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SHORT COMMUNICATION

Habitat differences and occurrence of native and exotic ants on Okinawa Island

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Abstract

Ant fauna on *Mallotus japonicus*, a shrub with extrafloral nectaries, was investigated in two types of habitat (the villages and the forest-edges) on subtropical Okinawa Island, Japan. Twenty and 16 ant species were found, including 11 and 6 tramp species in the villages and in the forest-edges, respectively. Occurrence of tramp species was higher in the villages than in the forest edges, supporting the idea that tramp species tend to dominate in disturbed habitats. Nevertheless, the richness of native ants was almost the same across the two habitat types. Consequently, the ant species diversity on *M. japonicus* appeared higher in the villages. However, monitoring has to be continued to determine whether the above findings represent a stable phenomenon of the community or just a temporary state.

Key words: ant-plant interactions, disturbance, EFNs, Euphorbiaceae, exotic ants, Formicidae, tramp ants.

Exotic ants, called tramp species, have invaded many regions of the world by unintentional transport by humans. Those ants often cause negative impacts on biodiversity of native organisms (Holway *et al.* 2002). Literature suggests that tramp species prefer disturbed environments (Holway *et al.* 2002; Nakamaru *et al.* 2007). This is true for the main island of Okinawa, a subtropical region of Japan, where many tramp species have already invaded (Japanese Ant Database Group 2007); tramp species are common in open and disturbed habitats but almost absent in primary forests (Yamauchi & Ogata 1995). However, a recent study showed that tramp species have already invaded edges of primary and semi-primary forests of this island (Suwabe *et al.* 2009), whereas their impact on the native ant fauna is still to be studied.

It is known that ants are strongly attracted to nectar-secreting glands called extrafloral nectaries (EFNs) of various plant species (Bentley 1977). Sugars are the largest constituent of the nectar, followed by little amino-acid contents (Koptur 1992; Heil *et al.* 2000; Blüthgen *et al.* 2004). Such resource substantially benefits ant workers (Lach *et al.* 2009) especially those of tramp species so that the availability of nectar is considered to make tramp species dominant against native ant species (Addison & Samways 2000; Lach 2003). *Mallotus japonicus* (Thunb.) Muell. Arg. (Euphorbiaceae) is a pioneer woody plant dominating disturbed lands at an early stage of ecological succession in Okinawa (Horikawa 1972). This plant possesses EFNs, as other species belonging to the genus *Mallotus* do (Fiala & Maschwitz 1991; Blüthgen & Reifenrath 2003). Given the characteristics of tramp ants and *M. japonicus*, one could infer that tramp species might be more easily detectable on *M. japonicus* than in other microhabitats, because its nectar might be an important food resource for tramp ants. Here we compared occurrence of tramp and native ant species between habitats experiencing a different degree of human disturbance in Okinawa by focusing on ants found on *M. japonicus* trees.

Field survey was conducted in Kunigami village, the northern part of the main island of Okinawa where natural and semi-natural forests are relatively well conserved, in September and November 2006 (Fig. 1). *Mallotus japonicus* trees were chosen haphazardly in two types of habitat (the villages and the forest-edges). The habitat type the "villages", consists of open lands such as back yards located inside three settlements, i.e. Yona

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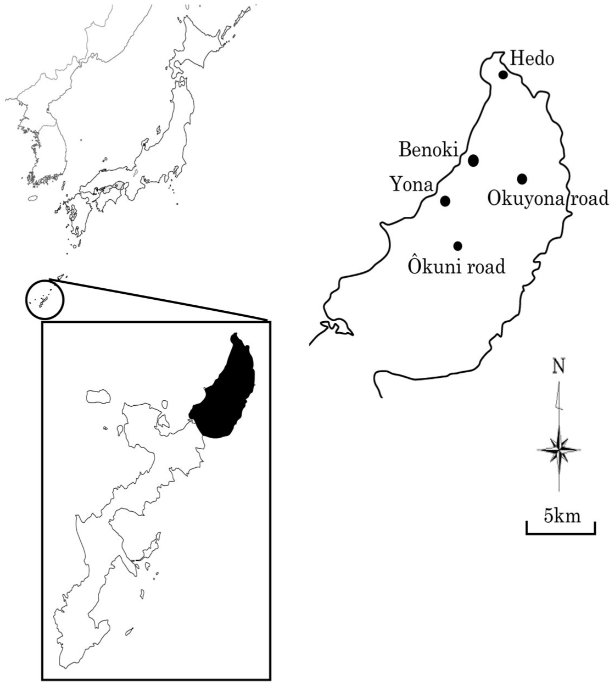

Figure 1 Map of study sites on the main island of Okinawa, Japan. All these study sites are located in Kunigami village, the northern part of this island.

($n = 26$), Benoki ($n = 29$), and Hedo ($n = 20$), and the "forest-edges" represents semi-primary forest borders faced to the paved roads, i.e. Ookuni-road ($n = 31$) and Okuyona-road ($n = 37$) (Fig. 1). The former habitat type should be subject to more frequent human disturbances than the latter. On each *M. japonicus* tree, ants feeding on extrafloral nectar were sought and collected by an aspirator for 3 min in the daytime. The number of ants collected during a 3-minute sampling unit is usually small. However, a preliminary study indicates that this procedure has a high repeatability with regard to following variables: the proportion of exotic ant individuals to all ant individuals and that of exotic ant species to all ant species (data not shown). The ant biology, i.e. conspecific individuals usually distribute in aggregation around their nest, might account for such temporal stability of these variables, i.e. the proportion of the number of exotic ant species to all ant species, and that of exotic ant individuals to all ant individuals. Ants that had touched their mouth parts to EFNs were assumed to have been feeding on nectar. The study areas and the height (mean ± SD) of investigated trees were presented in Table 1.

Twenty ant species in the villages and 16 in the forest-edges were recorded, including 11 and 6 tramp species, respectively (Table 2). We identified and classified native

Table 1 The height of investigated trees in each study site

	Study area (m^2)	Height (cm)		The number of trees investigated
		Mean	SD	
The villages				
Yona	600	102.6	64.9	26
Benoki	400	65.5	48.0	29
Hedo	300	22.8	12.4	20
The forest-edges				
Okuyona road	500	77.6	48.7	37
Ookuni road	400	98.9	49.9	31

and tramp species following descriptions of previous studies (Yamauchi & Ogata 1995; Yamane *et al.* 1999; Seifert 2003; Japanese Ant Database Group 2007; LaPolla *et al.* 2010; K. Yamauchi pers. com.). The native ant species caught in this study represent 14% of native ant fauna in the main island of Okinawa, and the tramp species collected represent 50% of tramp species recorded so far in this island (Japanese Ant Data Base 2007). The mean number of native species collected per tree was not statistically significantly different between the two habitat types (in the villages 1.2 ± 0.84 SD and in the forest-edges 1.15 ± 0.83 SD, $t = 0.38$, d.f. = 141, $P = 0.71$), whereas the mean number of tramp species captured per tree was higher in the villages [(0.64 ± 0.54 SD (villages) and 0.43 ± 0.50 SD (forest-edges), $t = 2.46$, d.f. = 141, $P = 0.015$)] (Fig. 2).

The mean number of native ant individuals per tree was larger in the villages (the villages 4.32 ± 5.34 SD and the forest-edges 3.04 ± 4.10 SD, nested ANOVA, $P = 0.012$), whereas that of tramp ants did not differ between the two habitats (the villages 1.97 ± 2.65 SD and the forest-edges 1.58 ± 2.38 SD, nested ANOVA, $P = 0.25$) (Fig. 2). The total ant abundance per tree was also significantly higher in the villages than in the forest-edges (6.21 ± 5.05 SD and 4.63 ± 3.86 SD, nested ANOVA, $P = 0.013$).

The ant species diversity on *M. japonicus* was compared between the two habitat types using the species rank-abundance relationship (Hubbell 2001) (Fig. 3). The abundance in Figure 3 (Y axis) represents the total number of workers of the focal species captured in each type of habitats. There was a statistically significant difference in the slope of the regression line between the villages and the forest-edges ($t = 3.80$, d.f. = 32, $P < 0.001$). The lower species richness and the steeper slope in the forest-edge may suggest that the ant community is more diverse in the villages than in the forest-edges (see also the results of other diversity indices mentioned later).

Since the height of trees investigated differed between the two habitats (the villages vs. the forest-edges,

Table 2 Number of ant individuals and the number of trees on which each ant species found in each study site

	Number of ant individuals pooled over all sites	The villages			The forest-edges	
		Yona (26)	Benoki (29)	Hedo (20)	Okuyona road (37)	Ookuni road (31)
Dolichoderinae						
Tapinoma melanocephalum (Fabrisius)†	1	1	0	0	0	0
Technomyrmex brunneus Forel†	65	0	8	5	9	2
Formicinae						
Anoplolepis gracilipes F. Smith†	23	2	2	0	1	1
Camponotus bishamon Terayama	1	0	0	0	0	1
Camponotus sp.	1	0	0	0	0	1
Nylanderia amia (Forel)	1	1	0	0	0	0
Nylanderia ryukyuensis (Terayama)	101	15	13	4	16	10
Nylanderia yambaru (Terayama)	18	1	0	1	7	2
Myrmicinae						
Cardiocondyla kagutsuchi Terayama†	7	0	3	0	2	0
Cardiocondyla wroughtonii (Forel)†	19	0	1	0	5	1
Monomorium chinense Santschi	48	3	0	13	2	1
Monomorium floricola (Jerdon)†	1	0	0	2	0	0
Monomorium intrudens F. Smith	143	5	19	0	0	0
Pheidole fervens F. Smith†	96	5	1	6	0	9
Pheidole megacephala (Fabricius)†	16	5	0	0	0	0
Pheidole noda F. Smith	81	4	0	0	9	10
Pheidole pieli Santschi	10	0	3	0	0	0
Prystomyrmex punctatus (F. Smith)	99	1	4	0	5	0
Pyramica benten (Terayama, Lin et Wu))	1	0	0	0	1	0
Temnothorax indra (Terayama & Onoyama)	2	0	0	0	2	0
Tetramorium bicarinatum (Nylander)†	31	1	2	0	2	3
Tetramorium lanuginosum Mayr†	8	1	1	1	0	0
Tetramorum nipponense Wheeler	4	0	0	1	0	1
Tetramorium simillimum (F. Smith)†	3	2	0	0	0	0

The number of trees investigated in each study site is in parentheses.
†tramp ant.

$t = -2.23$, d.f. = 141, $P = 0.027$) (Table 1), this could cause the patterns observed above. The multiple logistic regression analysis of the occurrence of each of the four most common ant species (found on more than 10 trees: *Technomyrmex*. *brunneus* Forel, *Nylanderia ryukyuensis* (Terayama), *Monomorium chinense* Santschi, *Monomorium intrudens* F. Smith), in which the site-average tree height (covariate) and the "site" (random factor) were used as the independent variables, detected no statistically significant effect of the tree height on the occurrence of any ant species (data not shown), whereas the effect of "site" was statistically significant in two species (*M. chinense* and *M. intrudens*: $P < 0.05$). Furthermore, none of the three indices for species diversity (the mean number of ant species per tree, Simpson's index of diversity, MacArthur's index of diversity; calculated in each study site) was statistically significantly correlated to the site-mean tree height (the mean species number: r = 0.13, $P > 0.05$, Simpson's index: r = –0.63, $P > 0.05$, MacArthur's index: r = 0.72, $P > 0.05$).

Tramp species more strongly dominated (both in species richness and abundance) in the villages than in the forest-edges, supporting the view that ecological dominance of tramp species is associated with human disturbance (Holway *et al.* 2002; King & Tschinkel 2006, 2008; Nakamaru *et al.* 2007). Although it is known that tramp species tend to competitively exclude native ants in many island ant communities (Holway *et al.* 2002), this tendency was unclear in this study, and a substantial number of native ants were found in both habitats (9 in the villages and 10 in the forest-edges). As a result it was suggested that the species diversity was higher in the villages. Underlying ecological mechanisms of the observed coexistence of exotic and native ants are of interest. However, it is possible that the observed pattern represents temporary state and tramp ants might exclude native ants in the future. Therefore, monitoring has to be continued.

Various ants, both native and exotic, are found on *M. japonicus*. Although the observation that many of them

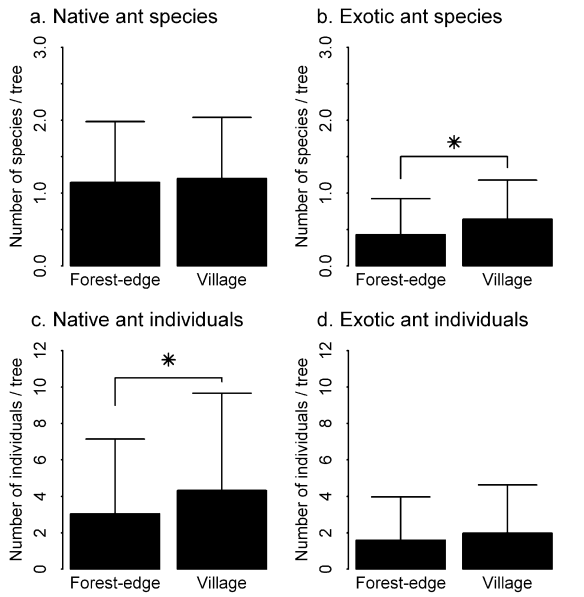

Figure 2 The mean number (±SD) of ant species (a, b) and individuals (c, d) per tree in each habitats. (a, c): native ants; (b, d): exotic ants. *: $P < 0.05$.

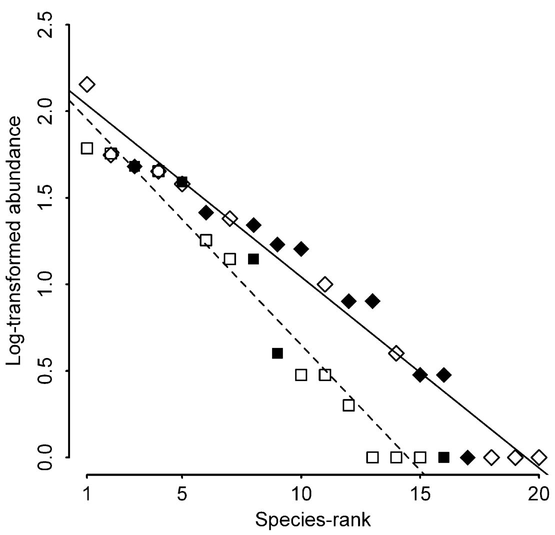

Figure 3 The relationship between species rank and log-transformed abundance in the two habitat types. open diamonds: the villages, native ants; solid diamonds: the villages, tramp ants; open squares: the forest-edges, native ants; solid squares: the forest-edges, tramp ants. The regression line in the villages (solid) and that of in the forest-edges (dashed) were shown (the villages: $y = -0.11 + 2.15$, $R^2 = 0.968$; the forest-edges: $y = -0.14 + 2.1$, $R^2 = 0.957$). *X* axis represents the species-rank according to the abundance and *Y* axis represents the log-transformed abundance.

were touching their mouthpart to EFNs of this plant might suggest that ants were consuming the nectar, we admit that a more rigorous experimental study is required to examine if ants really consume the nectar or not. Furthermore, given that *M. japonicus* provides foods for ants including exotic species, future studies should focus on whether the use of EFNs of *M. japonicus* accounts for the domination of tramp species in disturbed habitats in Okinawa, or not.

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