

First survey of ground-dwelling ants (Hymenoptera: Formicidae) on the uninhabited Gaja-jima Island, the Ryukyu archipelago, Japan

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The ground-dwelling ant fauna on the uninhabited Gaja-jima Island, the Tokara Islands, the Ryukyu archipelago, Japan was investigated, which was the first survey on ants of the island. Twenty-three ant species were found during a visit of only eight hours in daytime. Four of them were new records to the Tokara Islands. Of the four new records, the southern limit of distributions was renewed for three species. Three exotic species, *Pheidole fervens*, *Tetramorium bicarinatum*, and *Tapinoma melanocephalum* were recognized, which seems relatively low given that ten exotic species have been altogether recorded from the Tokara Islands. The relationship between invasion by ants and the scale of human activity is discussed.

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1. Introduction

Species checklists are fundamentals of many scientific studies and contribute to biodiversity conservation (Myers *et al.* 2000, Pfeiffer *et al.* 2011). However, they are recently considered as minor contributions to science, partly because of the low impact factor they achieve (Krell 2000). Unfortunately, species inventory remains insufficient es-

pecially in places where diverse species would be expected like in tropical and sub-tropical regions (Myers *et al.* 2000).

The Tokara Islands consists of seven inhabited and five uninhabited islands located in the northern part of the subtropical Ryukyu archipelago (Fig. 1). They have been repeatedly connected and disconnected to Eurasia by the glacial-interglacial cycles, which make them interesting

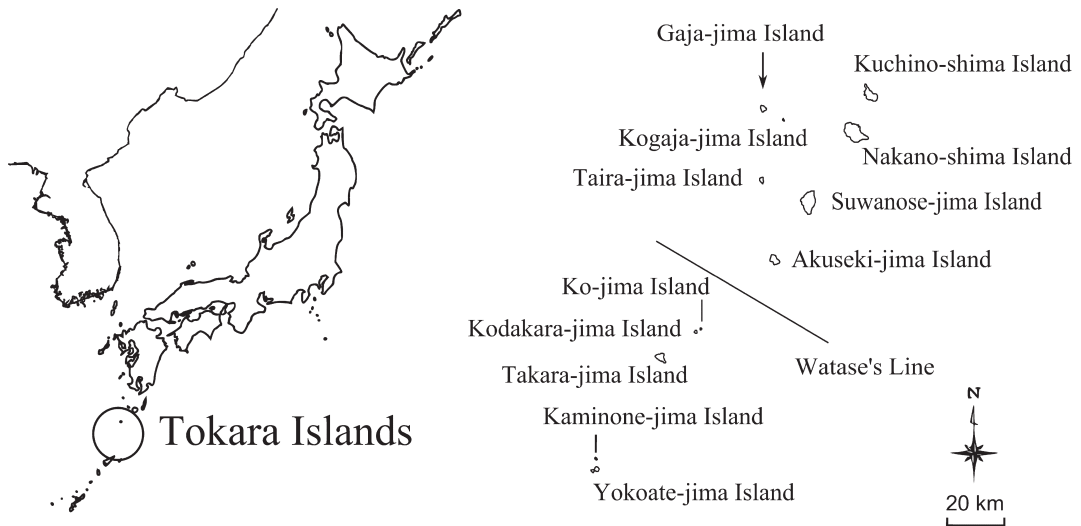


Fig. 1. Map of the location of Gaja-jima Island in Japan. Left: the location of the Tokara Islands. Right: the location of Gaja-jima Island in the Tokara Islands.

subjects to biogeographical studies (e.g. Kato & Yagi 2004, Nakamura *et al.* 2010). A hypothesized biogeographical boundary between Palearctic and Oriental regions called Watase's line has been recognized between Akuseki-jima Island and Kodakara-jima Island (Fig. 1).

We got a chance to investigate the ant fauna on one of these uninhabited islands, Gaja-jima Island (29°32'24"N, 129°19'12"E) (Fig. 1), which is located in the Palearctic zone, north to the Watase's line. The island is small (4.07 km²) and has 492.2 m height at maximum. People had lived on this island probably from 12th century to 1970 (Kozono 1995). Since 1970, there have been no residents on the island, but landing has been made occasionally by people who maintain a lighthouse. Landing on the island is now restricted by Toshima Village.

There exist a few studies on the insect fauna on Gaja-jima Island (termites: Ikehara 1959, beetles: Matsushita 1999, Toki & Hosoya 2012, butterflies: Fukuda 2007, mosquitoes: Noda 2011). Environmental degradation on the island is a concern because of increased populations of two introduced vertebrate herbivores, Sika Deer (*Cervus nippon mageshimae* Kuroda and Okada) and domestic goat (*Capra hircus* Linnaeus) (Terada 1999).

This article reports on the ground-dwelling

ant fauna on Gaja-jima Island. Ants are easily collected, identified, and an indicator group of biodiversity (Alonso 2000), but no faunal investigations of ants, to our knowledge, have been conducted on this island. As exotic ants often invade new areas accompanied with human activities, it would be worth to examine in future studies the differences in ant fauna between inhabited and uninhabited islands in the Tokara Islands (Holway *et al.* 2002).

2. Material and methods

Gaja-jima Island is a small volcanic island surrounded by a sea cliff more than 100 m in height. The flora of this island reaches up to 408 species of plants (Terada 1999). Most parts of the island are covered with *Pleioblastus linearis* Nakai 1925 (Poaceae) bamboos especially on the west side where residents had lived, whereas rich forests exist on the east side (Terada 1999). A paved road runs from the landing point to a lighthouse and collections of ground-dwelling ants were mainly made along this road (in about 2 m width out from each side of the road). The region around the road was divided into three areas based on three major environments along the road: entrance, former village, and lighthouse. Dry and

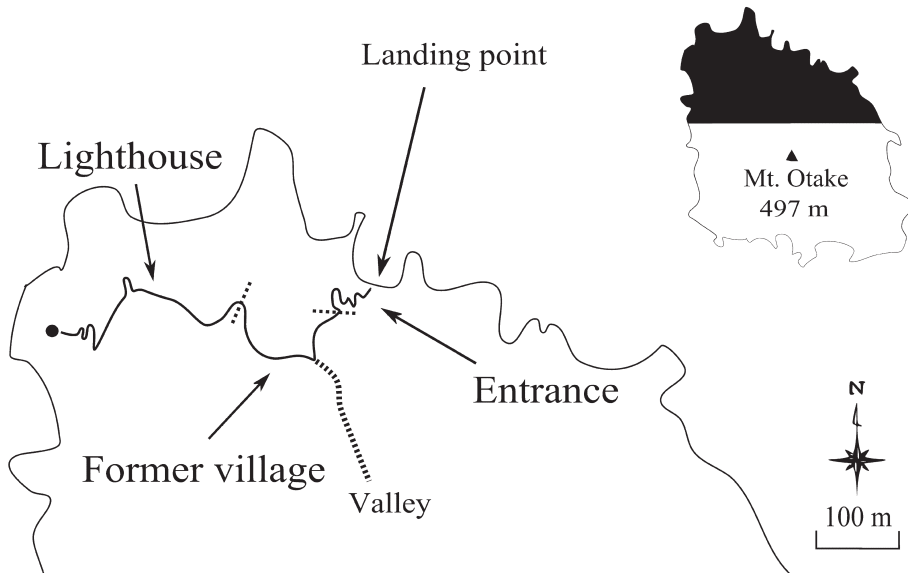


Fig. 2. Detailed map of the research areas on Gaja-jima Island. Solid line represents the paved road investigated. "Lighthouse", "Entrance", and "Former village", separated by dotted lines perpendicular to the solid line, show different subsets of the investigated area. The dashed line stretching southeast from the southernmost tip of the road represents the dry-up valley which is included as a part of the "Former village" area. The solid circle represents the lighthouse.

open grasslands spread in the entrance and lighthouse areas. The lighthouse area was also surrounded by a bamboo thicket. In contrast, many shrubs and trees covered the sampling site in the former village area, creating relatively moist and dark environments. The trees were mainly *Pinus thunbergii* Parl. 1868 (Pinaceae), *Ardisia sieboldii* Miq. 1867 (Myrsinaceae) and *Machilus thunbergii* Siebold & Zucc. 1846 (Lauraceae). A dry valley in the former village area was also searched for the ants (Fig. 2). This valley was covered with trees like *A. sieboldii*, *M. thunbergii* and *Castanopsis sieboldii* (Makino) Hatus. 1971.

Ant collections on Gaja-jima Island under the permission from Toshima Village were carried out during an 8 hours visit (from 8 a.m. to 4 p.m.) on 13.VII.2011. The sampling was restricted because of only a day-time permission for a one-day visit. Ant foragers walking on the ground were haphazardly collected using an aspirator. Decaying woods, grounds under stones, and slopes along the road were also searched for ant colonies. Because the number of individuals we could collect was restricted to about 10 individuals for each species by the permit, only some workers,

queens and males if available were caught even if a whole colony was found.

All ants collected were identified to species and classified into native or exotic species based on taxonomic literatures by M. K. (Onoyama 1980, Yamane *et al.* 1999, Onoyama & Yoshimura 2002, Japanese Ant Database Group 2007, Yoshimura & Onoyama 2007, Yoshimura *et al.* 2009, Katayama & Tsuji 2010). Voucher specimens are deposited at the Entomological Laboratory of University of the Ryukyus.

3. Results

Twenty-three ground-dwelling ant species were found on Gaja-jima Island: 2 in the subfamily Ponerinae, 1 in Proceratiinae, 14 in Myrmicinae, 1 in Dolichoderinae, and 5 in Formicinae (Table 1). Among them, 4 species were recorded in the Tokara Islands for the first time: *Proceratium itoi* A. Forel, 1918, *Aphaenogaster famelica* (F. Smith, 1874), *Aphaenogaster japonica* A. Forel, 1911, and *Camponotus yamaokai* Terayama *et* Satoh, 1990. The other 19 species have been re-

Table 1. List of ant species collected on Gaja-jima Island with regions of distributions (E, exotic; O, Oriental; P, Palaeartic), sites of collection (E, entrance; V, former village; L, lighthouse), types of sampled specimens (F, forager; C, colony), numbers of specimens collected (W, workers; Q, queens; M, males; minor and major workers were separated for Pheidole as minors+majors). Collectors (Leg.): TH, T. Hosoya; MK, M. Katayama; WT, W. Toki. V-No. is for the number of the voucher specimen and stars (*) denote species new to Tokara Islands.

Species	Region	Site	Type	Numbers			Leg.	V-No.
				W	Q	M		
Ponerinae								
<i>Hypoponera nippona</i> F. Santschi, 1937	P, O	V	F	0	1	0	MK	7
<i>Ponera tamon</i> Terayama, 1996	P, O	V	C	2	1	0	MK	6
		V	F	1	0	0	MK	12
Proceratiinae								
* <i>Proceratium itoi</i> A. Forel, 1918	P, O	V	F	1	0	0	MK	18
Myrmicinae								
* <i>Aphaenogaster famelica</i> (F. Smith, 1874)	P	V	C	1	1	0	MK	2
* <i>A. japonica</i> A. Forel, 1911	P	V	F	1	0	0	MK	16
		V	C	4	0	0	TH	23
		V	C	3	3	0	MK	31
		V	C	3	0	0	MK	37
<i>A. osimensis</i> Teranishi, 1940	P, O	E	F	3	0	0	MK	37
<i>A. tokarainsulana</i> Watanabe et Yamane, 1999	P, O	V	C	6	1	4	MK	8
<i>Carebara yamatonis</i> (Terayama, 1996)	P, O	V	C	5	0	0	MK	1
<i>Monomorium chinense</i> Santschi, 1925	P, O	E	F	3	0	0	MK	34
<i>Pheidole fervens</i> F. Smith, 1858	E	V	C	6+7	6	0	MK	5
		V	C	2+1	0	0	MK	21
		E	F	4+1	0	0	MK	33
		V	C	7+3	0	0	MK	30
<i>Ph. pieli</i> Santschi, 1925	P, O	V	C	5	0	0	MK	25
<i>Pristomyrmex punctatus</i> F. Smith, 1860	P, O	V	C	5	0	0	MK	25
		E	F	2	0	0	MK	39
		V	C	1	0	0	MK	10
<i>Solenopsis japonica</i> Wheeler, 1928	P, O	L	F	1	0	0	MK	10
		V	C	7	0	0	MK	14
		V	C	16	0	0	MK	29
		V	C	5	0	0	MK	45
<i>Strumigenys lewisi</i> Cameron 1886	P, O	V	C	11	0	0	MK	3
		V	F	1	0	0	MK	13
		V	C	18	0	0	MK	28
		V	F	1	0	0	MK	43
		V	F	1	0	0	MK	44
<i>Temnothorax anira</i> (Terayama et Onoyama, 1999)	P, O	E	F	1	0	0	MK	35
<i>Tetramorium bicarinatum</i> Nylander, 1846	E	E	F	5	0	0	MK	32
		E	C	2	3	0	MK	38
		V	C	5	3	0	MK	4
<i>Vollenhovia benzai</i> Terayama et Kinomura, 1998	P, O	V	C	7	0	0	MK	11
		V	F	1	0	0	MK	17
		E	F	1	0	0	MK	40
		V	F	1	0	0	MK	19
Dolichodelinae								
<i>Tapinoma melanocephalum</i> Fabricius, 1793	E	V	F	1	0	0	MK	19
Formicinae								
<i>Acropyga sauteri</i> A. Forel, 1912	P, O	V	C	9	0	0	MK	15
		V	C	8	0	0	MK	26
<i>Camponotus devestivus</i> Wheeler, 1928	P, O	V	C	4	1	0	TH	27
* <i>C. yamaokai</i> Terayama et Satoh, 1990	P	L	C	18	0	1	WT	22
<i>Nylanderia amia</i> (H. Forel, 1913)	P, O	E	F	4	0	0	MK	42
<i>N. ryukyensis</i> (Terayama, 1999)	P, O	L	C	2	1	0	MK	9
		L	C	4	1	0	MK	20
		V	C	4	0	0	MK	24
		E	F	2	0	0	MK	36
		E	F	4	0	0	MK	41

Table 2. Numbers of ant species recorded on each of the Tokara Islands. Information is based on Yamane *et al.* (1999), except for Gaja-jima Island.

	Numbers of ant species			Island area km ²	Residents
	Total	Ground- dwelling ¹	Exotic (%)		
Kuchino-shima	33	29	7 (24.1)	13.33	+
Nakano-shima	33	29	7 (24.1)	34.47	+
Suwanose-jima	13	12	3 (25)	27.66	+
Taira-jima	11	8	3 (37.5)	2.08	+
Akuseki-jima	24	18	4 (22.2)	7.49	+
Takara-jima	33	28	8 (28.6)	7.14	+
Yokoate-jima	15	13	3 (23.1)	2.76	–
Gaja-jima	23	22	3 (13.6)	4.07	–
Ko-jima	3	3	1 (33.3)	0.36	–
Kodakara-jima	4	2	0 (0)	1	+

1) The not ground-dwelling genera *Amblyopone*, *Crematogaster*, and *Camponotus* are excluded.

recorded before on other islands of the Tokara Islands which comprise a total of 41 ground-dwelling ant species.

The number of species collected in the open entrance area, the forested former village area, and the open lighthouse area (Fig. 2) were 9, 17, and 3 respectively. Three exotic species, *Pheidole fervens* F. Smith, 1858, *Tetramorium bicarinatum* Nylander, 1846, and *Tapinoma melanocephalum* Fabricius, 1793, were obtained from the entrance and/or former village areas (Table 1).

4. Discussion

Of the 23 ground-dwelling ant species found on Gaja-jima Island, 3 (13%) have been recorded only from the Palearctic region and 20 (86.9%), including the three exotic species, have distributions on the both sides of the Watase's line (Table 1). Accordingly, all but three ant species found in this study were distributed regardless of Watase's line. Although Watase's line have been postulated as the boundary between Palearctic and Oriental regions for animal geographical distributions (Kuroda 1939), ants often have wide distributions in the Ryukyu archipelagos (Yamane *et al.* 1999). While *A. famelica*, *A. japonica*, and *C. yamaokai* had their southern distribution limit on Yaku-shima Island before this study (Yamane *et al.* 1999), they were also found to be on Gaja-jima

Island. Because the Tokara Islands are not oceanic islands, the three species could have existed on Gaja-jima Island before it was isolated geographically from the main land of Japan, including Yaku-shima Island. These results suggest that Watase's line might have no clear meaning on geographic distributions of ants.

The three exotic ants recorded from Gaja-jima Island are widely distributed in the Tokara Islands: *P. fervens* and *T. bicarinatum* on Kuchino-shima, Nakano-shima, Suwanose-jima, Taira-jima, Akuseki-jima, Takara-jima and Yokoate-jima islands, and *T. melanocephalum* on Kuchino-shima, Nakano-shima, Suwanose-jima, Taira-jima and Takara-jima islands. Gaja-jima Island showed the lowest percent (13.6%) of exotic species compared to most other islands (13.6 – 37.5%), except for two islands having only few ant species (Table 2). Because exotic ants often reproduce and migrate without flights (Holway *et al.* 2002), human activities would be required to spread their distributions from an island to another. Minor human activities, such as lighthouse repairing, should have small contributions to the invasion of exotics, because it cannot carry large stuffs hiding a fraction of a colony. Ants can spread their distributions over a sea also by rafting (Abe *et al.* 2012). However, rafting to Gaja-jima Island from other islands is not very likely, because the Kuroshio Current flows from the west to the east of the Tokara Islands. Some ex-

otic ants in the Ryukyu archipelago were recorded in the early years of the 20th century. For instance, the invasive yellow crazy ant, *Anoplolepis gracilipes* F. Smith 1857, was found on Amami-Oshima Island in 1930 (Wetterer 2005). Though the precise information on the date the three exotic species invaded is not available, the chance that those three species invaded before 1970 is relatively high compared to that it happened after 1970, because human activities by inhabitants on Gaja-jima Island practically ceased by 1970. Therefore, it would be most likely that the three Gaja exotics invaded Gaja-jima Island already before left by residents.

Information about the ant fauna on the Tokara Islands is insufficient, including this preliminary report on ground-dwelling ants of Gaji-jima Island. Accordingly, more detailed surveys are needed to clarify distributional differences of ant fauna among islands in the Ryukyu archipelago.

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