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Preliminary Report on Unnoticed Establishment of *Pheidole parva* Mayr Complex (Insecta: Hymenoptera: Formicidae: Myrmicinae) in the Ogasawara Islands: a Potential Risk to Native Ground-dwelling Invertebrates

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Abstract. An unnoticed establishment of *Pheidole parva* complex (Hymenoptera: Formicidae) to Chichi-jima Island of the Ogasawara Islands, which were nominated as a UNESCO Natural World Heritage Site, was recognized in 2007. Furthermore, *P. megacephala*, a famous invasive ant species, has also been highly prevalent in Chichi-jima Island in recent years. Since the majority of *Pheidole* spp. are generalist foragers, *P. parva* complex may has a potential risk to native ground-dwelling invertebrates in natural/seminatural forests of the Ogasawara Islands. Therefore, we conducted a survey of ants' distribution as the basis for further foreseeable management. Current distribution and habitat preference of the two *Pheidole* species were surveyed in Chichi-jima, Ani-jima and Ototo-jima Islands of the Chichi-jima Island Group by Quadrat Sampling and Time-Unit sampling. *Pheidole parva* complex was widespread from the coastal area to the inland area in the three islands, and exhibited no clear habitat selection in the three islands. On the other hand, *P. megacephala* was absent in Ani-jima and Ototo-jima, but was frequently found in coastal lowland of Chichi-jima.

Key words: invasive, ant, Bonin islands, distribution

Introduction

Ants are dominant animal taxa in major terrestrial ecosystems, making up as much as 10% or more of the total animal biomass, and they play indispensable roles as keystone controllers of trophic webs and ecological engineers (Wilson, 2000). On the other hand, by accompanying with human activities, an increasing number of ant species have been introduced to regions and environments where they did not occur naturally; of the approximately 15,000 species of ants described from the world (Antwiki. org, 2018), 147 species have been recorded outside of their native distributional ranges (McGlynn, 1999). Some of them have been recognized as serious invasive species having negative impacts on natural ecosystems, and/or economic activities and public health (Lach & Hopper-Bùi, 2010). *Anoplolepis gracilipes*, *Linepithema humile*, *Pheidole megacephala*, *Solenopsis invicta* and *Wasmannia auropunctata* are most notorious invasive ant species, and included in the "100 of the worst invasive alien species" (Lowe et al., 2000). Furthermore, there are many alien species of which introductions and range expansions have been unnoticed or ignored (Heinze et al., 2006).

Pheidole parva Mayr complex sensu Eguchi et al. (2013) is one of ignored alien ant species. It has been increasingly recorded in various localities of the Indo-West Pacific region, and it has been occasionally found in green houses in European counties (Sarnat et al., 2015). It was collected in a variety of different habitats, from parks and gardens, to mangrove and coastal

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scrub, to degraded dry forest, littoral and mixed forest, and rainforest, in elevations between 1 and 445 m (Fischer & Fisher, 2013). Discoveries of living workers onboard two different marine vessels at Barrow Island off Western Australia's coast indicates that the range has been expanded at least partly through human commerce (Eguchi et al., 2013). Although its negative impacts on natural ecosystems are unknown, it is one of the major ant species which frequently invade healthcare facilities in Singapore (Man & Lee, 2012), and thus it has a potential to become a nuisance pest (Sarnat et al., 2015). Eguchi et al. (2007) recognized introduction of *P. parva* complex to Chichi-jima Island of the Ogasawara Islands and to Okinawa Island of the Ryukyus which occurred before 2000 and 2001, respectively. Since that time it has been rapidly spread across the Ryukyus (Terayama et al., 2009; Yamane et al., 2014; Harada et al., 2015). A similar situation is probably going on in the Ogasawara Islands which were nominated as a UNESCO Natural World Heritage Site in 2011.

The Ogasawara Islands have been isolated since their formation and consequently have an extremely high proportion of endemic species, e.g., ca. 40% of the plants overall, 70% of trees only, ca. 30% of the insects and more than 90% of the land snails being endemic (Kato, 1992; Tomiyama, 1992; Shimizu, 2003). Proper management of invasive species is, therefore, one of the basic requirements for the nomination in the Natural World Heritage List. As a part of our long-term monitoring and risk evaluation programs on alien ant species in the Ogasawara Islands, we conducted a survey of the current distributions of *P. parva* complex and *P. megacephala* in Chichi-jima, Ani-jima and Ototo-jima Islands of the Chichi-jima Island Group. The latter is one of the most famous invasive ant species as mentioned above, and has been highly prevalent in Chichi-jima Island in recent years (Uchida et al., 2016). A preliminary report is herein presented in order to notice a potential risk of the unnoticed establishment of *P. parva* complex to native ground-dwelling invertebrates.

Material and methods

The characteristics of the studied islands are summarized as below by referring to Ministry of the Environment et al. (2010) and Kanto Regional Environment Office of Japan et al. (2010, 2014). Chichi-jima Island (23.45 km^2; 326 m; hereafter referred to as Chichi-jima) is inhabited and is the largest island of the Ogasawara Islands, and has a variety of habitats. Dense sclerophyllous scrubs, distributed from the Higashidaira and Mt. Chuosan region to the Yoakedaira and Nagasaki region, are important habitat for various threatened endemic plants and animals, and are important for conservation of biodiversity on Chichi-jima. Ani-jima Island (area: 7.87 km^2; highest elevation: 254 m; hereafter referred to as Ani-jima) under a dry climatic condition supports the largest sclerophyllous scrub forest (mainly *Distylio lepidoti-Pouterietum dubiae* and *Machilo kobu-Schimetum mertensianae* communities) among the Ogasawara Islands, as well as rocky desert plant communities, and has many threatened endemic plants, insects including the tiger beetle *Cicindela bonina* and snails. Ototo-jima Island (5.2 km^2; 235 m; hereafter referred to as Ototo-jima) is characterized with a moderately humid climate and relatively rich soil if compared to the other islands of the Chichi-jima Island Group, and the central part of the island is widely covered with mesic forests dominated by *Schima mertensiana*. Ani-jima and Ototo-jima are now uninhabited, but Ototo-jima was relatively intensively settled in late 19th and early 20th. The level of human-induced disturbance is relatively low in Ani-jima. Marginal areas of the two islands are largely covered with invasive *Casuarina equisetifolia* forests.

By referring to aerial photographs and land cover maps (mentioned below) and taking account of reasonable coverage of major habitat types, accessibility to the sampling locations and minimization of disturbances to the conservation areas, quadrats and sampling sites were set, and then spatial distribution of *P. parva* complex and its congener *P. megacephala* was surveyed by the following manners. A total of 443 quadrats (1 m x 1 m) were set along coastal lines and inland trails in Ani-jima, 155 quadrats in Ototo-jima, and 209 quadrats in Chichi-jima (hereafter referred to as "Quadrat Sampling"). In each quadrat the coordinates and elevation were recorded by a handy GPS receiver, and the habitat condition was briefly recorded. The target ant species were visually searched and collected within 2 subquadrats (0.3 m x 0.3 m) set in each quadrat. This "Quadrat Sampling" was conducted by T. Matsumoto from 18th to 21st June 2015, from 7th to 9th July 2015, from 9th to 16th September 2015, from 30th October to 3rd November 2015, from 3rd to 10th December 2015, and from 8th to 14th January 2016. Furthermore, a total of 86 sampling sites were set along roads and trails, and coastal lines in Chichi-jima. In each sampling site the coordinates and elevation were recorded by a handy GPS receiver, and then ant species (but not individuals) were collected as many as possible on the ground and lower vegetation up to approximately 1.5 m, within approximately 5m-radius from the GPS point, for ten minutes. This "Time-Unit Sampling" was conducted by H. Kobayashi or A. Yamamoto in Chichi-jima from 26th October to 10th November 2015, from 10th to 25th May 2016, from 18th to 27th August 2016, and from 27th October to 19th November 2016; the sampling was repeated in each sampling sites two to five times.

Ants were identified by referring to Terayama et al. (2014). Parts of the specimens identified as *Pheidole parva* complex and *Pheidole megacephala* were reexamined by Katsuyuki Eguchi, who is a taxonomist of Asian *Pheidole*, for confirming the identification. Voucher collection of the present study will be deposited in the collection of the Systematic Zoology Laboratory, Tokyo Metropolitan University.

Land cover map was obtained from the Ogasawara Islands Nature Information Center of the Ministry of the Environment, Japan (http://ogasawara-info.jp/specialist/gis/map_default.phtml; http://ogasawara-info.jp/pdf/isan/shokuseizu.pdf). Land cover types in the map are merged into three habitat types: natural/seminatural forest (the type I.1 in the map); disturbed forest (I.2, I.3 and I.4); open land (II and III). The most dominant habitat type within approximately 20m-radius from the GPS point was regarded as the habitat type of each of the quadrats or sampling sites. (Table 1)

Results and Discussions

Pheidole parva complex was found from 40 of 209 quadrats and 44 of 86 sampling sites in Chichi-jima, and from 130 of 443 quadrates in Ani-jima, from 60 of 155 quadrates in Ototo-jima. It was widespread from the coastal area to the inland area in the three islands (Figs. 1–3), and exhibited no clear habitat selection in the three islands, (Fig. 4; Table 1). On the other hand, *P. megacephala* was not found in Ani-jima and Ototo-jima, but found from 15 of 209 quadrats and 27 of 86 sampling sites in Chichi-jima (Figs. 1, 2). It was frequent in coastal lowland, and in open land and disturbed forest (Fig. 3; Table 1). The two *Pheidole* species coexisted only 2 of 209 quadrats and 2 of 86 sampling sites in Chichi-jima.

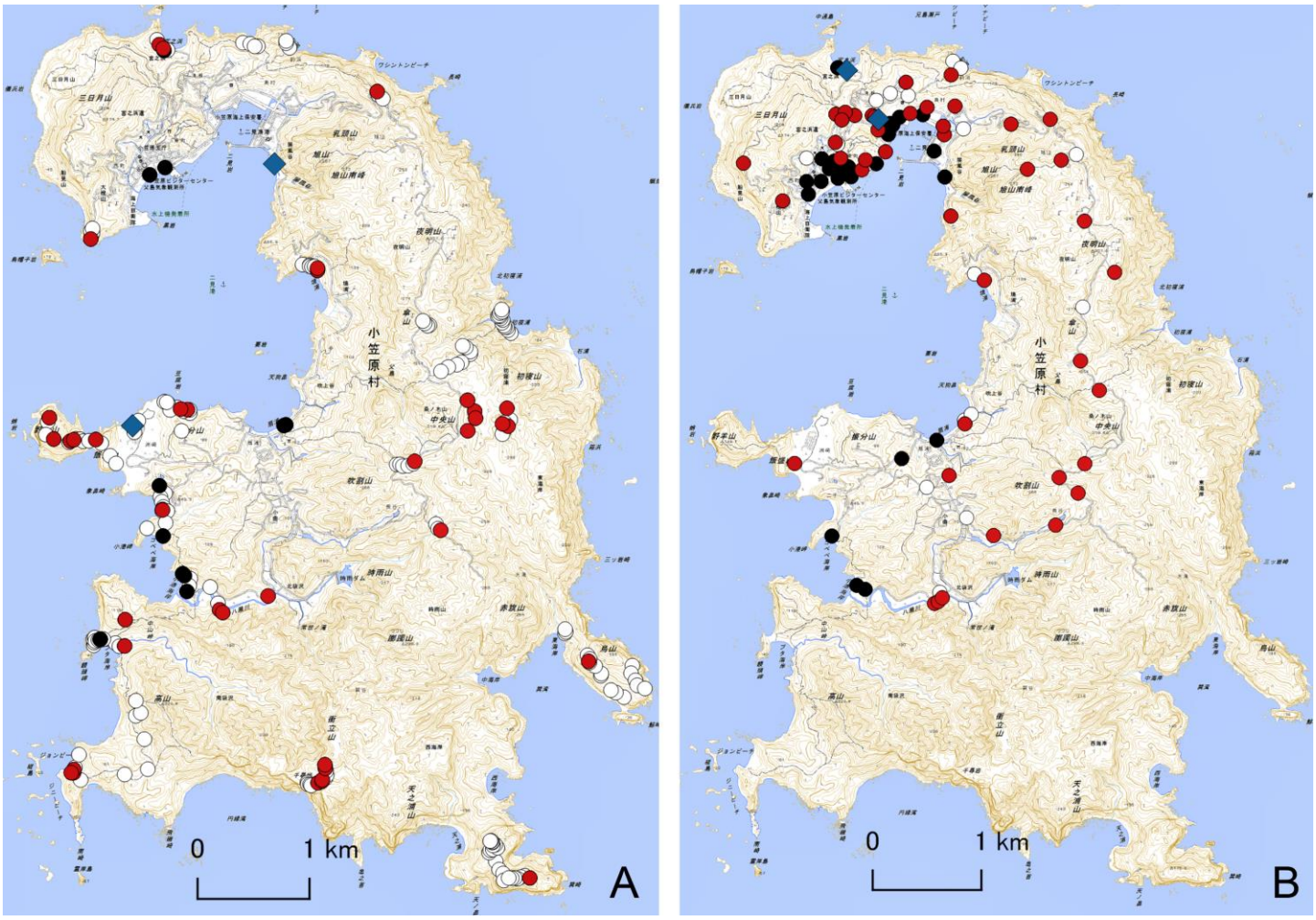

Figure 1. Distribution of *Pheidole parva* complex and *P. megacephala* in Chichi-jima based on Quadrat Sampling (A) and Time-Unit sampling (B) datasets. Red circle: presence of *P. parva* complex; black circle: presence of *P. megacephala*; blue diamond: presence of both the two *Pheidole* species; white cercle: absence of both the two *Pheidole* species.

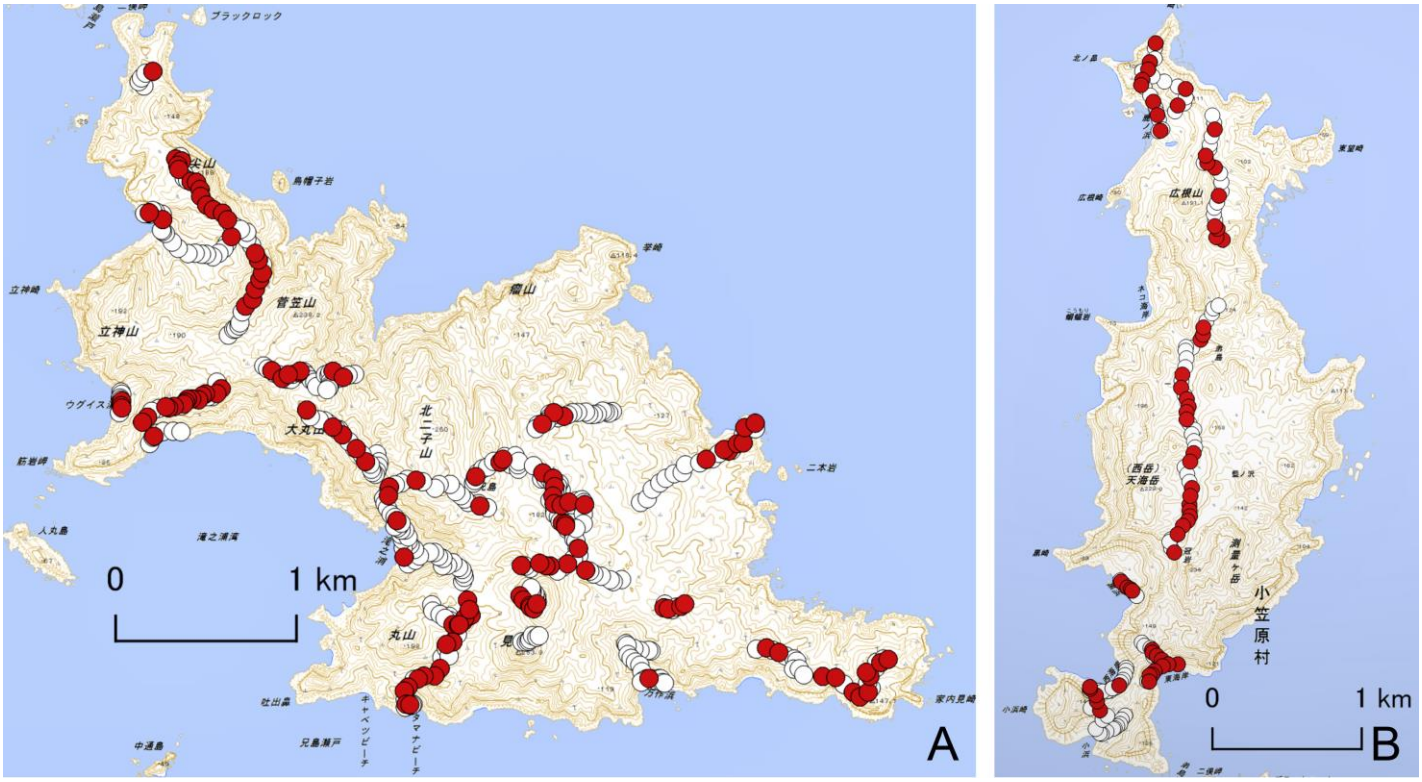

Figure 2. Distribution of *Pheidole parva* complex in Ani-jima (A) and Ototo-jima (B) based on Quadrat Sampling datasets.

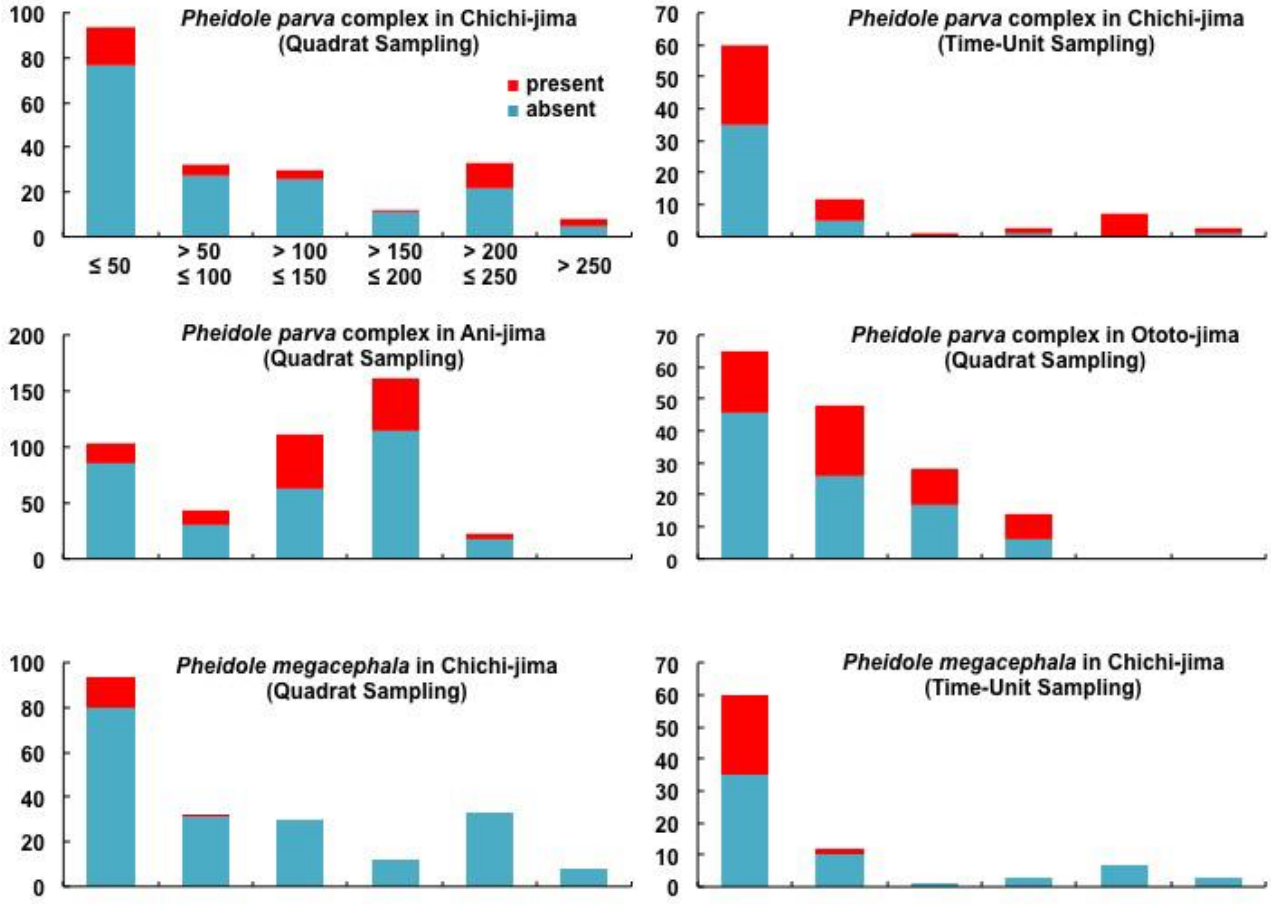

Figure 3. Vertical distribution of *Pheidole parva* complex and *P. megacephala* in Chichi-jima, Ani-jima and Ototo-jima. Vertical axis: number of quadrats or Time-Unit Sampling sites; horizontal axis: altitude (m).

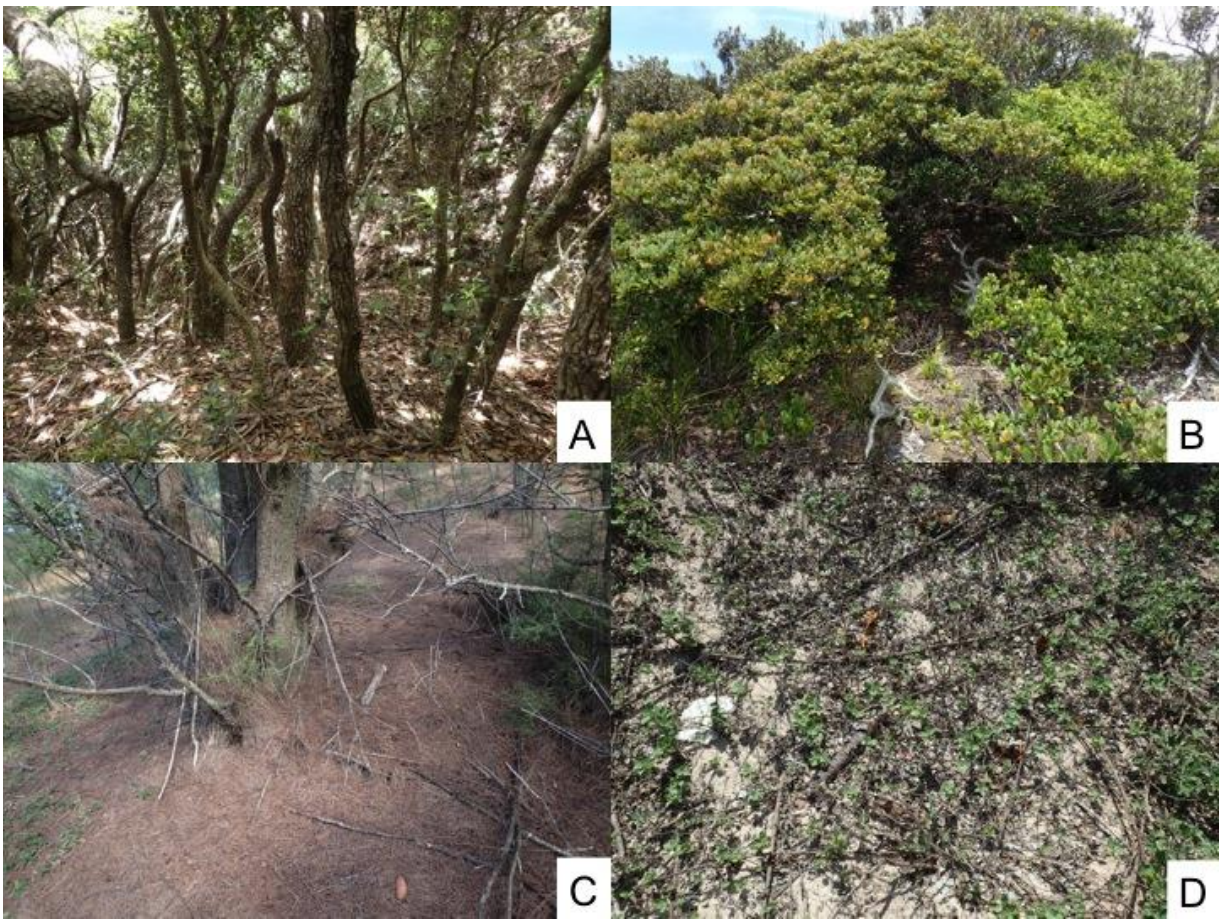

Figure 4. Habitats of *Pheidole parva* complex. A, *Schima mertensiana* forest, Quadrat AC5 in Chichi-jima; B, dwarf sclerophylious scrub, Quadrat AA11 in Ani-jima; C, *Casuarina equisetifolia* forest, Quadrat AO39 in Ototo-jima; D, sand beach dominated by *Vitex rotundifolia*, Quadrat AC109 in Chichi-jima.

Table 1. The occurrence frequency of *Pheidole parva* complex and *P. megacephala* in each land cover type. N/SF, the natural/seminatural forest; DF, disturbed forest; OL, open land; QD, Quadrat Sampling; TU, Time-Unit Sampling.

	N/SF	DF	OL
Pheidole parva complex			
Chichi-jima (QD)	19.7% (24/122)	16.7% (8/48)	20.5% (8/39)
Chichi-jima (TU)	76.2% (16/21)	61.5% (8/13)	38.5% (20/52)
Ani-jima (QD)	28% (77/275)	27.3% (3/11)	31.8% (50/157)
Ototo-jima (QD)	40.9% (27/66)	36.8% (7/19)	37.1% (26/70)
Pheidole megacephala			
Chichi-jima (QD)	3.3% (4/122)	6.3% (3/48)	20.5% (8/39)
Chichi-jima (TU)	9.5% (2/21)	15.4% (2/13)	44.2% (23/52)

Such habitat preference of *P. megacephala* has been reported in the other introduced areas; this is likely because open, disturbed habitats with weedy vegetation can support high densities of the honeydew-producing Hemiptera which is one of the important food sources for *P. megacephala* (Wetterer, 2007). On the other hand, *P. megacepala* invade some natural/seminatural

forests in Australia's monsoonal tropics, and is a serious potential threat to the region's rain forest invertebrate fauna (Hoffmann et al., 1999). Invasion of *P. megacephala* is limited by rainfall and rarely found in very dry (< 380–500 mm annual rainfall) or wet areas (> 2,500 mm annual rainfall) (Whetterer, 2007), and workers of *P. megacephala* are active outside the nest at temperatures of 24–30˚C, but not active at temperatures below 5˚C (Whetterer, 2007). The mean annual precipitation is 1,276.7 mm, and the mean temperature of the coldest month (February) and of the hottest month (August) is 17.7˚C and 27.6˚C, respectively, in Chichi-jima (Ministry of the Environment et al., 2010). Therefore, habitat and climate conditions may not prevent *P. megacephala* from expanding to the inland forests of Chichi-jima. Further studies will be needed to confirm the factors maintaining the allopatric existence of the two invasive *Pheidole* species in Chichi-jima.

P. parva complex has been established in Haha-jima Island (hereafter referred to as Haha-jima) (Eguchi et al., 2013), and introduction of *P. megacephala* to Haha-jima was recognized in early 2015 (Uchida et al., 2016). Because Haha-hima is one of the core areas for biodiversity conservation in the Ogasawara Islands (Ministry of the Environment et al., 2010; Kanto Regional Environment Office of Japan et al., 2010, 2014), the impact of *P. megacephala* on native ground-dwelling invertebrates such as endemic land snails is concerned (Uchida et al., 2016). It is worth noting that *P. parva* complex has a potential to dominate in inland area and natural/seminatural forests (Table 1). Although little is known about the biology of *P. parva* complex, the majority of *Pheidole* spp. are generalist foragers that prey on ground-dwelling invertebrates, scavenge on dead bodies of animals and feed on fruits and seeds (Sarnat et al., 2015). Therefore, *P. parva* complex has a potential risk to native ground-dwelling invertebrates in natural/seminatural forests of Haha-jima and other islands.

Dietary, foraging behavior, reproductive and dispersal strategies (independent or dependent colony foundation), colony structure (absence or presence of supercolony formation) and interactions with native and non-native species as well as detailed habitat preference should be revealed for evaluating the invasiveness of *P. parva* complex and setting it properly in the priority list of invasive species in the Ogasawara Islands.

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References

Eguchi, K., Yamane, Sk. & Zhou, S. 2007. Taxonomic revision of the *Pheidole rinae* Emery complex. Sociobiology 50 (1): 257-284.

Eguchi, K., Widmer, M., Oguri, E., Fischer, B.L. & Murakami, N. 2013. Discovery of cryptic species within Pheidole parva Mayr, 1865 (Insecta: Hymenoptera: Formicidae) widespread in the Indo-West Pacific. ARI – Journal of the Myrmecological Society of Japan 35: 16-27.

Fischer, G. & Fisher, B.L., 2013. A revision of *Pheidole* Westwood (Hymenoptera: Formicidae) in the islands of the Southwest Indian Ocean and designation of a neotype for the invasive *Pheidole megacephala*. Zootaxa 3683: 301-356.

Harada, Y., Enomoto, M., Nishimuta, K. & Minamata, H. 2015. Ants in Amami Islands. Nature of Kagoshima 41: 199-208.

Heinze, J., Cremer, S., Eckl, N. & Schrempf, A., 2006. Stealthy invaders: the biology of *Cardiocondyla* tramp ants. Insectes Sociaux 53: 1-7.

Hoffmann, B.D., Andersen, A.N. & Hill, G.J.E. 1999. Impact of an introduced ant on native rain forest invertebrates: *Pheidole megacephala* in monsoonal Australia. Oecologia 120 (4): 595-604.

Kato, M., 1992. List of insects in the Ogasawara Islands. WWFJ Science Report 1(Part 1): 73-105.

Kanto Regional Environment Office of Japan, Kanto Regional Forest Office, Tokyo Metropolitan Government, Ogasawara Village. 2010. Ogasawara Islands Ecosystem Conservation Action Plan (English translation for World Heritage nomination). Available from: http://ogasawara-info.jp/pdf/isan/ActionPlan_eigo.pdf

Kanto Regional Environment Office of Japan, Kanto Regional Forest Office, Tokyo Metropolitan Government, Ogasawara Village. 2014. Ogasawara Islands Ecosystem Conservation Action Plan 2. Available from: http://ogasawara-info.jp/pdf/isan/ActionPlan2_nihongo.pdf

Lach, L. & Hopper-Bùi, L.M. 2010. Consequences of ant invasions. pp. 261–286. In: Lach, L., Parr, C.L. Abbott, K.L. (eds.). Ant Ecology. Oxford University Press Inc., New York, xvii+402 pp.

Lowe, S., Browne, M., Boujelas, S. & De Poorter, M. 2000. 100 of the world's worst invasive species — a selection from the Global Invasive Species Database. IUCN/SSC Invasive Species Specialist Group, Auckland, New Zealand.

Man, L. S. & Lee, C.Y. 2012. Structure-invading pest ants in healthcare facilities in Singapore. Sociobiology 59 (1): 241-249.

McGlynn, T.P. 1999. The worldwide transfer of ants: geographical distribution and ecological invasion. Journal of Biogeography 26 (3): 535-548.

Ministry of the Environment, Forestry Agency, Agency for Cultural Affairs, Tokyo Metropolitan Government, Ogasawara Village. 2010. Ogasawara Islands Management Plan (English translation for World Heritage nomination). Available from: http://ogasawara-info.jp/pdf/isan/kanrikeikaku_eigo.pdf

Sarnat, E.M., Fischer, G., Guénard, B. & Economo, E.P. 2015. Introduced *Pheidole* of the world: taxonomy, biology and distribution. ZooKeys 543: 1-109.

Shimizu, Y. 2003. The nature of Ogasawara and its conservation. Global Environmental Research 7 (1): 3-14.

Terayama, M., Takamine, H. & Kubota, S. 2009. Ants of Okinawa. Seiinndo-Insatsu, Naha, Japan, xvi+165 pp.

Terayama, M., Kubota, S. & Eguchi, K. 2014. Encyclopedia of Japanese Ants. Asakura Syoten, Tokyo, 48+viii+278 pp.

Tomiyama, K. 1992. Terrestrial molluscan fauna of Ani-jima Island, the Ogasawara Islands and present situation of land mollusks of the site scheduled for the Ani-jima airstrip. WWFJ Science Report 1 (Part 1): 149-195.

Uchida, S., Mori, H., Kojima, T., Hayama, K., Sakairi, Y. & Chiba, S. 2016. Effects of an invasive ant on land snails in the Ogasawara Islands. Conservation Biology 30 (6): 1330-1337.

Wetterer, J.K. 2007. Biology and impacts of Pacific Island invasive species. 3. The African Big-Headed Ant, *Pheidole megacephala* (Hymenoptera: Formicidae). Pacific Science 61 (4): 437-456.

Wilson, E.O. 2000. Foreword. pp. xv-xvi. In: Agosti, D., Majer, J.D., Alonso, L.E. Schultz, T.R. (eds.). Ants: Standard Methods for Measuring and Monitoring Biodiversity. Smithsonian Institution Press, Washington & London, xix+280 pp.

Yamane, Sk. 2014. Species composition of ants and seasonal change in their activity level in disturbed areas of Naze, Amami-oshima, southern Japan (Hymenoptera: Formicidae). Nature of Kagoshima 40: 123-126.

原生地棲無脊椎動物的潛在風險——有關被忽視的小笠原群島褐大頭家蟻複合群之野外族群建立初探

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摘要: 鮮引人關注的褐大頭家蟻複合群 (*Pheidole parva* complex) (膜翅目：蟻科) 於 2007 年時被發現立足於名列世界自然遺產的小笠原群島之中的小島——父島。此外，知名的入侵性螞蟻——熱帶大頭家蟻 (*P. megacephala*)，近年來於父島亦非常普遍。而由於大頭家蟻屬大多物種為廣食性的覓食者，我們推測褐大頭家蟻複合群對小笠原群島的原生林/次生林的原生地棲無脊椎動物可能具有潛在風險，因此我們著手調查蟻群分布以為未來可能的防治工作提供基礎資料。我們以方形取樣法及時間單位取樣法調查父島群島中的父島、兄島、弟島的大頭家蟻屬 (*Pheidole*) 物種的分布狀況及棲地，並發現褐大頭家蟻複合群在三座島中從內陸到沿海地區非常普遍，且對棲地沒有明顯偏好性。另一方面，熱帶家蟻則沒有分布於兄島及弟島，在父島的沿海低地則頻繁可見。

關鍵詞: 入侵性、螞蟻、小笠原群島、分布