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A preliminary checklist of the ant genera of Pulau Ubin, Singapore, from rapid opportunistic sampling (Hymenoptera: Formicidae)

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Abstract. A preliminary checklist is provided for the ant genera of Pulau Ubin, the second largest offshore island of Singapore. Thirty-five genera representing seven subfamilies were collected on the island using rapid opportunistic hand sampling. This unexpected diversity on an island may reflect the high ant diversity in the tropics in general. The samples comprised both tramp and native species associated with the island's habitat matrix of urban vegetation and secondary forest. Four native ant genera (*Buniapone*, *Liomyrmex*, *Myopopone*, and *Proceratium*) rarely collected on Singapore Island and with scarce collections globally were found on Pulau Ubin. This indicates that secondary forests on offshore islands can support rare ant fauna.

Key words. ant, diversity, island, Singapore, Pulau Ubin

INTRODUCTION

Ants (Hymenoptera: Formicidae) are a speciose and morphologically diverse group of insects with 15,217 valid species and subspecies, classified into 334 genera and 17 subfamilies (Bolton, 2016). The ubiquity of ants and the many ecosystem functions they support, such as bioturbation and insect predation (Philpott & Armbrecht, 2006; Del Toro et al., 2012), make them important components of the many habitats in which they occur.

On the global scale, ant diversity has been shown to decrease with increasing latitude (Guénard, 2013), making equatorial Singapore a potential hotspot for ants. This is further supported by records of high ant diversity in surrounding regions, e.g., Sumatra, 547 species; Java, 446 species; Thailand, 423 species (Janicki et al., 2016); and Borneo, 711 species (Pfeiffer, 2011). However, there is a dearth of published research on ants in Singapore in general; the only and last extensive collection was made by Hans Friedrich Overbeck prior to 1913, cumulating in Viehmeyer (1916) and Overbeck (1924) (AntWiki, 2013). Although the country's landscape has been largely urbanised (Brook et al., 2003), remnant old-growth forests in several nature reserves and even disturbed patches of vegetation may still harbour speciose native ant assemblages.

Despite an overall lack of consistent long-term sampling efforts in Singapore, new ant species continue to be discovered in this miniature metropolis. For example, a colony of the rarely collected *Tyrannomyrmex rex* was recently discovered near the Central Catchment Nature Reserve (Wong & Yong, 2017), and a new species of the rare hypogaeic ant genus *Leptanilla* was described from a similar locality (Wong & Guénard, 2016a). Furthermore, another new species, *Myrmecina magnificens*, was also recently discovered and reported to occur in considerable densities at the CCNR (Wong & Guénard, 2016b). The recent spate of new species discoveries highlight the fact that very little is known about ant diversity of Singapore's forests.

With an approximate area of 1,000 hectares, Pulau Ubin is the second largest offshore island in Singapore (Cornelius-Takahama, 2004). The shortest distances of Pulau Ubin from Singapore Island and Johor, Peninsular Malaysia are 1.2 km and 560 m, respectively (Google Earth, 2016). Pulau Ubin was previously a granite quarry in the early 20th century (Cornelius-Takahama, 2004) and is now predominantly secondary forest. To date, there has been no inventory published for the ant fauna in Pulau Ubin. In 2016, the 'Ubin BioBlitz', an initiative by the National Parks Board, permitted a rapid preliminary census of the ant communities on the island within a single morning. Based on the findings of the 'Ubin BioBlitz' as well as a recent prior instance of opportunistic hand sampling on Pulau Ubin, this paper aims to highlight the considerable diversity of ants found with limited sampling on this offshore island. It is also the first report on Pulau Ubin's ant fauna. While this preliminary report only identifies the ants to generic level, it is still notable owing to the sheer diversity and rarity of some of the genera encountered.

MATERIAL & METHODS

Sampling locality and dates. Ants were sampled from multiple sites in Pulau Ubin on two separate occasions in 2016 (Fig. 1). On 15 October 2016 between 0900–1300 hours, the secondary forest at Jalan Ubin (JU) and Jalan Sam Heng (JS) were sampled; only individuals found in nesting colonies were collected, so as to meet the aims of an unrelated study (P. Escoubas, pers. comm.). On 4 December 2016 between 0800–1100 hours, three additional sites were sampled: the urban Assembly Area (AA), a garden on Butterfly Hill (BH), and a secondary forest in the Outward Bound School's premises (OB). As part of the National Parks Board's 'Ubin BioBlitz' event, all ants encountered were collected. Sampling details are summarised in Table 1.

Sampling method. All of the ants incorporated into the present generic list (see Appendix) were collected via opportunistic hand sampling on the two dates described above, with the exception of an *Echinopla* specimen collected by Zestin Soh at Chek Jawa in 2016. Opportunistic hand sampling refers to manually searching all locations that are accessible to a person walking through a site, and using a pair of hand-held forceps to retrieve any ants encountered into tubes containing 70% ethanol (v/v). One tube was used per site per collector. In forested areas, this included lifting and dismantling small rotting logs on the forest floor, as well as displacing leaf-litter to search for ants on the exposed soil surface.

Identification and repository. Sampled specimens of each tube were sorted to morphospecies. Then, one individual of each morphospecies from every sampling tube was mounted and examined using a Leica MZ16 stereomicroscope. All mounted specimens were identified to genus using the Southeast Asian taxonomic keys (Eguchi et al., 2011, 2014). These were subsequently sorted to final morphospecies. Selected genera were imaged with Dun Inc™ Passport II macrophotography imaging system using a Canon MP-E 65 mm lens. A synoptic and representative collection was deposited in the Zoological Reference Collection (ZRC) of the Lee Kong Chian Natural History Museum at the National University of Singapore.

Table 1. Breakdown of sampling effort by opportunistic hand sampling at five sites of varying habitat in Pulau Ubin.

Site	Habitat	Duration (H)	N Personnel	Effort (Man-Hours)
Assembly Area (AA)	Urban	0.5	1	0.5
Butterfly Hill (BH)	Managed garden	0.5	2	1
Jalan Ubin (JU)	Secondary forest	1	2	2
Jalan Sam Heng (JS)	Secondary forest	1	2	2
OBS Grounds (OB)	Secondary forest	2	2	4
			Total	9.5

Fig. 1 Sampling sites. AA = Assembly Area, BH = Butterfly Hill, JU = Jalan Ubin, JS = Jalan Sam Heng, OB = Outward Bound Singapore. Source: © OpenStreetMap contributors.

Reference material used for identification. A preliminary generic checklist largely based on data sampled from Pulau Ubin was compiled to which we referenced to existing Singaporean records (see Appendix). These records were obtained from 1) authoritative catalogues, i.e., Bolton (2007) of all ants and Chapman & Capco (1951) of Asian ants; 2) more recent specimens uploaded on Ant Web and consolidated on the Singapore page (Antweb, 2016a), including records from other published material (Taylor, 1968; Moffet, 1986; Rigato & Bolton, 2001; Davison et al., 2008; Tan, 2010; Jacqueminn et al., 2015; Wong & Guénard, 2016a, b; Williams & La Polla, 2016); and 3) personal observations from prior ant surveys by EJYS of which samples are now based at the ZRC.

RESULTS & DISCUSSION

High diversity. In total, 36 genera were sampled on Pulau Ubin (see Appendix). Of these, 35 genera were sampled within a total of 9.5 man-hours across two sampling dates, each involving two persons (see Table 1). The generic diversity recorded at Pulau Ubin represents almost half of the genera known from Singapore (84 genera, with at least 235 species). Pulau Ubin is a non-pristine, secondary forest habitat on an offshore island roughly 1.6% the area of mainland Singapore (Turner & Tan, 1991). The high generic diversity of ants observed on Pulau Ubin suggests a high diversity of Singapore ants in general, indicating strong potential for more species waiting to be discovered. This can be compared to just 17 species and 13 genera found on tropical Santa Cruz Island, Galápagos (98,600 ha) using baited traps and similar hand collection methods (Clark et al., 1982) as well as 27 species and 15 genera collected using leaf litter sifting at the Yasawa islands in Fiji (Ward & Beggs, 2007).

The high diversity of ants may be attributed to the high diversity of habitats of the island. The surveys were conducted in open habitats of urban and managed greenery (BH, AA) as well as the secondary forest (JS, JU, OB). Thus, both urban-adapted tramp species (e.g., *Anoplolepis gracilipes*, *Paratrechina longicornis*, *Tapinoma melanocephalum*) (Silverman, 2005) and forest-associated genera (e.g., *Myopopone*, *Proceratium*, *Strumigenys*) were collected (see Appendix). Although sampling at Pulau Ubin's mangrove and coastal areas would have likely yielded additional species, these have yet to be surveyed.

Uncommon genera. Four ant genera (discussed below) collected by hand from the brief opportunistic sampling in Pulau Ubin were seldom encountered in previous systematic sampling efforts, involving a variety of methods such as hand collection, leaf litter sampling, and pitfall traps, by the authors on Singapore Island (Yong, G. W. J., Wong, M. K. L., and Soh, E. J. Y., unpublished data). This is potentially owing to their patchy distribution and small colony sizes. The scarcity of collections for these ants may impede revisionary taxonomic work that includes molecular data. Short generic accounts on the biology and local records of the four uncommon genera are given below with accompanying images.

Subfamily Amblyoponinae

Myopopone Roger, 1861 (Fig. 2)

Myopopone is a monotypic genus with only one species, *Myopopone castanea* Smith, 1860. Previous local records of *Myopopone castanea* include individuals collected from Bukit Timah on Singapore Island in 1968 by D. H. Murphy under a rotten log, based on specimens deposited at the Australian National Insect Collection (ANIC) (AntWeb, 2016b). At a secondary forest in Pulau Ubin, a partial colony (workers and larvae) was found in a rotting log with abundant Scarabaeidae beetle larva, which is consistent with the known nesting habits and specific prey of this species (Ito, 2010). Like other amblyoponine ants, *Myopopone castanea* workers are also known to feed off the haemolymph of their own larvae (Ito, 2010).

Subfamily Myrmicinae

Liomyrmex Mayr, 1865 (Fig. 3)

The species collected at Pulau Ubin is identified as *Liomyrmex gestroi* (Emery, 1887), which is the sole species in this monotypic genus. *Liomyrmex gestroi* is rarely collected in its natural range (Oriental and Indo-Australia regions), as well as in Singapore. The only known local record for this species was by S. K. Yamane without a collection date cited in the paper (Rigato & Bolton, 2001). This ant, typically found under rotting wood, is reported to be associated with termites (Wheeler & Morton, 1914). At Pulau Ubin, *Liomyrmex gestroi* was found nesting in a dead log that was shared by termites, concurring with previous observations. However, the nature of the interspecific relationship between *Liomyrmex gestroi* and termites remains unknown (Rigato & Bolton, 2001).

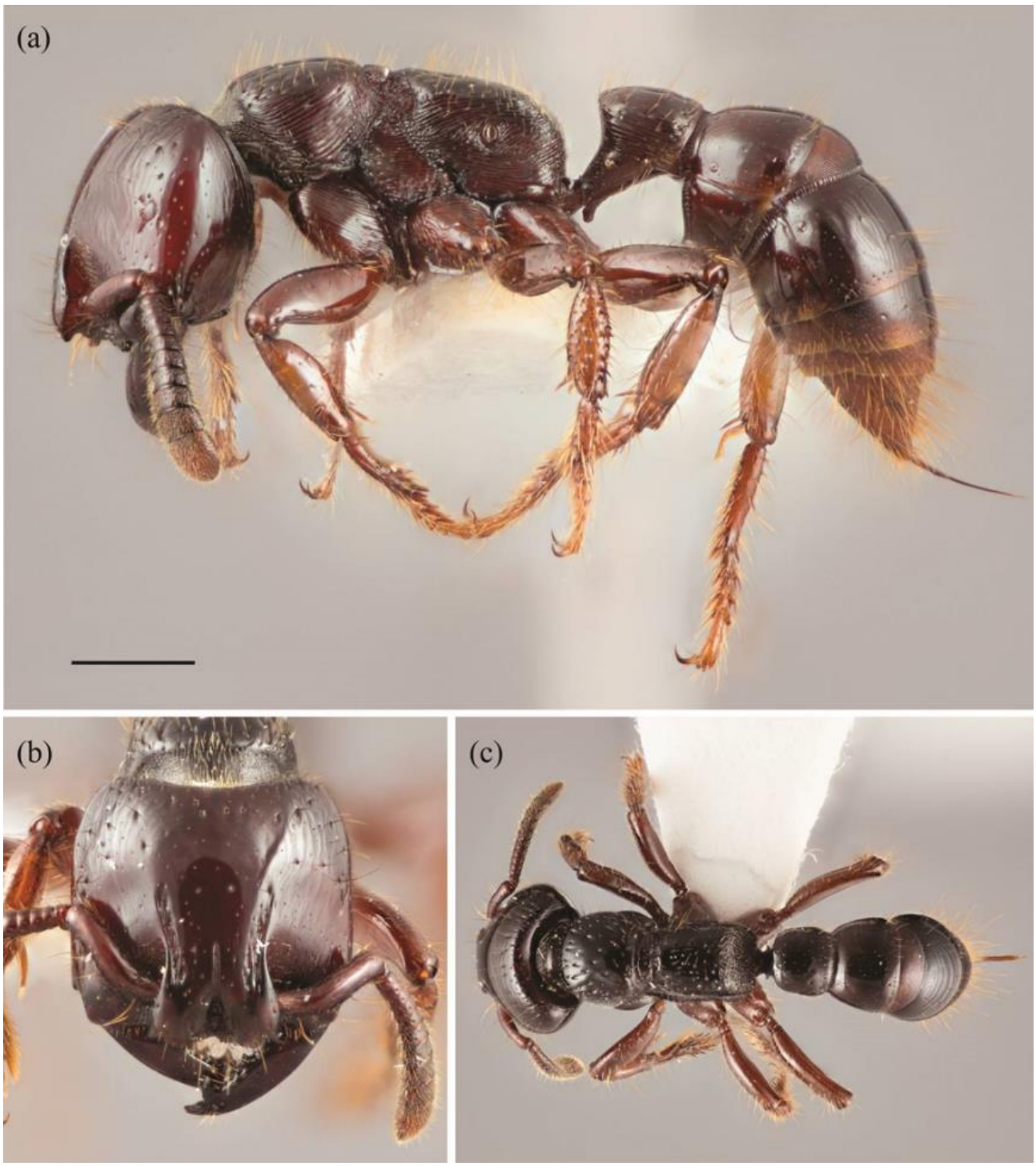

Fig. 2. *Myopopone castanea*. (a) lateral, (b) full-face, and (c) dorsal. Scale bar = 1 mm.

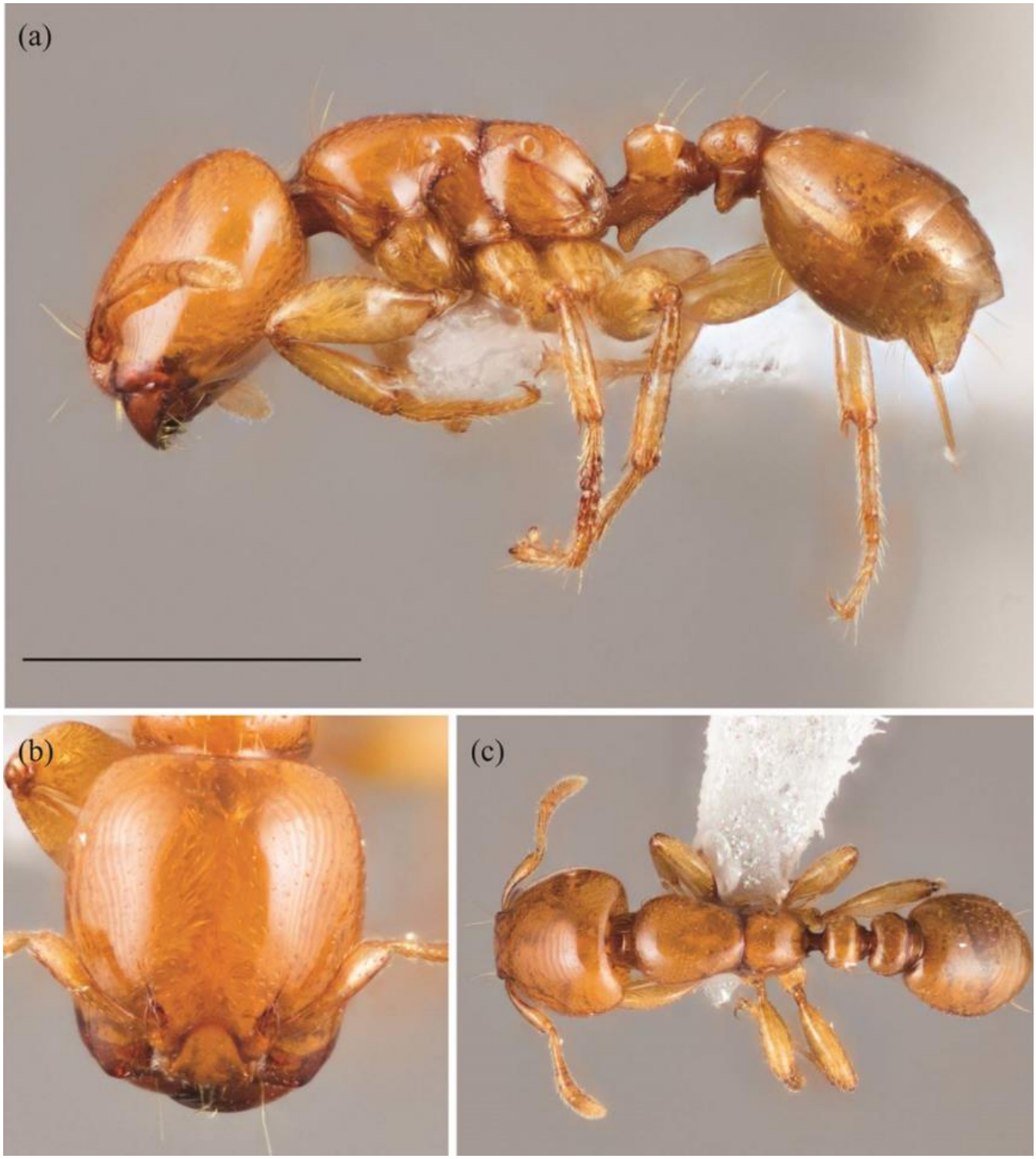

Fig. 3. *Liomyrmex gestroi*. (a) lateral, (b) full-face, and (c) dorsal. Scale bar = 1 mm.

Fig. 4. *Buniapone amblyops*. (a) lateral, (b) full-face, and (c) dorsal. Scale bar = 1 mm.

Fig. 5. *Proceratium* sp. (a) lateral, (b) full-face, and (c) dorsal. Scale bar = 1 mm.

Subfamily Ponerinae

Buniapone Schmidt & Shattuck, 2014 (Fig. 4)

The species collected at Pulau Ubin is identified as *Buniapone amblyops* Emery, 1887, which is the sole species in the monotypic genus *Buniapone.* These ants are restricted to Southern and Southeast Asia. *Buniapone* ants are predominantly hypogaeic, and in Singapore *B. amblyops* was last collected in 1967 by D. H. Murphy under stones at Bukit Timah, based on a specimen at the ANIC (Ant Web, 2016c). The single worker specimen from Pulau Ubin was also found in soil below a resting stone at the OB site. Little is known about the biology of this genus.

Subfamily Proceratiinae

Proceratium Roger, 1863 (Fig. 5)

The individual collected at Pulau Ubin is a female gyne collected from rotting wood at the OB site. *Proceratium* ants are considered to be rarely collected, although they are a diverse (> 70 described species), cosmopolitan genus found in both tropical and temperate regions (Baroni Urbani & de Andrade, 2003). They nest in rotten wood or soil, have relatively small colonies of up to 200 individuals (Baroni Urbani & de Andrade, 2003) and are likely to be specialist predators of spider eggs (Brown, 1980). While the genus has been revised (see Baroni Urbani & de Andrade, 2003), determination of species for the specimen collected is not straightforward as the taxonomic key is based on the worker caste. However, descriptions and available Antweb images of *Proceratium deelemani*, which was previously recorded in Singapore, do not match the specimen we collected from Pulau Ubin.

The microhabitat and life history of the four uncommon genera found at Pulau Ubin corroborates with observations recorded by past collectors such as D. H. Murphy in the late 1960s. Most of these ants are associated with soil, leaf litter or rotting wood; a lack of comprehensive sampling in these microhabitats may explain the apparent scarcity of collection records for these genera. Furthermore, the ants' association with these specific microhabitats suggests that they require relatively undisturbed forest, where loose soil, humus layers, and dead woody debris are allowed to accumulate. Our results show that fragments of secondary forest may still be a refuge for uncommon ants when such attributes are present.

CONCLUSIONS

Given the sheer diversity of ants in Singapore, it is envisaged that more resources, sampling and taxonomic expertise will be required in order to systematically document the country's native ant assemblages. In addition, conservation strategies should incorporate safeguards for secondary forests due to their potential for supporting uncommon and understudied invertebrate faunas.

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APPENDIX

A list of ant genera recorded from Singapore and Pulau Ubin, based on material from published catalogues, papers and collections.

The respective abbreviations refer to:

- Under 'Singapore', representing number of species obtained from: B—Bolton (2005); C—Chapman & Capco (1951); O—Other references, as cited in the next column 'Reference'; N—number of species from literature records (first three columns); A— AntWeb records; N+ —number of species from literature records and AntWeb.
- Under 'Pulau Ubin', with × representing the localities to which the ants were found: JS—Jalan Sam Heng (15 October 2016); JU—Jalan Ubin (15 October 2016); AA—Assembly Area (4 December 2016); BH—Butterfly Hill (4 December 2016); OB—Outward Bound Singapore (5 December 2016); N—total number of species from the two sampling events; O—number of species from other recent records at Pulau Ubin.

	Singapore							Pulau Ubin						
Genus	**B**	**C**	**O[1]**	**Reference**	**N**	**A**	**N+**	**JS**	**JU**	**AA**	**BH**	**OB**	**N**	**O[2]**
Subfamily Amblyoponinae														
Myopopone						1	1					×	1	
Mystrium						1	1							
Stigmatomma					1	2	2							
Subfamily Dolichoderinae														
Dolichoderus	2				2	5	5	×			×	×	2	
Iridomyrmex						1	1							
Philidris	1				1		1					×	1	
Tapinoma	2	1			2	2	2			×	×		1	
Technomyrmex	3				5	6	7							
Subfamily Dorylinae														
Cerapachys	2	2			2	2	2							
Simopone	1	1			1	1	1							
Subfamily Ectatomminae														
Gnamptogenys	3				3	4	4							
Subfamily Formicinae														
Acropyga	2				2	2	2							
Anoplolepis	1				1	1	1				×	×	1	
Camponotus	12	13			17	19	22				×	×	2	
Colobopsis	4	4			4	1	4					×	2	
Dinomyrmex	1	1			1		1							
Echinopla	1	2			2	2	2							Z(1)
Euprenolepis			*											
Lepisiota	1	1			1	1	1							
Myrmoteras					1	2	2							
Nylanderia						1	1			×		×	2	
Oecophylla					1	1	1				×	×	1	
Overbeckia	1				1	1	1							
Paraparatrechina	1	1			1		1					×	1	
Paratrechina			1	Tan, 2010	1	1	1			×			1	
Plagiolepis			*											
Polyrhachis	12	25			27	19	31					×	2	
Prenolepis			1	Williams & LaPolla, 2016	1		1							
Pseudolasius	3	3			3	3	3							
Subfamily Leptanillinae														
Leptanilla	1	1	1	Wong & Guenard, 2016a	2	1	2							
Protanilla	1				1	1	1							

	Singapore												Pulau Ubin	
Genus	**B**	**C**	**O[1]**	**Reference**	**N**	**A**	**N+**	**JS**	**JU**	**AA**	**BH**	**OB**	**N**	**O[2]**
Subfamily Amblyoponinae														
Subfamily Myrmicinae														
Aphaenogaster			*											
Calyptomyrmex	1	1			1	1	1							
Cardiocondyla	1	1			1	1	1							
Carebara[3]	4	1	3	Tan, 2010	5	2	2	×				×	2	
Cataulacus	1	2			3	4	4							
Crematogaster	9	4	2	Hoisoishi & Ogata, 2009	11	12	14	×			×	×	4	
Dilobocondyla	1	1			1	1	1							
Eurhopalothrix	1					1	1							
Liomyrmex			1	Rigato & Bolton, 2001	1		1					×	1	
Mayriella	1				1	1	1							
Meranoplus	1	1			2	1	2			×			1	
Monomorium	4	3			5	5	6					×		
Myrmecina			1	Wong & Guenard, 2016b	1		1							
Myrmicaria					1	2	1					×	1	
Paratopula					1		1							
Pheidole	4	5	6	Tan, 2010	12	7	15	×		×	×	×	5	
Pristomyrmex	3				3	3	3					×	1	
Proatta			1	Moffet, 1986	1	1	1		×			×	1	
Rhopalomastix	1				1	2	1							
Rostromyrmex						1	1							
Rotastruma					1	1	1							
Solenopsis	1	1			1	1	1							
Strumigenys	10		1	Taylor, 1968	10	10	10					×	1	
Syllophopsis						1	1							
Tetramorium	3	4	1	Tan, 2010	5	4	6	×		×	×	×	4	
Trichomyrmex						1	1							
Tyrannomyrmex			1	Jacquemin et al., 2015	1		1							
Vollenhovia	1	2			2	2	2				×	×	2	
Subfamily Ponerinae														
Anochetus	1	1			1	5	5				×		1	
Bothroponera						1	1							
Brachyponera												×	1	
Buniapone		1			1	1	1					×	1	
Centromyrmex	1				1	1	1							
Cryptopone						1	1							
Diacamma	2	1			3	1	3	×				×	2	
Ectomomyrmex	1	2			2	1	2	×					1	
Euponera	1	1			1	1	1							
Harpegnathos			1	Davison et al., 2008	1		1							
Hypoponera	1	1			1	2	1	×				×	?	
Leptogenys		3			3	2	5					×	1	
Mesoponera	1	2			2	2	3	×						
Neoponera						1	1							
Odontomachus	1	1			1	2	2	×	×	×			2	
Odontoponera	1	1			1	2	2					×	1	
Parvaponera		1			1		1							
Platythyrea	1	2			2	1	2					×	1	
Pseudoneoponera	1	1			1	1	1							
Subfamily Proceratiinae														
Discothyrea			*			1	1							

	Singapore							Pulau Ubin					
Genus	**B**	**C**	**O[1]**	**Reference**	**N**	**A**	**N+**	**JS**	**JU**	**AA**	**BH**	**OB**	**N**	**O[2]**
Subfamily Amblyoponinae														
Probolomyrmex	1				1	1	2							
Proceratium	1				1	1	1					×	1	
Subfamily Pseudomyrmicinae														
Tetraponera	6	6			9	9	9	×					1	
84 genera				Total spp.	190	184	235						53	1
				Total genera	68	68	80						35	1

[1]* indicates that the specimen was obtained from prior ant collecting by ES and specimens are currently based at ZRC but not formally catalogued with the collection.
[2]numbers in brackets indicate the number of morphospecies; Z refers to a specimen contributed by Zestin Soh collected on 10 September 2016 at Chek Jawa.
[3]*Pheidologeton* is synonymised under *Carebara*.