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Seasonal Cycle of the Nest Composition in the PonerineAnt *Cryptopone sauteri* (Hymenoptera: Formicidae)

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Abstract
The annual life history is a basic and important factor in ecological studies on temperate ant species. The biology of Ponerinae species has been studied for many species, but little attention has been paid to their life history. *Cryptopone sauteri* is one of the most common ants in temperate regions of Japan. However, there is no quantitative information on the life history of this species. We report seasonal changes in brood development, the emergence of reproductives and social structures of *C. sauteri*. Additionally, we found that the nuptial flight of alate females and males occurs in the end of summer in this species.

Introduction

The annual life history is a basic and important factor in ecological studies on temperate ant species (Bourke & Franks, 1995), but those of only a small number of model species have been investigated in detail (Hölldobler & Wilson, 1990; Peeters & Molet, 2010). For example, "Encyclopedia of Japanese ants", which was published in 2014, listed more than 290 species in Japan and provided important taxonomic descriptions; however, the life histories and biological characteristics of the listed ant species have not yet been examined in detail (Terayama et al., 2014). Life history data are indispensable to establish molecular and chemical studies (Schlick-Steiner et al., 2005; Katzerke et al., 2006; Purcell & Chapuisat, 2012).

Recently, the biology of Ponerinae ants has been studied for many species (e.g. Monnin & Peeters, 2008; Oliveira et al., 2011; Murata et al., 2016), but little attention has been paid to their life history. In fact, the information of life history with the sampling of enough nests have been available for only two species of Ponerinae ants (Gotoh & Ito, 2008; Hart & Tschinkel, 2012). Gotoh and Ito (2008) reported all adults of *Brachyponera chinensis* emerged once a year, and brood are not present in the nests during the winter. Hart and Tschinkel (2012) reported the colonies of *Odontomachus brunneus* produce brood for 6 months and are broodless for 6 months that includes the winter in north Florida.

The genus *Cryptopone* is a small group of ponerinae, including about 20 species, and is distributed in the Neotropical, Nearctic, Palearctic, Afrotropical, Oriental, Indo-Australian and Australian regions (Bolton et al., 2012 referred from Bharti & Wachkoo, 2013). *C. sauteri* is distributed in all islands excluding Hokkaido and one of the most common ants in temperate regions of Japan (Terayama et al., 2014). Murata (1994) reported the occurrence of alate queens in the nests and described the number of stadia in the larval stages and feeding habitats. Yamaguchi et al. (2016) compared body sizes, the number of ovarioles and

ovariole development between queens and workers to show the reproductive system of *C. sauteri*. The authors also found that this species is commonly monogyny, but partially appears to exhibit functional monogyny. However, there is no quantitative information on the life history of this species. Here, we reported seasonal changes in brood development, the emergence of reproductives and social structures of *C. sauteri* in temperate regions of Japan.

Methods

We studied *C. sauteri* at coppice forest (37°05′N, 138°37′E), Niigata Prefecture in Japan. The area is dominated by deciduous (*Fagus* spp. and *Quercus serrata*) and coniferous trees (*Cryptomeria japonica*) with an annual average temperature of approximately 11.7°C (maximum: 24.9°C in August; minimum: -0.2°C in February). Insect activity in the area is limited from November to May due to snowfall during the winter. We collected dead branches that *C. sauteri* nested in every two weeks between May and November in 2008 and 2009 to investigate seasonal changes in the nest composition.We defined the nests as independent if the dead branches existed separately. We carefully removed all adults and brood from every dead branch in the laboratory and recorded the numbers of mated queens, unmated queens, workers, alate females, alate males, and immature at each development stage (eggs, larvae, and pupae).The alate queens were possibly unmated, because they shed their wings after nuptial flight.

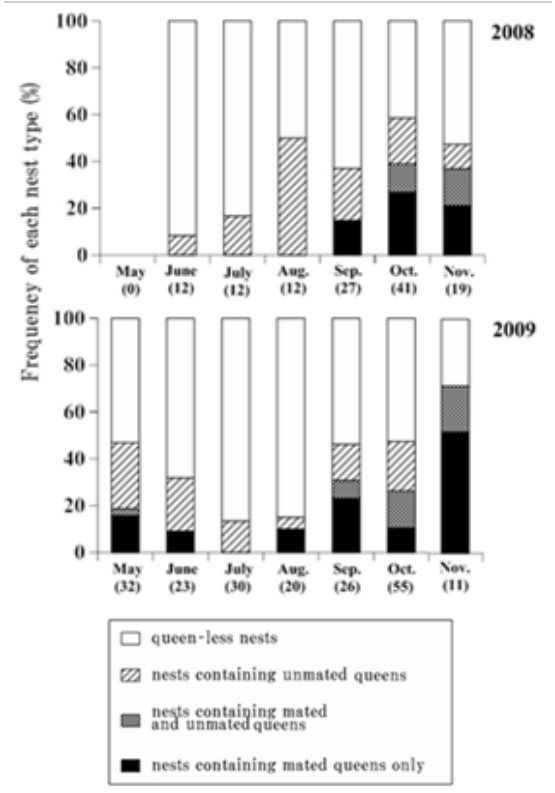

Fig 1. Seasonal changes in the frequency of the four nest types. The numbers in the parentheses indicate the number of nests collected.

All the queens collected for two years were dissected under a binocular microscope (OLYMPUS, SZ2-ILST) to assess their insemination status. However, data of two queens collected on May 28 2008 were not included in this study due to failures in dissection.

Results

A total of 331 nests were collected in the two years (2008: 134 nests, 2009: 197 nests), 199 of which were queenless. A total of 170 queens were collected in two years, and approximately half of these (61.7%) had been mated. As a result, the nest type was classified into four types (Figure 1). Although the number of mated queens markedly increased toward the end of the season, unmated queens were observed throughout the years.

Figure 2 shows seasonal changes in the number of adults (alate females and males, mated queens, unmated queens, and workers) and brood (larvae and pupae) per nest. Alate females (unmated individuals) and males were only collected between August and September, suggesting that the nuptial flight occurs in the end of summer in this species. This view is also supported by the fact that the average number of mated queens/nest in October and November was significantly larger than that between May and September (t-test, 2008: $p<0.01$, 2009: $p<0.01$). The number of workers also increased between August and September, suggesting that worker production occurs simultaneously with alate individuals. Eggs were only detected three times in our collection (2008: 1 nest in September; 2009: 2 nests in August and September). Although larvae were collected throughout the year, the numbers tended to decrease toward the end of the season. Pupae were detected between July and September in both years.

Discussion

We examined seasonal changes in the number of adults and brood in the ponerine ant *C. sauteri* and found that the nuptial flight of alate females and males occurs in the end of summer in this species.

One of the most striking characteristics of *C. sauteri* is that pupal cocoons were only detected at the end of summer, which suggested that all adults including workers and alates emerged once a year. All queens had wings, suggesting that they exhibit the nuptial flight in that season. Because eggs were detected only three times in our collection, we were not able to determine the activities of egg laying by queens. However, mated queens with a developed ovary were collected between May and November (Yamaguchi et al., 2016), suggesting that they lay eggs over the months. There were not consistent results on the existence of overwinter larvae in poneroid ants. The lack of overwinter larvae in the nests were reported in some Ponerine ants *Brachyponera chinensis* and *Odontomachus brunneus* (Gotoh & Ito, 2008;

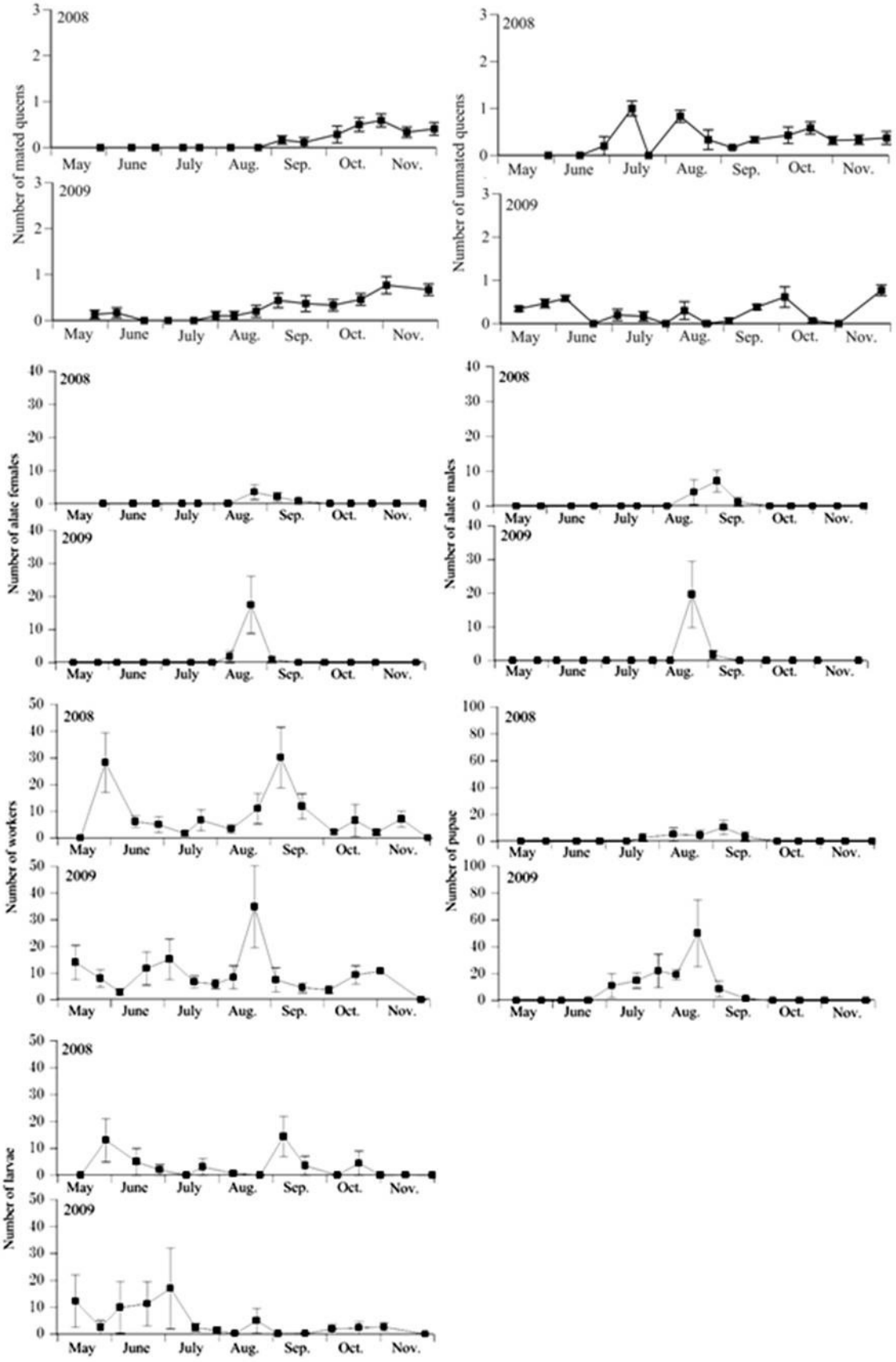

Fig 2. Seasonal changes in the number of adults (alate females andmales, mated queens, unmated queens, and workers)/ nest and brood (larvae and pupae)/nest in 2008 and 2009.The error bars represent SE.

Hart & Tschinkel, 2012), while Talbot (2012) reported that *Ponera* differed from *Amblyopone* or *Proceratium* in that it did not overwinter larvae. In *C. sauteri*, the developed larvae were collected even in the beginning of spring (May), strongly suggesting that larvae overwinter. However, it is not clear that detail of life history, such as larval duration and life span of adults. Future studies will have to focus on detail of life history by rear this ant species.

The number of unmated queens was high throughout the year. Five hypotheses on the presence of unmated queens have been proposed to date: producing trophic eggs, producing male-destined eggs, working queens, failure of nuptial flight and postponement of reproduction (Vargo 1993; Bourke & Franks, 1995; Brown 1999; Kikuchi & Tsuji, 2005; Johnson et al. 2007). Yamaguchi et al. (2016) suggested that the two possibilities (failure of nuptial flight or postponement of reproduction) are plausible for explaining the presence of unmated queens in *C. sauteri*, because the unmated queens had neither egg laying nor labor. Our study showed that the unmated queens increased from June to August in 2008, but no such tendency was observed in 2009. However, it is unknown how such difference occurred among the years. The seasonal change of unmated queen frequency need to be examined in future studies.

Approximately 60% of the *C. sauteri* nests collected in the present study were queenless, which suggested that this species may use a polydomous nesting system. Polydomous ants use at least two spatially segregated nests that exchange workers and broods, and this has been reported previously in some ponerine species (*Hypoponera bondroiti*: Yamauchi et al., 1996; *Pachycondyla goeldii*: Denis et al., 2006). We further need to investigate whether *C. sauteri* exhibits polydomy by testing inter-nest aggressiveness or observation of inter-nest network.

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References

Bharti, H. & Wachkoo, A.A. (2013). *Cryptopone subterranea* sp. nov., a rare new cryptobiotic ant species (Hymenoptera: Formicidae) from India. Asian Myrmecology, 5: 1-4.

Bourke, A.F.G. & Franks, N.R.(1995). Social Evolution in Ants. Princeton University Press, Princeton, NJ. pp. 299-326.

Brown MJF. (1999). Semi-claustral founding and worker behaviour in gynes of *Messor andrei*. Insectes Sociaux. 46: 194-195. doi: 10.1007/s000400050133

Denis, D., Orivel, J., Hora, R., Chameron, S. & Fresneau, D. (2006). First record of polydomy in a monogynous ponerine ant: a means to allow emigration between *Pachycondyla goeldii* nests. Journal of Insect Behavior, 19: 279-291. doi: 10.1007/s10905-006-9024-5.

Gotoh, A. & Ito, F. (2008). Seasonal cycle of colony structure in the Ponerine ant *Pachycondyla chinensis* in western Japan (Hymenoptera, Formicidae). Insectes Sociaux, 55: 98-104. doi: 10.1007/s00040-007-0977-y.

Hart, L.M. & Tschinkel, W.R.(2012). A seasonal natural history of the ant, *Odontomachus brunneus*. Insectes Sociaux, 59: 45-54. doi: 10.1007/ s00040-011-0186-6.

Hölldobler, B. & Wilson, E.O. (1990). The Ants. Cambridge: Harvard University Press, 732 p.

Johnson, RA., Holbrook, CT., Strehl, C. & Gadau, J. (2007). Population and colony structure and morphometrics in the queen dimorphic harvester ant, *Pogonomyrmex pima*. Insectes Sociaux, 54: 77-86. doi: 10.1007/s00040-007-0916-y

Katzerke, A., Neumann, P., Pirk, C.W.W., Bliss, P. & Moritz, R.F.A. (2006). Seasonal nestmate recognition in the ant *Formica exsecta*. Behavioral Ecology and Sociobiology, 61: 143–150. doi: 10.1007/s00265-006-0245-6.

Kikuchi T. & Tsuji K. (2005). Unique social structure of *Probolomyrmex longinodus*. Entomological Science, 8: 1-3. doi: 10.1111/j.1479-8298.2005.00094.x

Monnin, T. & Peeters, C. (2008). How many gamergates is an ant queen worth? Naturwissenschaften, 95: 109-116. doi: 10.1007/s00114-007-0297-0.

Murata, K. (1994). Life history of *Cryptopone sauteri* Wheeler. Ari, 17: 3.

Murata, N., Tsuji, K. & Kikuchi, T. (2016). Social structure and nestmate discrimination in two species of *Brachyponera* ants distributed in Japan. Entomological Science, 20: 86-95. doi: 10.1111/ens.12232.

Oliveira, P.S., Camargo, R.X. & Fourcassié, V. (2011). Nesting patterns, ecological correlates of polygyny and social organization in the neotropical arboreal ant *Odontomachus hastatus* (Formicidae, Ponerinae). Insectes Sociaux, 58: 207-217. doi: 10.1007/s00040-010-0138-6.

Peeters, C. & Molet, M. (2010). Colonial Reproduction and Life Histories. Oxford University Press, 159-176 pp.

Purcell, J. & Chapuisat, M. (2012). Bidirectional shifts in colony queen number in a socially polymorphic ant population. Evolution, 67: 1169-1180. doi: 10.1111/evo.12010.

Schlick-Steiner, B.C., Steiner, F.M., Stauffer, C. & Buschinger, A. (2005). Life history traits of a European *Messor* harvester ant. Insectes Sociaux, 52: 360-365. doi: 10.1007/s00040-005-0819-8.

Talbot, M. (2012). The natural history of the ants of Michigan's E. S. George Reserve: a 26-year study. Museum of Zoology, University of Michigan, 228pp.

Terayama, M., Kubota, T. & Eguchi, K. (2014). Encyclopedia of Japanese ants. Asakurasyoten, 278pp.

Vargo, EL. (1993). Colony reproductive structure in a polygyne population of *Solenopsis geminate* (Hymenoptera: Formicidae). Annals of the Entomological Society of America, 86: 441-449. doi: 10.1093/aesa/86.4.441

Yamaguchi, Y., Yazawa, H., Iwanishi, S . & Kudô, K. (2016). Differences in body sizes and physiological conditions among castes in the ponerineant *Cryptopone sauteri* (Hymenoptera: Formicidae). Entomological Science, 19: 124-128. doi: 10.11 11/ens.12176.