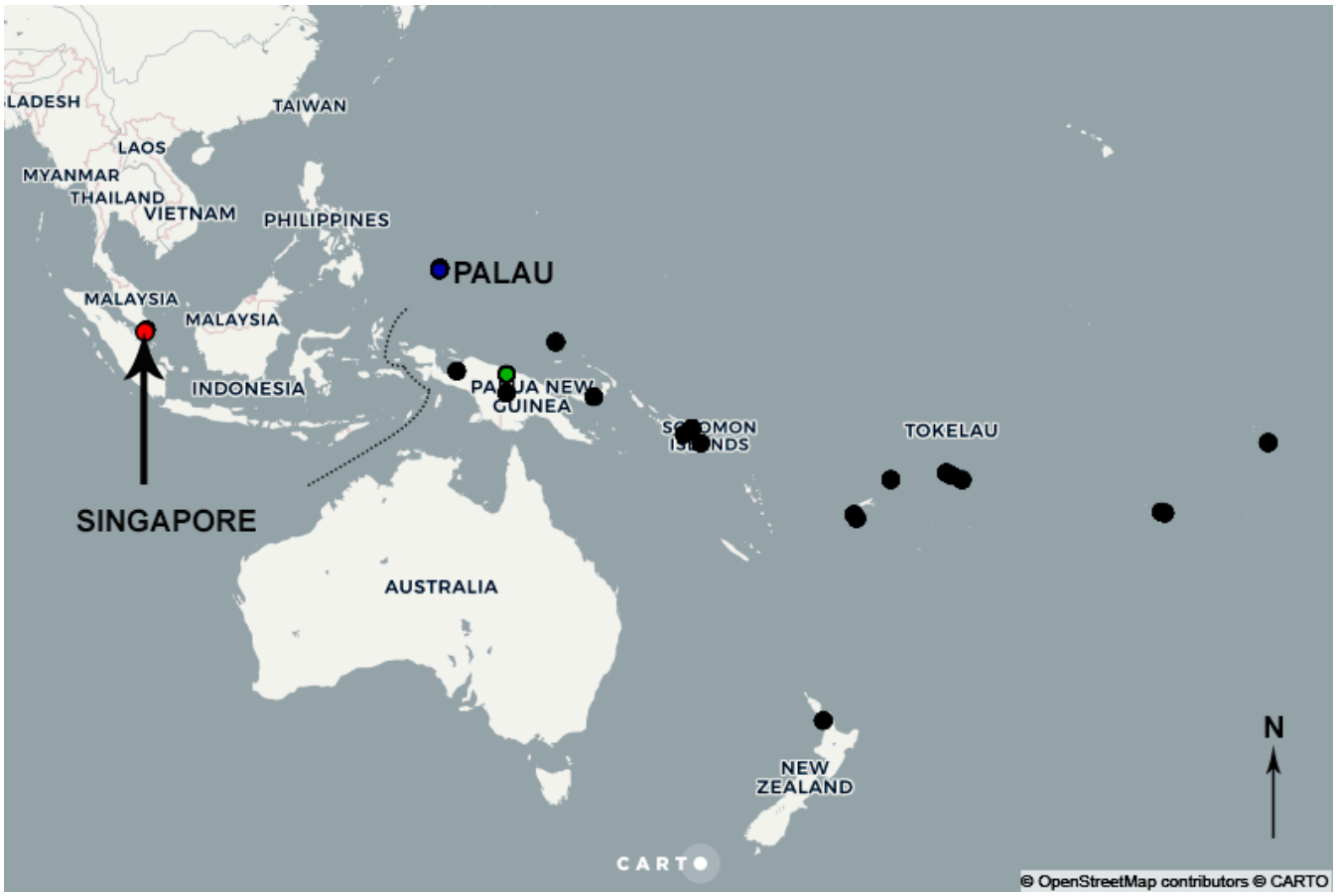


Fig. 1. Map of current known geographic distribution of *Pheidole sexspinosa*. The Lydekker Line is shown as a dotted line. Geographic coordinates of localities where *P. sexspinosa* was recorded were obtained from antmaps.org (http://www.antmaps.org). Localities for barcoded specimens are indicated with solid circles in red (*Pheidole sexspinosa*: MH726208 – 726210; Singapore; present study), blue (*Pheidole sexspinosa*: KJ141794.1, EF518404; Palau; Economo et al., 2015) and green (*Pheidole sexspinosa biroi*: KJ141800.1; Papua New Guinea; Economo et al., 2015), respectively.

"*P. sexspinosa* subsp. *biroi*" (GenBank accession number: KJ141800.1; det.: Economo et al., 2015; loc.: West Sepik, Papua New Guinea) (Fig. 1).

The majors of the Singaporean populations (hereafter referred to as SG) are morphologically most similar to the syntype/cotype majors of "*P. sexspinosa* subsp. *adamsoni*" (hereafter referred to as PSA; CASENT0249104, LACMENT182082), and *P. sexspinosa* subsp. *biroi* (hereafter referred to as PSB; CASENT0904306); the syntype major of *P. sexspinosa* (CASENT0919761) could not be examined in detail as the specimen was heavily damaged; the type material of *Pheidole sexspinosa* subsp. *fuscescens* was not examined in this study. The following small differences were recognised: 1) ventrolateral face of head largely smooth and shining in SG, but longitudinally rugulose and dull in the types of PSA and PSB; 2) base of gaster blackish brown in SG, but pale brown in the types of PSA and PSB; 3) PmI 68–70 in SG, but 61–66 for PSA and PSB; 4) dorsum of promesonotal dome densely ruguso-reticulate in SG, but with sparse rugae in the types of PSA and PSB; 5) pronotal spine long and narrow at the base in SG, but relatively short and broad at the base in PSB (PSA exhibits an intermediate condition). No difference was recognised between the minors of SG and the syntype minor of PSB. Based on the results of high similarities in COI sequences and worker morphology, the Singaporean populations were herein determined as *Pheidole sexspinosa* Mayr, 1870.

Economo et al. (2015), based on their phylogeographic analysis, noted that *P. sexspinosa* originating in New Guinea have colonised eastward to most of the remote Pacific but not westward to Sundaland or mainland Asia. However, our finding challenges their view – *P. sexspinosa* has evidently expanded its range both east and west of New Guinea. We postulate two possible dispersal scenarios that may explain the apparent wide distribution of *P. sexspinosa*: 1) human-mediated dispersal, and/or 2) dispersal by means of seasonal circulatory currents connecting the west Pacific Ocean to the South China and Java Seas.

The *Pheidole sexspinosa* species complex is known to be widespread across Oceania and various islands in the Pacific, and its ubiquity in that region has been associated with human-mediated transport (Sarnat et al., 2015). Human-mediated introduction of *P. sexspinosa* to Singapore following increased anthropogenic activity between regions is therefore quite plausible; *P. sexspinosa* has furthermore been recorded once in New Zealand as a human-introduced species (Ward et al., 2006). Its seemingly high tolerance for harsh habitat conditions, such as in the mangroves and coral rubble (Clouse, 2007; present study), may be testament towards

the species' remarkable dispersal and colonisation abilities, driving advancement into the Oriental region beyond its presumed native range (Sarnat et al., 2015). This scenario fits well with our genetic result, i.e. the extraordinarily wide distribution without high genetic divergence.

It is also possible that *P. sexspinosa* could have spread from Oceania to the Oriental region by means of seasonal circulatory currents connecting the Pacific Ocean to the South China and Java Seas. In particular, the yearly northeast monsoon winds drive surface currents from the west Pacific Ocean westward through the Luzon Strait, and then southward into the South China and Java Seas (Hu et al., 2000; Zhu et al., 2016). Rotten logs and branches, viviparous seeds, and epiphytes of mangrove trees in which fertilised queens and queen-right colonies of *P. sexspinosa* nest might be transported by such seasonal currents over long distances into the Oriental region. Alternatively, oceanic currents from the Pacific could bypass the South China Sea and directly enter the Java Sea via the Makasaar Straits, but this scenario is unlikely because of the Indonesian Throughflow (Hall, 2009). The Indonesian Throughflow would probably sweep propagules or organisms riding on those currents southwards into the Indian Ocean. It is worth noting that the two colonies recently collected from Sungei Buloh Wetland Reserve (colony: WW-SG18-Phei3, ZRC_ENT00000908) and Mandai mangroves (colony: WW-SG18-Phei4, ZRC_ENT00007290) were both found nesting inside the cable roots of a mangrove tree species – *Excoecaria agallocha* L. (Euphorbiaceae), while another colony collected from Mandai mangrove in 1977 (colony: DHM-SG77-Phei-ss2, ZRC_ENT00000770) was found nesting inside a decayed stem of a *Rhizophora* L. (Rhizophoraceae) tree. Viviparous seeds of *E. agallocha* are known to be transported by ocean currents over long-distances. (Zhang et al., 2008).

TAXONOMIC ACCOUNTS

Pheidole sexspinosa Mayr, 1870
(Figs. 2–24)

Pheidole sexspinosa Mayr, 1870: 977, soldier, worker. Combination in *Pheidole* (*Pheidolacanthinus*): Mann, 1919: 307.

Pheidole (*Pheidolacanthinus*) *sexspinosa* subsp. *adamsoni* Wheeler, W.M., 1932: 157, soldier, worker, queen, and male; junior synonym of *P. sexspinosa*: Wilson & Taylor, 1967: 52.

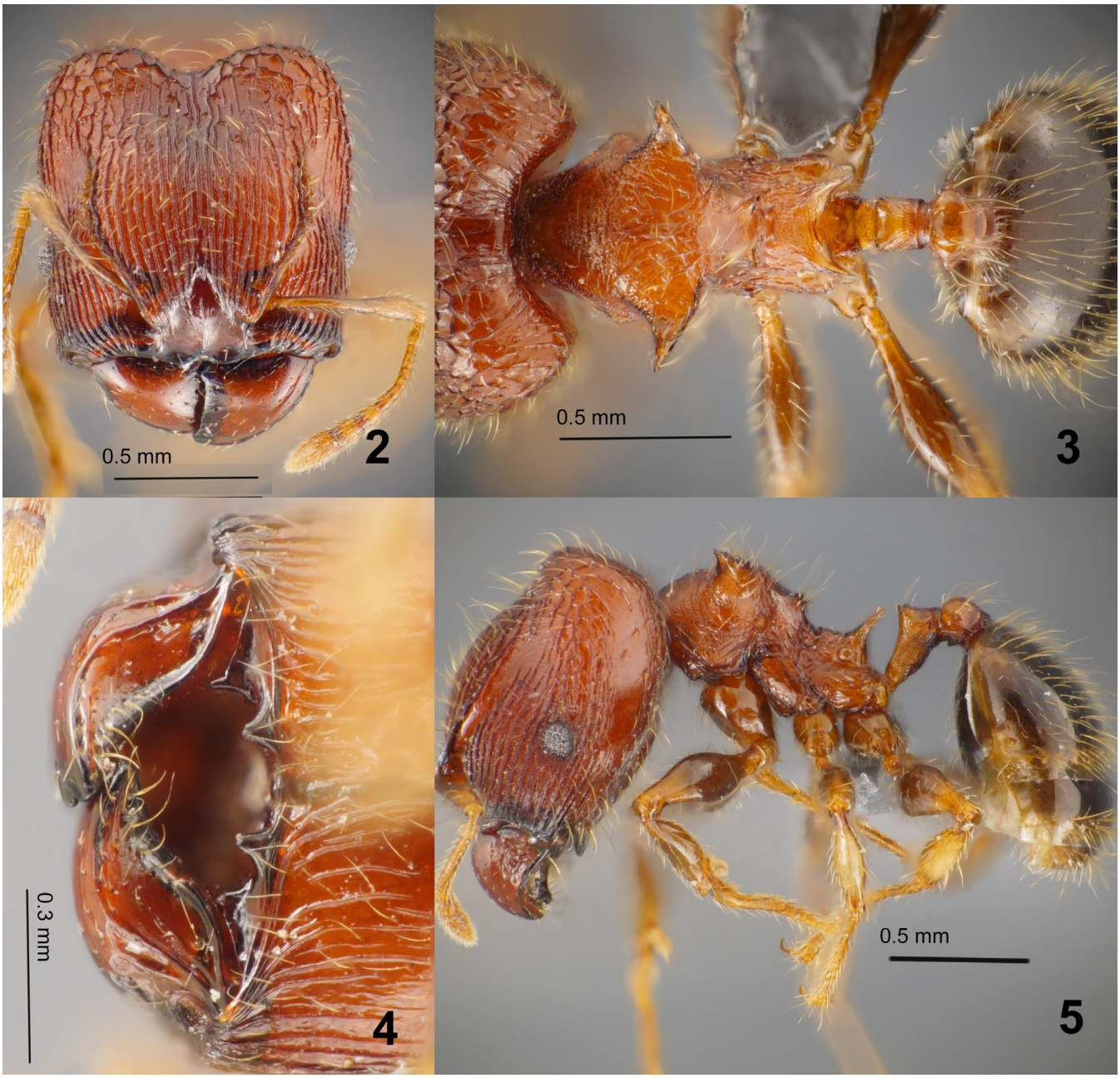
Material examined. ZRC, SINGAPORE: 10 workers, 3 males (colony ID: WW-SG18-Phei3; ZRC catalog number: ZRC_ENT00000908), Sungei Buloh Wetland Reserve, back mangroves, nest in sandy soil and roots of living tree *Excoecaria agallocha*, coll. W. Wang, 14 March 2018; 6 workers, 1 male (WW-SG18-Phei4; ZRC_ENT00007290; accession numbers: MH726208 – 726209), Mandai mangroves, nest in soil substrate and cable root of *Excoecaria agallocha*, coll. W.Wang, 8 May 2018; 1 queen (ZRC_BDP0017401; accession number: MH726210), Sungei Buloh Wetland Reserve, malaise trap SB1 (register no. 29569), coll. M.S. Foo and J. Puniamoorthy, 7 – 12 November 2012; 10 workers (DHM-SG77-Phei-ss1; ZRC_ENT00000767), Mandai mangroves, nest in bosky material 1.5 m above ground level, coll. D.H. Murphy, 27 October 1977; 12 workers, 1 queen (DHM-SG85-Phei-ss1; ZRC_ENT00000768), Kranji mangroves, coll. D.H. Murphy, 9 May 1985; 12 workers, 4 queens (DHM-SG87-Phei-ss1; ZRC_ENT00000769), Lim Chu Kang mangrove, in soil of *Thalassina* mound, coll. D.H. Murphy, 10 March 198710.3.1987; 12 workers, 1 queen (DHM-SG77-Phei-ss2; ZRC_ENT00000770), Mandai mangrove, *Rhizophora* decayed stem at ~ 2 m, coll. D.H. Murphy, 27 Oct 1977; 4 workers (ZRC_ENT00000771), Sungei Buloh mangrove, in *Thalassina* mound, coll. D.H. Murphy, 8 May 1985; 10 workers (DHM-SG77-Phei-ss3; ZRC_ENT00000772), Mandai mangroves, in *Thalassina* mound, coll. D.H. Murphy, 18 October 1977.

Diagnosis. In the major, posterior margin of head in full-face view with deep median concavity; dorsal and lateral faces of vertexal lobe coarsely reticulate, with interspaces superficially micro-reticulate and shining; frons longitudinally rugose, with interspaces smooth and shining; antennal scrobe present as a deep trench beneath frontal carina; hypostoma without median process, with triangular submedian processes laterally; pronotal spine broadly based, directed anterolaterally; mesonotal spine present as a dent; mesopleuron and metapleuron irregularly ruguso-reticulate; propodeal spine horn-shaped; apex of petiolar node in posterior view with a deep emargination; postpetiole expanded laterally to form a pair of small tooth-like protrusions; gaster largely smooth and shining.

In the minor, posterior margin of head in full-face view broadly and weakly concave; preoccipital carina well developed as a low lamella which in full-face view forms a minute tooth-like protrusion at the posterolateral corner of head; posterior part of vertex and lateral face of head rugose-reticulate, with interspaces mostly smooth and shining; frons mostly smooth and shining; pronotal spine horn-shaped; mesonotal and propodeal spines as in the major; dorsal and lateral faces of promesonotal dome largely smooth and shining with sparse superficial reticulation; mesopleuron, metapleuron and dorsal face of propodeum rugulose-reticulate, with interspaces smooth and shining.

Redescription (based on the Singapore population). *Major* (Figs. 2–5): Body generally reddish orange-brown; antenna, apical part of femora, tibia and tarsus light brown; gaster blackish-brown. Body largely covered with abundant long yellowish standing hairs.

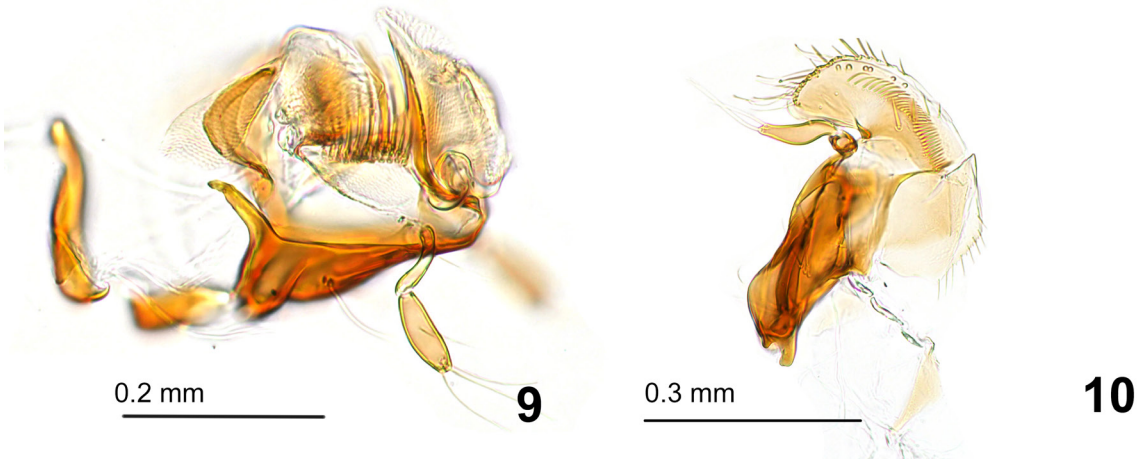
Head in full-face view subrectangular, with posterior margin deeply concave medially, in lateral view relatively high dorsoventrally, weakly impressed on vertex; frons and gena longitudinally rugose; vertex coarsely rugose; dorsal and lateral faces of vertexal lobe coarsely rugoso-reticulate; posterior face of vertexal lobe weakly longitudinally rugose; interspaces on dorsal and lateral faces of head superficially reticulate and shining; ventrolateral face of head largely smooth and shining. Frontal carina conspicuous, extending beyond the midlength of head. Antennal scrobe present



Figs. 2–5. *Pheidole sexspinosa*, non-type major (ZRC_ENT00007290, Singapore, Mandai mangroves). 2, Head in full-face view; 3, mesosoma and waist in dorsal view; 4, hypostoma in ventral view; 5, body in lateral view.

as a deep trench beneath frontal carina. Median part of clypeus largely smooth and shining, with a very weak median longitudinal carina which is flanked laterally by faint longitudinal rugulae. Hypostoma without median process, with triangular submedian processes and distinct lateral processes which are broadly based and strongly tapered apically. Masticatory margin of mandible with large, stout apical and preapical teeth, followed by a long diastema and then a short and crenulate tooth just before the rounded basal angle; mandibular dentition in some majors worn-out and blunt. Outer surface of mandible mostly smooth and shining, with weak superficial reticulation; lateroventral part of mandibular base weakly impressed and with rugae, covered with scattered short erect hairs; outer edge of mandible with longer suberect hairs. Antenna 12-segmented, with 3-segmented club. Maximal diameter of eye ca. 1.5 times longer than antennal segment X.

Promesonotal dome striate anterodorsally and coarsely rugose dorsomedially, with interspaces weakly rugulose and shining; posterior slope of the dome smooth and shining medially and carinate laterally; lateral face of promesonotal dome, metapleuron, and lateral face of propodeum irregularly rugoso-reticulate; mesopleuron largely smooth and shining. Pronotal spine large, broadly based, pointed apically, slightly curved and directed anterolaterally. Mesonotal spine present as a dent, directed posterolaterally. Propodeum with dorsal face and posterior slope weakly rugulose-reticulate but shining; propodeal spine in lateral view horn-shaped and slender, pointed apically, almost straight or slightly down-



Figs. 6–10. *Pheidole sexspinosa*, non-type minor (ZRC_ENT00007290, Singapore, Mandai mangroves). 6, Head in full-face view; 7, mesosoma and waist in dorsal view; 8, body in lateral view; 9, labial palpus in lateral view; 10, maxillary palpus in lateral view.

curved, directed posterolaterally. Ventral surfaces of mid- and hind-coxae smooth and shining.

Petiole up to twice as long as postpetiole excluding helcium; anterior slope in lateral view long and broadly concave; ventral face of petiole rugulose-reticulate; petiolar node in lateral view subtriangular, pointed apically, in posterior view laterally carinate, medially with a deep emargination. Postpetiole in dorsal view much broader than long, spindle-shaped, with lateral part expanded and tapered to form a tooth-like protrusion which bear 1-2 laterally-directed elongate hairs at apex; anteroventral part extended to form a sharp transverse ridge. Entire gaster mostly smooth and shining; base of first gastral tergite weakly rugoso-reticulate.

Non-type majors (n = 6): HL 1.14–1.20 mm; HW 1.10–1.16 mm; SL 0.56–0.58 mm; ML 0.90–0.96 mm; PW 0.54–0.58 mm; HFL 0.66–0.70 mm; PtL 0.28–0.30 mm; PtW 0.16–0.18 mm; PPtL 0.16–0.18 mm; PPtW 0.26–0.30 mm; CI, 96–97; SI, 48–53; MI, 158–167; HFI, 60; PtI1, 167–175; PtI2, 53–61; PmI, 68–70.

Minor (Figs. 6–10): Body generally dark orange-brown; gaster (excluding base of gastral tergite I) a little darker than head capsule and mesosoma, with lateral and posterior margin of each tergite translucent and dark-yellowish; base of gastral tergite I blackish brown, sometimes with dark-yellowish patches; antennal funiculus, joints of legs and tarsus lighter and yellowish. Body except ventrolateral face of head and propodeum largely covered with abundant long yellowish standing hairs.

Head in full-face view suborbicular, with lateral margins broadly convex, posterior margin broadly and weakly concave; preoccipital carina well developed as a low lamella which in full-face view forms a minute tooth-like protrusion at the posterolateral corner of head; frons largely smooth and shining, with scattered superficial reticulation; posterior part of vertex and lateral face of head including gena coarsely rugose-reticulate, with interspaces superficially rugulose-reticulate and shining. Frontal carina distinct but discontinuous, broken into a few longitudinal rugae. Antennal scrobe weak and shallow. Median section of anterior clypeal margin broadly and roundly convex; median portion of clypeus smooth and shining, with a short median longitudinal carina that does not extend beyond the midlength of the clypeus. Masticatory margin of mandible with large apical tooth and slightly smaller preapical tooth, followed by 5-6 smaller teeth before the basal angle, sometimes with minute intercalary denticles; outer surface of mandible mostly smooth and shining, covered with moderately-long erect hairs; lateroventral part of mandibular base weakly rugose. Palp formula of (2, 2). Antenna 12-segmented, with 3-segmented club. Maximal diameter of eye about as long as antennal segment X.

Promesonotal dome with two pairs of spines as in the major; pronotal spine horn-shaped, pointed apically, slightly curved and directed anterolaterally; mesonotal spine present as a dent, directed posterolaterally. Promesonotum largely smooth and shiny, with scattered superficial reticulation; lower half of posterior slope of promesonotum with a short median longitudinal carina; mesopleuron, metapleuron, both dorsal and lateral faces of propodeum rugulose-reticulate, with interspaces shining; posterior slope of propodeum smooth and shining; propodeal spine in lateral view horn-shaped and pointed apically as in the major, weakly down-curved and directed posterolaterally.

Petiole up to twice as long as postpetiole excluding helcium; anterior slope in lateral view long and weakly concave; petiolar node in lateral view subtriangular and pointed at apex, in posterior view with apical margin weakly concave medially. Postpetiole in dorsal view spindle shaped, with lateral part less strongly produced; ventral faces of petiole and postpetiole without any obvious processes or extensions. Gaster mostly smooth and shining.

Non-type minors (n = 8): HL 0.58–0.60 mm; HW 0.56–0.58 mm; SL 0.48–0.52 mm; ML 0.66–0.70 mm; PW 0.36–0.38 mm; HFL 0.52–0.54 mm; PtL 0.20–0.22 mm; PtW 0.09–0.11 mm; PPtL 0.10 mm; PPtW 0.13–0.16 mm; CI, 96–97; SI, 86–91; MI, 179–184; HFI, 93–95; PtI1, 200–220; PtI2, 67–71.

Queen (Figs. 11–13): Body overall dark reddish-brown; mandible, mesoscutum, petiole, postpetiole and gaster blackish-brown, darker than the remaining parts of body; antenna and legs including coxae lighter and more yellowish than body; body except lateroventral face of head covered with abundant yellowish standing hairs.

Head in full-face view subrectangular, slightly wider than long, with posterior margin broadly and shallowly concave, with posterolateral corners roundly convex; head in lateral view high dorsoventrally, impressed on vertex; frons and gena longitudinally rugose, with interspaces weakly rugulose and shining; vertex coarsely rugose; dorsal and lateral faces of vertexal lobe coarsely rugoso-reticulate, with interspaces superficially reticulate and shining; upper half of ventrolateral face of head largely smooth and shining, and lower half longitudinally rugose. Frontal carina conspicuous, extending slightly beyond the midlength of head. Antennal scrobe present as a deep trench beneath frontal carina. Median part of clypeus, hypostomal processes, mandible and antenna as in the major. Maximal diameter of eye ca. 2.4 times longer than antennal segment X. Median ocellus located above the level of the posterior margin of compound eye, slightly higher than the level where antennal scape meets lateral margin of head; maximum diameter of median ocellus much shorter than distance between median and lateral ocelli.

Pronotum rugoso-reticulate anteriorly and laterally; pronotal spine short and stout, pointed apically, directed anterolaterally. Mesoscutum largely longitudinally rugose, with interspaces shining; notaulus absent; parapsidal line indistinct or present as rugae; lateral strip adjacent to parapsidal line smooth and shining; scuto-scutellar suture fairly deep and broad, strongly scrobiculate; mesoscutellar disc largely smooth and shining dorsally, weakly rugulose along its posterior margin. Mesopleuron distinctly subdivided into anepisternum and

Figs. 11–13. *Pheidole sexspinosa*, non-type dealate queen (ZRC_ENT00000768, Singapore, Kranji mangroves). 11, Head in full-face view; 12, mesosoma and waist in dorsal view; 13, body in lateral view.

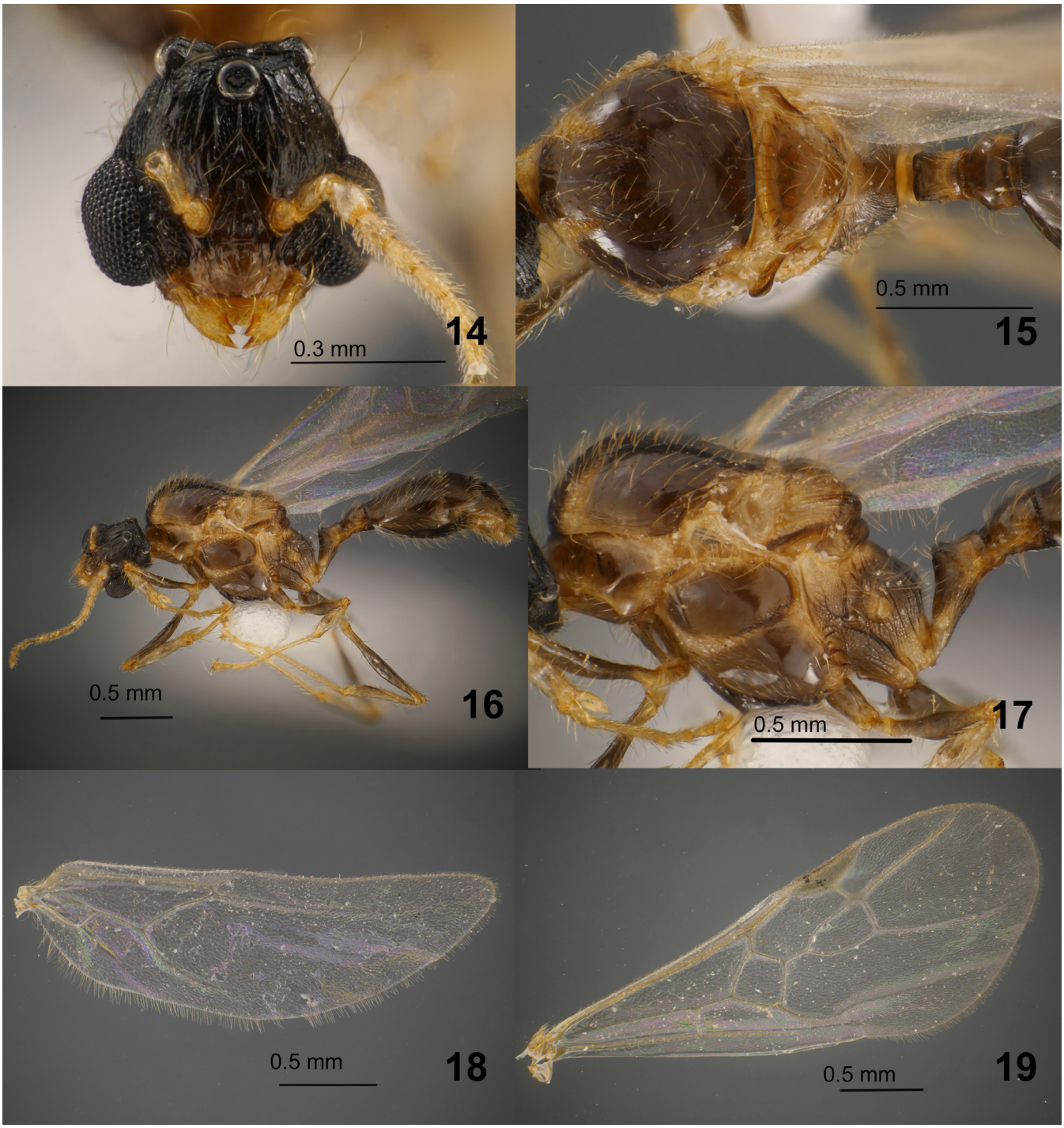
katepisternum by mesopleural sulcus which runs obliquely and is strongly scrobiculate; anepisternum smooth and shining in anterior half, largely rugoso-reticulate in posterior half; katepisternum largely smooth and shining in upper half, longitudinally rugose in lower half. Metapleuron irregularly rugoso-reticulate, strongly longitudinally rugose in lower half. Propodeum with lateral face rugoso-reticulate, and posterior slope weakly rugulose and shining; propodeal spine acute triangular with pointed apex, directed dorsoposteriorly. Ventral surfaces of mid- and hind- coxae smooth and shining.

Petiole longer than postpetiole excluding helcium; anterior slope in lateral view longer than posterior slope and broadly concave; ventral face of petiole with conspicuous undulating longitudinal carina; petiolar node in lateral view subtriangular and blunt at apex; apex in posterior view medially with a deep emargination, with dorsal and lateral margins carinate. Postpetiole in dorsal view as in the major; anteroventral part of postpetiole strongly developed, forming a robust transverse ridge which is subtriangular in lateral view.

Base of gastral tergite I largely rugulose with microreticulate ground sculpture; gastral tergites II and III superficially alveolate-reticulate, interspaces shining.

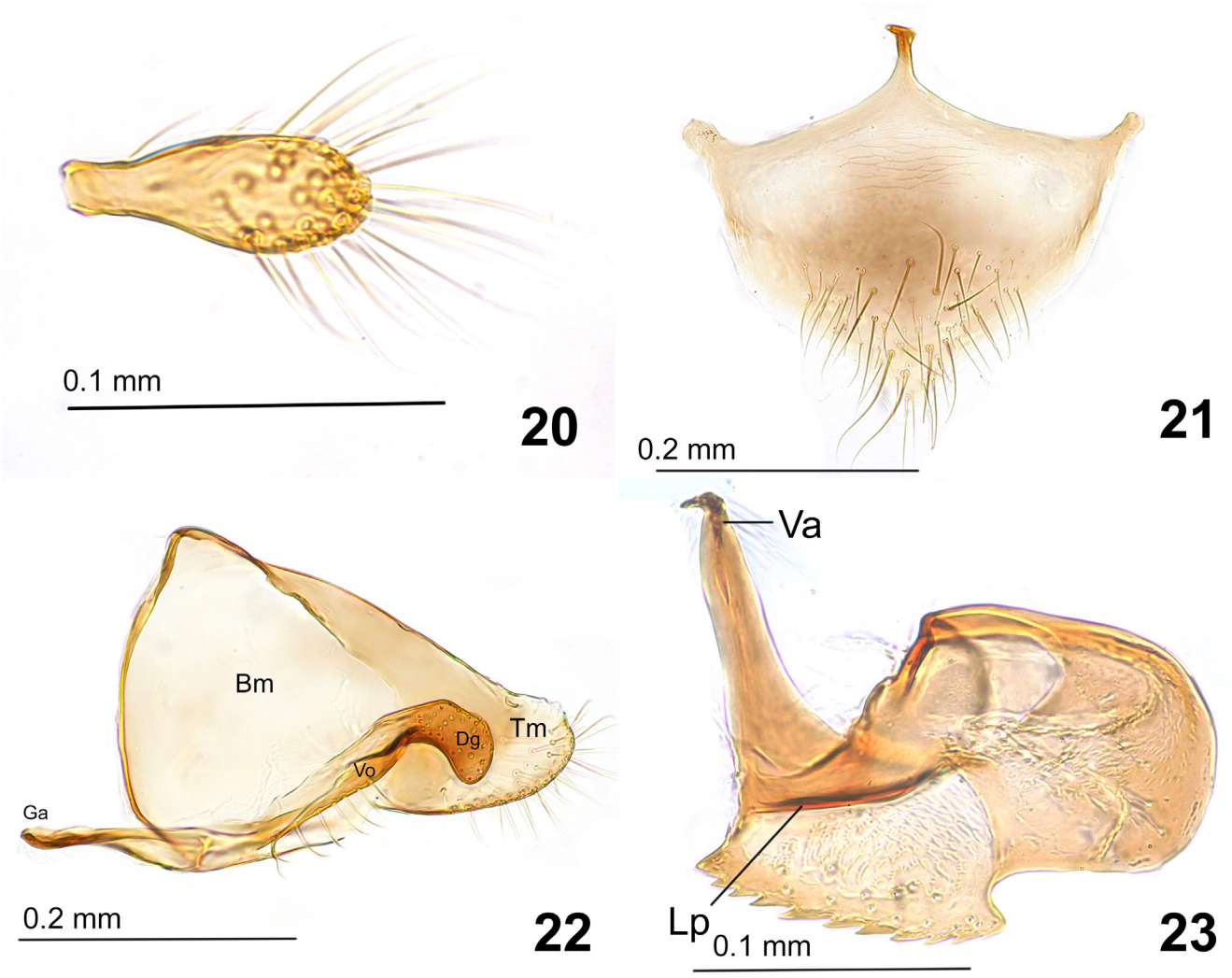
Non-type queens (alates, n = 2): HL 1.02–1.06 mm; HW 1.06–1.1 mm; OL 0.08–0.09 mm; SL 0.54–0.56 mm; ML 1.42–1.44 mm; MSW 0.92 mm; HFL 0.76–0.82 mm; PtL 0.4–0.42 mm; PtW 0.32–0.34 mm; PPtL 0.26 mm; PPtW 0.56–0.58 mm; CI, 104; SI, 49–53; MI, 154–157; HFI, 72–75; PtI1, 154–162; PtI2, 57–59.

Male (Figs. 14–19; genitalia: Figs. 20–23): Head almost entirely opaque black; mesosoma, petiole, gaster, coxae, femora generally uniform dark grey-brown; mandible, antenna, tarsus and joints of legs and margins of mesosomal sclerites yellowish brown; anterior halves of notauli pale whitish brown. Body covered with abundant yellowish standing hairs of variable length; anterior half of katepisternum with sparse decumbent and suberect hairs; hairs longer and more yellowish dorsally than ventrally.



Figs. 14–19. *Pheidole sexspinosa*, non-type male (ZRC_ENT00007290, Singapore, Mandai mangroves). 14, Head in full-face view; 15, mesosoma and waist in dorsal view; 16, body in lateral view; 17, closeup of mesosoma and waist segments in lateral view; 18, hind wing in lateral view; 19, forewing in lateral view.

Head in full-face view sub-oval, with posterior margin weakly concave medially, in lateral view broadly convex on the vertex; occipital carina well-developed; gena coarsely rugulose, with interspaces densely punctate and weakly shining; frons (area under median ocellus) with 2–3 median longitudinal carina extending from base of median ocellus; area between lateral ocelli densely rugulose-reticulate, with interspaces dully shining, overlain by coarse transverse carinae; the remainder of the dorsum of head capsule less coarsely rugulose, with interspaces punctate and shiny. Antennal scrobe absent. Dorsal outline of clypeus in lateral view convex; median portion of clypeus very weakly rugulose and shining; anterior clypeal margin broadly and weakly convex. Mandible subtrapezoidal with distinct basal and masticatory margins; masticatory margin with large apical and preapical teeth which are followed by a diastema, and then 1–2 minute and indistinct denticles just before the basal angle; outer surface of mandible weakly rugulose-punctate and shining. Palp formula of (2, 3). Antenna 13-segmented; scape relatively long, about twice as long as segment III; segment II ovoid in shape, wider than segments III to XIII at its maximum diameter.



Figs. 20–23. Genitalia of *Pheidole sexspinosa* male, non-type (ZRC_ENT00007290, Singapore, Mandai mangroves). 20, Pygostyle in dorsal view; 21, abdominal sternite IX in ventral view; 22, paramere and volsella, right side, inner view; 23, penisvalva, left side, outer view. Abbreviations: Bm = basimere; Cs = cuspis; Dg = digitus; Ga = gonostipital arm; Lp = lateral apodeme of penisvalva; Tm = telomere; Va = valvura; Vo = volsella.

Mesosoma in lateral view with mesoscutum highly raised, with ventral margin of mesopleuron broadly and roundly convex. Mesoscutum largely smooth and shining, with a short and weak anteromedian longitudinal carina; notaulus distinct and overlain with transverse rugae; parapsidal line very weak and indistinct; area close to parascutellar carina longitudinally carinate; scuto-scutellar suture deep and broad, strongly scrobiculate; mesoscutellar disc largely smooth and shining. Mesopleuron mostly smooth and shining; mesopleural suture oblique, strongly scrobiculate; propodeal junction in lateral view weakly and broadly convex; propodeum largely rugulose-reticulate and shining, overlain with longitudinal carinae.

Petiole much longer than postpetiole excluding helcium, in lateral view with weakly concave anterior and posterior slopes of which the former is much longer than the latter; dorso- and ventro- lateral faces of petiole longitudinally rugose and weakly shining. Petiolar node in lateral view low and subtriangular, with blunt apex, in dorsal view broadly convex anteriorly and weakly concave posteriorly, in posterior view subquadrate, with angulate dorsolateral corners, with dorsal margin almost straight but forming a very weak median depression. Postpetiole in dorsal view slightly wider than long, rounded in shape, with lateral margin expanded and forming a weak protuberance, largely smooth and shining, in lateral view with dorsal margin broadly and weakly convex.

Gaster mostly smooth and shining, covered with abundant long erect and suberect hairs.

Pygostyle digitiform, with abundant long setae on more than half of its apical area (Fig. 20). Abdominal sternite IX subpentagonal in outline, wider than long; spiculum (anterior apophysis of sternite IX) relatively long and narrow (Fig. 21); anterior margins of sternite meeting at an obtuse angle basal to the spiculum; anterolateral sternal corners strongly produced as digitiform extensions; lateral margins weakly convex, converging posteriorly; posteromedian part weakly produced as a blunt point, ventrally with numerous long setae (Fig. 21). Gonostipital arm well-developed; the outline of basimere + telomere in lateral view distinctly longer than broad and elongate-triangular, with a round apex of telomere bearing numerous long setae on the outer surface; ventral

ridge of volsella with ca. 10 setae (Fig. 22); cuspis in lateral view almost absent (Fig. 22); digitus in lateral view bluntly-pointed and weakly hooked ventrad; short and granular setae scattered on entire surface of digitus. Valviceps in lateral view divided into posterior and ventral lobes by a distinct ventral emargination; ventral margin of the ventral lobe weakly convex, with 11–12 denticles; posterior lobe roundly convex, not hooked (Fig. 23).

Non-type males (n = 2): HL 0.46–0.48 mm; HW 0.44–0.46 mm; OL 0.09 mm; OED 0.16 mm; SL 0.12 mm; ML 1.16–1.34 mm; MSW 0.72–0.76 mm; HFL 0.74 mm; PtL 0.32 mm; PtW 0.16 mm; PPtL 0.20–0.22 mm; PPtW 0.24–0.26 mm; CI, 96; SI, 26–27; MI, 161–163; HFI, 161–164; PtI1, 145–160; PtI2, 62–67.

Distribution. *Pheidole sexspinosa* can be found throughout the Oceanian realm sensu Holt et al. (2013), including, New Guinea, and the Solomon, Palau, Caroline, Fiji, Samoa, Tuvalu, Austral, Society and Marquesas Islands (antmaps.org, accessed on 24 October 2018; Guénard et al., 2017). The only record in Fiji is for a single worker (AntWeb v7.53, CASENT0194651) – this might indicate an incipient or transient occurrence of the species (Sarnat & Economo, 2012). It has also been recorded once in New Zealand as an exotic human-introduced species (Ward et al., 2006). With its discovery from Singapore in this paper, the distribution range of this species can thus be expanded to include the Oriental realm as well (Fig. 1).

Bionomics. In Singapore, this species has been found in mangrove back forest or swamp forest. Colonies were found nesting inside a decayed stem of *Rhizophora* sp. and cable roots of *Excoecaria agallocha*. The latter is a common mangrove tree species in Singapore, and secretes milky latex, which is toxic to animals including insects (Mendhulkar et al., 2017).

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