J. Fac. Agr., Kyushu Univ., **59** (1), 71–76 (2014)

Changes of Species Diversity of Ants Over Time: a Case Study in Two Urban Parks

Sang–Hyun PARK[1]*, Shingo HOSOISHI[1], Kazuo OGATA[1] and Eiiti KASUYA[2]

Institute of Tropical Agriculture, Kyushu University, Fukuoka, 812–8581, Japan
(*Received October 25, 2013 and accepted November 11, 2013*)

To compare the changes of ant faunas in urban parks over time, we surveyed two parks in Fukuoka City, Japan: Momochi Chuou Kouen (MC) and Minami Kouen (MK), both of which were studied in 1998. The survey was conducted in 2012 using 30–min. time unit sampling with 8 replicates. This sampling method is exactly the same as the one executed in 1998. In MC, 17 species were collected and estimated species number was 18.75±1.75 by Jack–Knife method. Compared with the data of 1998, the collected species number and estimated species number were almost same (17 spp. with 18.75±1.15 spp. in 1998). Changes of species composition could not be detected over time. On the other hand, the result of MK showed 23 collected species (20 spp. in 1998) with 28.25±2.56 estimated species (24.38±2.63 spp. in 1998). In MK, number of species and change of species composition cannot be commented, because the sampled species numbers were too low for comparing with the estimated species number.

Key words: over time, species composition, species number, urban park

INTRODUCTION

A conspicuous consequence of urbanization is the creation of habitat islands (fragments or patches) within a matrix of urban land use (Davis and Glick, 1978; Niemelä, 1999). Within cities, urban parks provide a significant opportunity to retain some of the natural biodiversity. Understanding the characteristics of areas that enhance biodiversity is critical in order to preserve and manage them effectively (Niemelä, 1999; McIntyre *et al*., 2001). Studying ecological processes in urban environment is a relatively new direction in ecology (Grimm *et al*., 2000; Zipperer *et al*., 2002). Many ecologists have tried to assess the characteristics of urban ecosystems by using the most important and functionally crucial group such as plants, mammals and arthropods (Chernousova, 1996; McKinney, 2008).

Ants play a key role on the structure and function of many terrestrial ecosystems (Wilson, 1987), including urban environments (Thompson and McLachlan, 2007). Ants are important agents of soil turnover, nutrient redistribution, and various disturbances (Folgarait, 1998). Each ant species has particular physiological and behavioral characteristics that allow them to utilize a particular habitat, slight changes in microhabitat conditions can shift and change the community composition (Sanders and Gordon, 2000).

Comparisons of species richness and composition of ant species in urban areas over time have been so far limited. Many studies have focused on the inventory of ants (Antonova, 2005), comparison of communities in different habitats (Uno *et al*., 2010), changes of diversity followed by environmental changes (Underwood and Fisher, 2006) or implicate urbanization as the major cause of extinctions (Thompson and McLachlan, 2007; Clarke *et al*., 2008; Sanford *et al*., 2008). However, for the correct evaluation of the spatial difference we need to understand the temporal difference of ant community structure within same environment.

The present study aims to investigate whether species richness and species compositions changes in urban parks over time. To assess the temporal comparison of ant communities, a previous record of urban parks which did not experience environmental changes is necessary. So, we use the data on two urban parks presented by Ogata *et al*. in 1998.

MATERIALS AND METHODS

To compare the species diversity of two urban parks over time, the study sites and sampling method followed those in Ogata *et al.* (1998).

Study area

Sampling was carried out in two urban parks, Momochi Chuou Kouen (MC) and Minami Kouen (MK) of Fukuoka City, Japan. Both parks are located in the central residential area of Fukuoka City (Fig. 1). MC was established on reclaimed land in Hakata Bay in

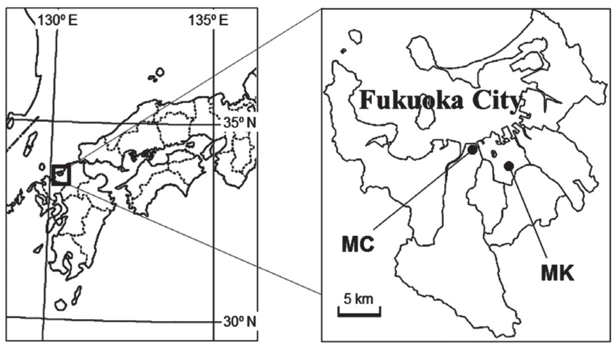

Fig. 1. Location of study sites. MC, Momochi Chuou Kouen; MK, Minami Kouen.

[1] Institute of Tropical Agriculture, Kyushu University
[2] Faculty of Science, Kyushu University
* Corresponding author's email: shpark@agr.kyushu–u.ac.jp

1988, with an area of 40,013 m^2. The park is an artificial open space: the central portion is a football ground and the peripheral area is predominantly grassland with planted trees and shrubs. MK was established on a low hill side in 1941 with an area of 294,799 m^2. The park is a woody conservation area and densely covered with higher broad–leaved trees.

Sampling

To compare the ant assemblages of the two urban parks in the equal sampling effort, 30–min. Time unit sampling (TUS) was carried out. The method was to collect as many species as possible in 30 minutes by visual/manual search on the ground surface, under stones or wood bark, and around the base of tree trunks using aspirators, sifter, pans, and vials with 70% ethanol. Sampling was carried out from April and July 2012. In each park, the 30–min. TUS were repeated 8 times.

Data analysis

To calculate the species accumulation by samplings and to estimate the number of species by Jack–Knife method, a software package EstimateS (Colwell, 2005) was used. To assess species composition in two parks or of each park over time, we computed the similarity by Jaccard's index, which is calculated as $S=[a/(a+b+c)]\times 100$, where S is the similarity over time and a=the number of species found in both years, b=number of species found only in 1998, and c=the number of species found only 2012, from presence–absence data (Radomski and Goeman, 1995). Values of Jaccard's index range from 0% (no species in common) to 100% (complete overlap in species compositions). In addition, to confirm the difference of ant species composition over time, we used Monte Carlo test using software, R. In the Monte Carlo test, a run consists of 1,000 trials.

RESULTS

Comparison of species diversity between parks

Table 1 shows a list of species and the presence of each species in the parks. Through the surveys in 1998 and 2012, a total of 38 species belonging to 23 genera of six subfamilies were sampled from the both parks. Nine species were common between two parks in 2012 and six in 1998.

According to their distribution range, the species listed in Table 1 were divided into two groups: eurychoric species which have a wide range of distribution (labeled as E in Table 1) and stenochoric species which have a narrow range (labeled as S in Table 1). We followed the categorization of species by Ogata *et al.* (1998). The ratio of the eurychoric to stenochoric species was 0.59 in MC (0.71 in 1998) and 0.30 in MK (0.25 in 1998).

The relative characteristics of two parks are the same as in Ogata *et al.* (1998) in terms of quantity and quality of species diversity. Higher species number and higher ratio of stenochoric species, or the species having narrow range of distribution, were observed in MK.

Comparison of species number over time

The species collected in the surveys of 1998 and 2012 are exactly the same in number (31 spp.) but this is not true in site level. In MC, 17 species were collected and the number of species estimated was 18.75±1.75 by Jack–Knife method (Table 2). Compared with the data of 1998 (Ogata *et al.*, 1998), the collected species number and estimated species number were almost same (17 spp. with 18.75±1.15 spp. in 1998). The species accumulation curves of MC in 1998 and 2012 reached the horizontally stable level (Fig. 2), indicating that the sampling effort was sufficient to represent the communities in both years.

In MK, the result showed 23 collected species (20 spp. in 1998) with 28.25±2.56 estimated species (24.38 ±2.63 spp. in 1998). Compared with the data of previous time (Ogata *et al.*, 1998), the collected species number was too low comparing with estimated species number. In addition, the species accumulation curves of MK in 1998 and show incline to increase (Fig. 2), indicating that the sampling effort was not sufficient to represent the communities in both years. Since the list of species in MK is far from complete and there is a strong possibility of many additional species, the results cannot be used directly. Therefore, it is difficult to confirm about new species or no recorded species.

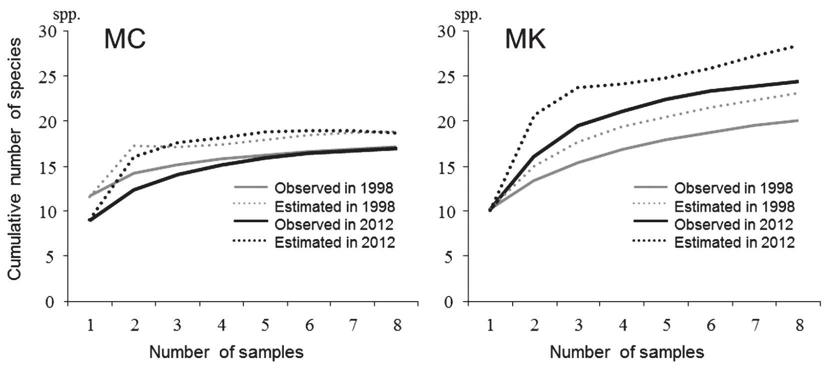

Fig. 2. Species accumulation two study sites surveyed in 1998 and 2012. MC, Momochi Chuou Kouen; MK, Minami Kouen.

Table 1. List of species. MC; Momochi Chuou Kouen; MK, Minami Kouen; S, stenochoric (E Asia); E, eurychoric (Oriental or beyond); hk, Hokkaido; hn, Honshu; sh, Shikoku; ry, Ryukyus

Code	Taxa	Sample				Distribution
		MC		MK		
		1998	2012	1998	2012	
	Amblyoponinae					
01	*Amblyopone silvestrii*			+		S: hk, hn, sh, ry; Korea, Taiwan
	Proceratiinae					
02	*Proceratium watasei*			+	+	S: hn, sh; Korea
	Ponerinae					
03	*Hypoponera sauteri*			+	+	S: hn, sh, ry; Taiwan
04	*Pachycondyla chinensis*	+	+	+	+	E: hn, hk, ry; China, Korea, Taiwan, New Zealand
05	*Ponera scabra*			+		S: hn, sh; Korea
06	*Proceratium itoi*			+		S: hn, sh, ry
	Myrmicinae					
07	*Aphaenogaster famelica*			+	+	S: hk, hn, sh, ry; China
08	*Crematogaster matsumurai*	+	+		+	S: hk, hn, sh; Korea
09	*Crematogaster osakensis*			+	+	S: hk, hn, sh; Korea, China
10	*Crematogaster teranishii*				+	E: sh, ry; Korea
11	*Monomorium chinense*	+	+		+	S: hn, sh, ry; China, Taiwan
12	*Monomorium intrudens*		+	+	+	S: hn, sh, ry; Korea
13	*Pheidole noda*	+	+	+	+	E: hn, sh; Taiwan, China, SE Asia, India
14	*Pheidole pieli*				+	S: sh, ry; China, Korea
15	*Pristomyrmex punctatus*	+	+	+	+	E: hk, hn, sh, ry; Korea, China, Taiwan, SE Asia
16	*Pyramica benten*				+	S: hn, sh
17	*Pyramica canina*			+		S: hn, sh
18	*Pyramica membranifera*	+				E: hn, sh, ry
19	*Solenopsis japonica*	+	+			S: hk, hn, sk, ry; Korea
20	*Strumigenys lewisi*			+	+	E: hk, hn, sh, ry; Korea, China, Taiwan, SE Asia
21	*Temnothorax congruus*		+			E: hk, hn, ry; Korea
22	*Temnothorax spinosior*		+			E: hk, sh, Korea
23	*Temnothorax koreanus*				+	S: hk, hn, ry, Korea
24	*Tetramorium bicarinatum*	+	+			E: hn, sh, ry
25	*Tetramorium nipponense*			+	+	S: hn, sh,ry; China, Taiwan, Vietnam, Bhutan
26	*Tetramorium tsushimae*	+	+			E: hk, hn, sh; Korea, China
27	*Vollenhovia benzai*			+	+	S: sh, ry
	Formicinae					
28	*Camponotus japonicus*	+	+		+	S: hk, hn, sh; Korea, China
29	*Camponotus keihitoi*				+	S: hn, sh; Korea
30	*Camponotus vitiosus*	+	+	+	+	S: hn, sh; Korea
31	*Formica hayashi*			+	+	S: hk, hn, sh; Korea
32	*Formica japonica*	+				E: hk, hn, sh; Korea, China, Far East Russia, Mongolia, Taiwan
33	*Lasius alienus*			+		S: hk, hn; Korea, China
34	*Lasius japonicus*	+	+	+	+	E: hk, hn; Korea, China, Eurasia
35	*Nylanderia amia*	+	+			E: hn, ry; Taiwan, SE Asia, USA
36	*Nylanderia sakurae*	+	+			S: hk, hn, sh; Korea
37	*Nylanderia flavipes*	+		+	+	E: hk, hn, sh; Korea, China, Taiwan, USA
	Dolichoderinae					
38	*Ochetellus glaber*	+	+			E: hn, sh, ry; SE Asia, Australia
	Total	17	17	20	23	

Table 2. Estimated species number and similarity of ant communities. MC; Momochi Chuou Kouen; MK, Minami Kouen

	MC		MK	
	1998	2012	1998	2012
Estimated species number (Jack–Knife)	18.75 ± 1.75	18.75 ± 1.75	24.38 ± 2.63	28.25 ± 2.56
	Temporal similarity		Spatial similarity	
	MC (1998–2012)	MK (1998–2012)	MC–MK (1998)	MC–MK (2012)
Jaccard's Index	70.00	53.57	19.35	29.03

Comparison of species composition over time

The similarity of species composition in each park over time was 70.00% in MC and 53.57% in MK (Table 2). In MC, three species (*Formica japonica, Nylanderia flavipes*, and *Pyramica membranifera*) were not found in 2012 and 3 species, *Monomorium intrudens, Temnothorax congruus*, and *Temnothorax spinosior* were newly recorded. These might be caused by species turnover, but we cannot decide the exact conclusion. Firstly, the estimated number shows, as mention in previous section, 3 additional species both in 1998 and 2012, so that 3 species are within sampling error. Second, the Monte Carlo simulation showed that species composition was not significantly changed over time ($P<0.05$). In the case of MK it was further difficult to mention about species composition over time because of insufficient sampling efficacy as discussed above.

Frequency of occurrence of the species over time

The frequencies of occurrence in each species were represented by the number of samples in each park over time (Fig. 3). Six species were still common in MC over time: *Tetramorium tsushimae, Camponotus japonicus, Crematogaster matsumurai, Monomorium chinense, Pachycondyla chinensis* and *Nylanderia sakurae*. However, other species (*Tetramorium bicarinatum, Solenopsis japonica* and *Ochetellus glaber*) were rare in this time. *Monomorium intrudens, Temnothorax congruus*, and *Temnothorax spinosior* were new recorded, but their frequencies were rare.

In MK, three species were still common over time: *Pheidole noda, Aphaenogaster famelica* and *Crematogaster osakensis*. However, *Vollenhovia benzai* was rare in this time.

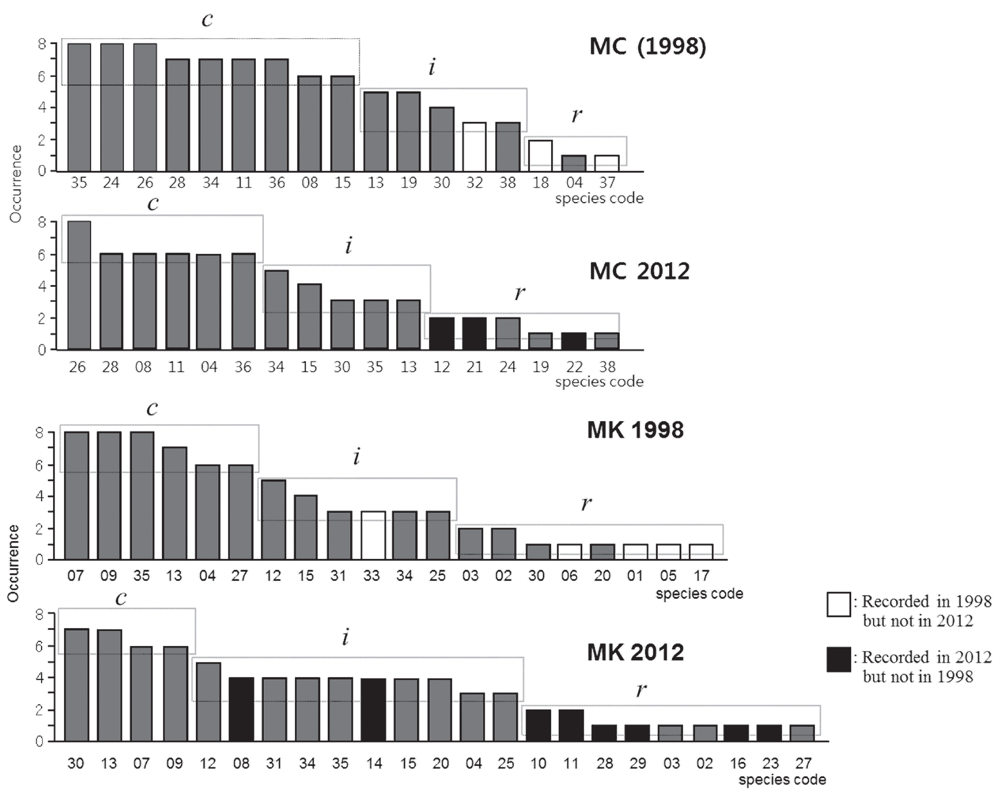

Fig. 3. Frequency of occurrence of two study sites surveyed in 1998 and 2012. MC, Momochi Chuou Kouen; MK, Minami Kouen. Frequency is categorized into 3 levels: *c*= commonly sampled with frequencies of 6–8; *i*= intermediately sampled with frequencies of 3–5; *r*= singleton and doubleton species.

DISCUSSION

The result shows that the characteristics of two parks have not changed over time in terms of quantity and quality of species diversity. Higher species number and higher ratio of stenochoric species in MK reported in 1998 were again observed in 2012. Our analysis of the comparison between the data in 1998 and 2012 within same park suggested that species richness is constant, but that the changes of species composition cannot be detected both in MC and MK even while the values of similarity index were low at 70 and 54, respectively.

To see the change of species composition, we need an exact inventory of species. The sampling method adopted here is a kind of direct sampling. In general, the direct sampling is suitable to check species richness but is weak for comparability (Bestelmeyer *et al*., 2000). TUS is designed to cover the weakness by repeated samplings using a fixed period of time as a unit. However, the gap between observed species and estimated species number suggested that the result is not a complete inventory of species, especially in the case of MK. Indeed, Ogata (1999) reported 42 species in their detailed survey of MK and most of the species that are "newly recorded in 2012" are covered in their list. Thus the observed difference of species composition does not always reflect the invasion or extinction of species.

The similarity index is a tool for comparing the species compositions of two communities, but it should be used carefully. Seemingly the similarity index of the present study may imply that the difference of ant community in MK over time is higher than in MC. But this is not true because of the poor quality of data in MK. On the other hand, the data of MC in 1998 and 2012 represents saturated accumulation curve of species richness. The value of similarity index (70.00%) documents that the temporal species turnover occurred in three species. But our Monte Carlo test did not confirm the statistical significance.

In conclusion, there is no significant change in species number between the ant communities in fourteen years before and in present. For the species composition, even the value similarity index shows 70% or 54%, we could not detected the occurrences of species turnover. In other words, the value of similarity index depends on the sampling quality that might include the sampling error. The careful application of the similarity index is necessary.

ACKNOWLEDGMENTS

This work was supported in part by Global COE Program (Center of excellence for Asian conservation ecology as a basis of human–nature mutualism), MEXT, Japan.

REFERENCES

Antonova, V. 2005 Species diversity and distribution of ants in different habitats in the parks of the city of Sofia. *In* "Biodiversity, Ecosystems, Global changes. I–st National Scientific Conference in Ecology." ed. by M. Chipev and V. Bogoev, Petekston Press, Sofia, pp. 231–236

Bestelmeyer, B. T., D. Agosti, L.E. Alonso, C. R. F. Brandao, W. L. Jr. Brown, J. H. C. Delabie and R. Silvestre 2000 Field techniques for the study of ground–dwelling ants: an overview, description, and evaluation. *In* "Ants: Standard Methods for Measuring and Monitoring Biodiversity" ed. by D. Agosti, J. D. Majer, L. E. Alonso and T. R. Schultz, Smithsonian Institution Press, Washington, DC, pp. 122–154

Chernousova, N. F. 1996 Effects of urbanization on communities of small mammals in park–forests in a large industrial center. *Russ. J. Eco*., **27**(4): 278–283

Clarke, K. M., B. L. Fisher and G. LeBuhn 2008 The influence of urban park characteristics on ant (Hymenoptera, Formicidae) characteristics. *Urban Ecosyst*., **11**: 317–334

Colwell, R. K. 2005 EstimatesS: statistical estimation of species richness and shared species from samples, Version 7.5 User's Guide and application published at: http://puri.ocic.org/estimates

Davis, A. M. and T. F. Glick 1978 Urban ecosystems and island biogeography. *Environ. Conserv*., **5**: 299–304

Folgarait, P. J. 1998 Ant biodiversity and its relationship to ecosystem functioning: a review. *Biodivers. Conserv*., **7**: 1221–1244

Grimm, N. B., M. Grove, S. T. A. Pickett and C. Redman 2000 Integrated approaches to long–term studies of urban ecological systems. *BioScience*, **50**: 571–584

McIntyre, N. E., J. Rango, W. F. Fagan and S. H. Faeth 2001 Ground arthropod community structure in a heterogeneous urban environment. *Landscape Urban Plan*., **52**: 257–274

McKinney, M. L. 2008 Effects of urbanization on species richness: A review of plants and animals. *Urban Ecosyst*., **11**: 1573–1642

Niemelä, J. 1999 Ecology and urban planning. *Biodivers. Conserv*., **8**: 119–131

Ogata, K. 1999 A study on the factors affecting biodiversity monitoring. A report for the Grant–in–Aid for Scientific Research, MEXT Japan for the years 1996 –1998. p. 153 (In Japanese)

Ogata, K., Y. Takematsu and S. Urano 1998 Species diversity of ants in two urban parks (Hymenoptera: Formicidae). *Bull. Inst. Trop. Agr. Kyushu Univ*., **21**: 57–66

Radomski, P. J. and T. J. Goeman 1995 The homogenizing of Minnesota lake fish assemblages. *Fisheries*, **20**: 20–23

Sanders, N. J. and D. M. Gordon 2000 The effects of interspecific interactions on resource use and behavior in a desert ant. *Oecologia*, **125**: 436–443

Sanford, M. P., P. N. Manley and D. D. Murphy 2008 Effects of urban development on ant communities: implications for ecosystem services and management. *Conserv. Bio*., **23**: 131–141

Thompson, B. and S. McLachlan 2007 The effects of urbanization on ant communities and mymecochory in Manitoba, Canada. *Urban Ecosyst*., **10**: 43–52

Underwood, E. C. and B. L. Fisher 2006 The role of ants in conservation monitoring: if, when, and how. *Biol. Cons*., **132**: 166–182

Uno, S., J. Cotton and S. M. Philpott 2010 Diversity, abundance, and species composition of ants in urban green spaces. *Urban Ecosyst*., **13**: 425–441

Wilson, E. O. 1987 The little things that run the world (The importance and conservation of invertebrates). *Conserv. Bio*., **1**: 344–346

Zipperer, W. C., J. Wu, R. V. Pouyat and S. T. A. Pickett 2002 The application of ecological principles to urban and urbanizing landscapes. *Ecol. Appl.*, **10**(3): 685–688