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Comparative Studies of Ant Faunas of Korea and Japan I. Faunal Comparison Among Islands of Southern Korea and Northern Kyushu, Japan

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Abstract. The faunal characteristics of ants in the islands of southern Korea and northern Kyushu of Japan were investigated. The species-area plots of 10 islands in log-log transformation showed a statisfactory of straight line with a slope parameter of 0.136 and a intercept parameter of 1.256, though the slope of the Korean set had lower value than that in northern Kyushu islands.

A cluster analysis using a similarity index (Nomura-Simpson's Coefficient) showed that islands of this area can be divided into 2 groups at the level of 67%. That is, the species composition of 7 Korean islands was similar to that of the mainland of southern Korea, while that of 3 Japanese islands (Tsushima, Iki and Hirado-shima) was similar to the mainland of northern Kyushu.

Implications of the slope parameter in the species-area relationship, hypotheses on the faunal cluster formation, and the pattern of nested sets in the ant assembleges were discussed.

Introduction

Recently, the information on the distribution of ants in Korea and Japan have been rapidly increasing with the progress of the taxonomic studies (*e.g.* Choi *et al.*, 1993; Choi & Bang, 1993; Terayama, 1992; Terayama *et al.*, 1992; The Myrmecological Society of Japan, 1988, 1989, 1991, 1992). But little has been studied the difference and/or similarity of ant faunas between both areas.

Although Korea and Japan are neighboring regions, the former is a part of a peninsula connecting with northeastern Continental China, while the latter is an island, comprising the four main islands. Korea has relatively low annual precipitation and mostly covered with cool temperate declivious woods in potential vegetation. On the other hand, Japan extends in an area of about 3,000 km northeast to southwest and its southwest part is mostly covered with evergreen broad-leaved forests. How are the distribution of ants related to these geographic, climatic, and other environmental differences between Korea and Japan ?

This study aims to summarize the biogeography of ants of Korea and Japan. In this paper (part I), we will discuss the ant fauna of smaller islands situated between the Korean Peninsula and the Japanese mainland. In the part II, we will extend a faunal comparison to the Korean and Japanese mainlands, and in the last part, analyze the distribution patterns of ants occurred in these areas.

There are many islands between southern and western parts of Korea and northern Kyushu of Japan. Among them, Cheju-do Island and Tsushima Island are larger ones and ants of these islands have been well surveyed (Choi *et al.*, 1985; Choi, 1986; Ogata, 1981, 1989). However, no sufficient faunal comparison of these islands have been made because of a taxonomic impediment. In the course of present study, we made a comparison of specimens collected from many islands of Korea and Japan. This paper attempts to reveal the biogeographic characteristic of ant fauna of islands between Korea and Japan, using quantitative analyses.

Materials and Methods

The data mainly treated in this paper are those from 7 southern Korean and 3 northern Kyushu islands which have been well investigated. The geographical position and size of each island are shown in Fig. 1 and Table 1, respectively.

For the comparison, the data from the following

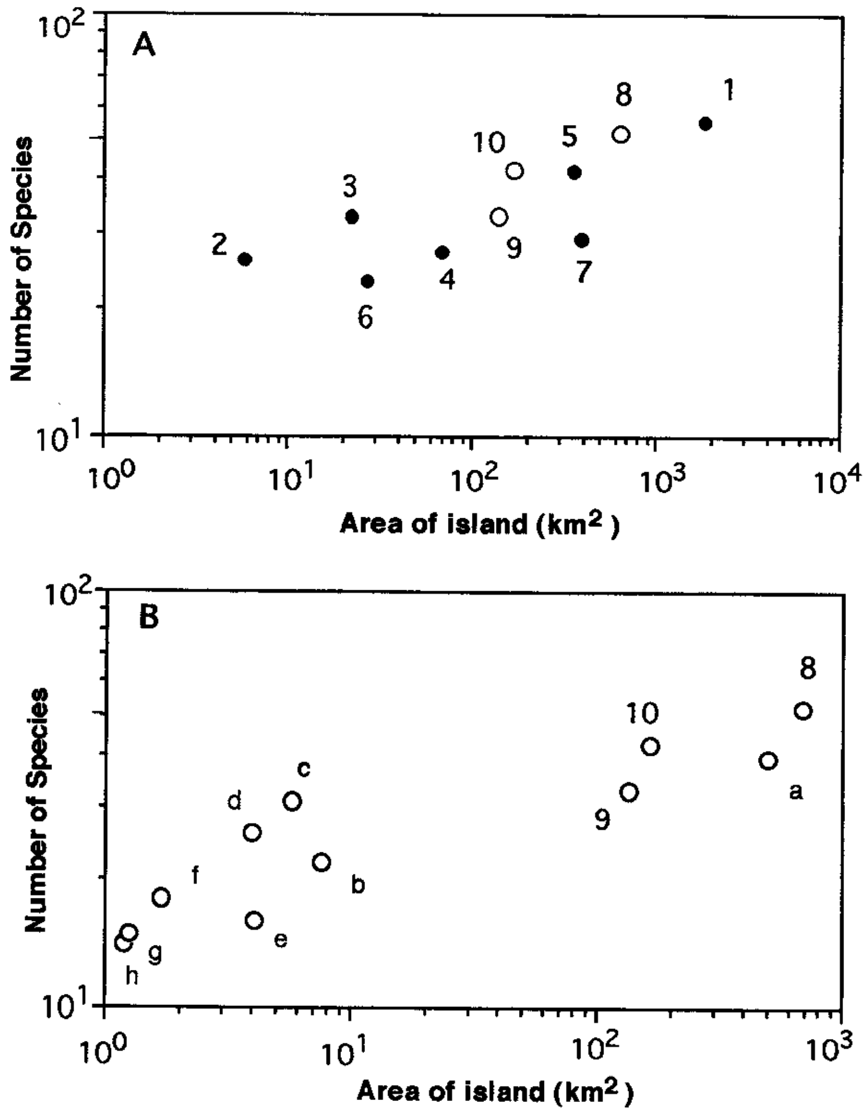

Fig. 2. The species-area relationship for ants of Korean islands (●) and those of Japanese islands (○). The numbers show the codes of Table 1. A: data from 10 islands in Table 1; B: data from 11 islands of northern Kyushu (partly Terayama, 1992), a: the Goto Isls., b: Oh-shima Is., c: Shikano-shima Is., d: Nokono-shima Is., e: the Danjo-gunto Isls., f: Jino-shima Is., g: Aino-shima Is., h: Genjai-jima Is. The regression lines are:

$\log S=1.256+0.136 \log A$ ($r^2=0.626$) for 10 islands of Korea and Japan;

$\log S=1.273+0.120 \log A$ ($r^2=0.594$) for 7 islands of Korea;

$\log S=1.205+0.169 \log A$ ($r^2=0.813$) for 11 islands of northern Kyushu.

These aspects are clearly shown in a cluster analysis of *NSC* using UPGMA method (Fig. 4). That is, the area is classified into 2 major faunal groups; islands of southern Korea and islands of northern Kyushu, at the similarity level 0.67. The fauna of mainland of southern Korea were included in the cluster consist of the islands of southern Korea, and the fauna of mainland of

Table 2. Number of common species (upper triangular matrix) and Nomura-Simpson's Coefficient (lower triangular matrix). For a area code see Table 1.

	1	2	3	4	5	6	7	8	9	10	11	K	J
1	—	25	30	26	39	20	28	33	23	29	29	47	43
2	0.962	—	19	18	23	13	18	20	11	16	16	24	25
3	0.882	0.647	—	17	26	15	23	22	16	18	17	26	24
4	0.963	0.692	0.630	—	25	17	20	20	14	17	17	24	24
5	0.907	0.885	0.824	0.926	—	20	29	28	20	26	22	36	32
6	0.867	0.565	0.529	0.739	0.870	—	16	13	13	15	16	20	20
7	0.966	0.692	0.706	0.741	1.000	0.552	—	22	19	22	20	27	25
8	0.635	0.769	0.667	0.741	0.667	0.565	0.759	—	25	33	34	32	48
9	0.670	0.423	0.485	0.519	0.606	0.565	0.655	0.758	—	30	27	22	32
10	0.690	0.615	0.545	0.630	0.619	0.652	0.758	0.786	0.909	—	33	29	43
11	0.518	0.615	0.515	0.630	0.524	0.696	0.690	0.654	0.818	0.786	—	30	52
K	0.839	0.923	0.788	0.889	0.857	0.870	0.931	0.615	0.667	0.690	0.469	—	48
J	0.768	0.962	0.727	0.889	0.762	0.870	0.862	0.923	0.967	1.000	0.813	0.738	—

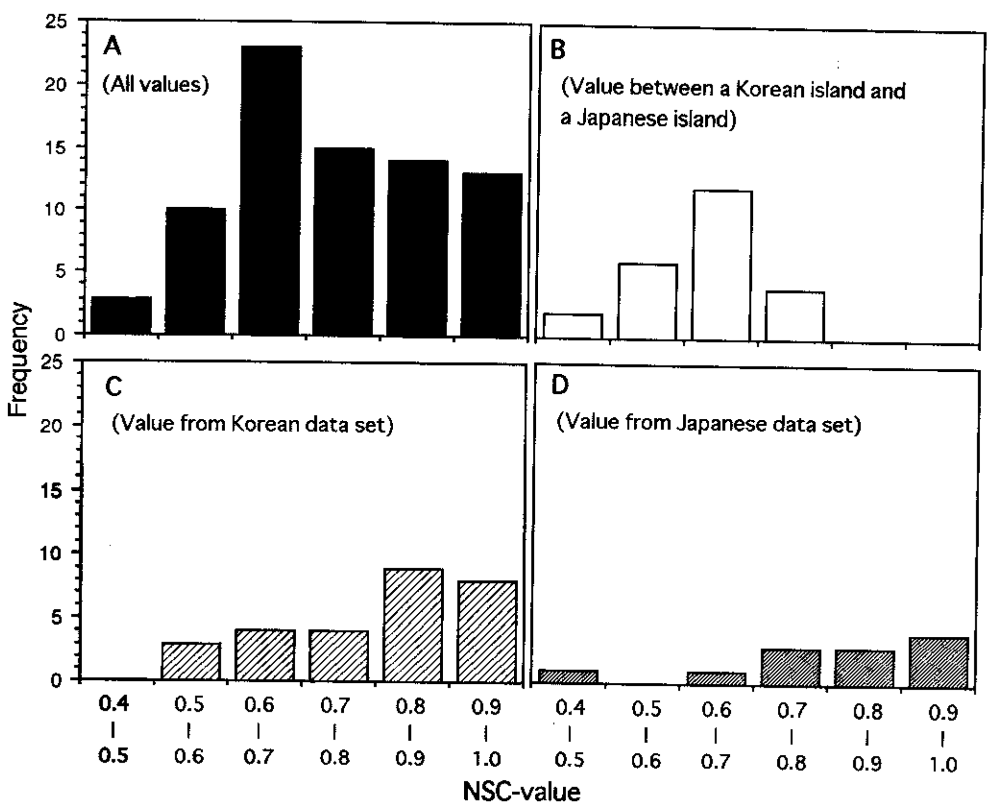

Fig. 3. Frequency distributions of *NSC*-value in different regional data sets. A: *NSC*-value from whole data set of Table 2; B: *NSC*-value from the data set of a Korean island—a Japanese island; C: *NSC*-value from the Korean data set; D: *NSC*-value from Japanese data set.

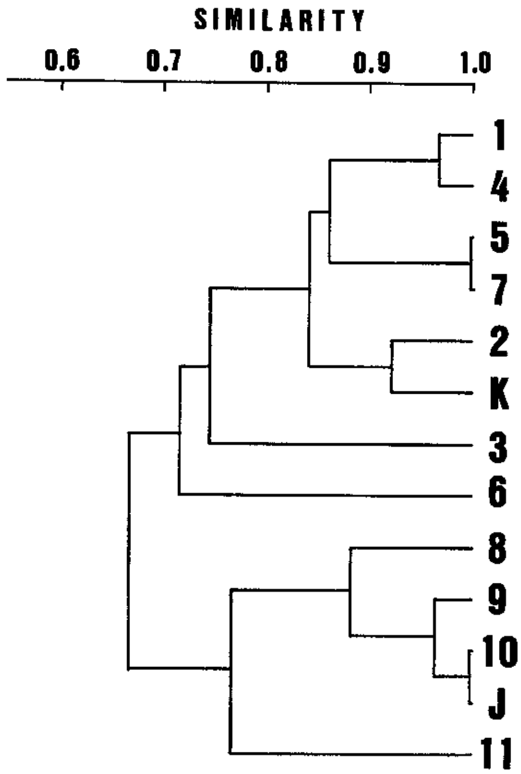

Fig. 4. Dendrogram showing the similarity among ant species compositions of the study area. 1: Cheju-do Is., 2: Hong-do Is., 3: Taehuksan-do Is., 4: Tolsan-do Is., 5: Namhae-do Is., 6: Saryang-do Is., 7: Koje-do Is., 8: Tsushima Is., 9: Iki Is., 10: Hirado-shima Is., 11: Yakushima Is., J: mainland of northern Kyushu, K: mainland of southern Korea.

Kyushu in the cluster consist of the islands of southern Kyushu. In the former cluster, the *NSC* between Saryang-do Is. and the other Korean areas has the lowest value of 0.72. In the latter cluster, on the other hand, the lowest value of *NSC* is that between Yakushima Is. and the rest of Japanese areas, though the areas excluding Yakushima form a rather compact cluster at the similarity level more than 0.88 in this data set. High similarity more than 0.90 is found in the following pairs: Cheju-do Is. — Tolsan-do Is.; Namhae-do Is. — Koje-do Is.; Hong-do Is. — mainland of southern Korea; Hirado-shima Is. — mainland of northern Kyushu; Iki Is. — (Hirado-shima Is. + mainland of northern Kyushu).

Discussion

Species-area relationship

Why is the slope parameter in Korean island data lower than that in Japanese island data ? There are several possible explanations. The first one is an effect of a difference of latitudinal gradient rates in different geographical scales. It is a general biogeographical pattern that the diversity of organisms increase from higher latitude to lower one. But the rate of increase in species richness with decreasing latitude varies in geographic scales. Table 3 and Fig. 5, which adopted from Terayama (1992) and Ogata & Choi (1993), show an example of this pattern. The implication of this phenomenon is that the range of the number of species in areas of higher latitude is narrower than in lower latitude, and thus the slope parameter would be lower in the areas of higher latitude.

This hypothesis would also be applicable for explaining the difference between the slope parameters of Korean island data and of Japanese island data, both situated in almost same latitudinal locations. The species composition of Korean islands contains higher ratio of the species of the Holoarctic genera such as *Myrmica, Lasius* and *Formica*, while that of Japanese islands contains higher ratio of species of ponerine and dacetine which are distributed from warm-temperate to tropical zones. In effect, the fauna of the former areas seems to be similar to the area of higher latitude, and thus it would have lower value of the slope parameter.

The second explanation is somewhat related to the habitat heterogenity. In this context the diverse habitats is roughly expressed by the diversity of the plant species. Terayama (1992) indicated that the number of ant species of islands are predicatable by the number of native plant species of islands more precisely than the island areas. When this relationship is also held on the islands of southern Korea, fewer number of ant species in larger Korean islands can be explained by fewer number of native plant species, because the intercept parameter of the species-area curve is almost the same as that of islands of northern Kyushu. However, this hypothesis should wait for further study because the flora of these islands

Table 3. Latitudinal gradients in species richness at different levels of area size. Data from Terayama (1992) and Ogata & Choi (1993).

Region	Area (km^2)	Latitude (N) (Median)	No. of species	Latitudinal gradient
Hokkaido	79,000	41°50′–45°30′ (43°40′)	61	
Shikoku	18,000	32°30′–34°30′ (33°30′)	96	S=357.92−7.11L (S: No. of spp., L: latitude)
Kyushu	36,000	31°00′–34°00′ (32°30′)	123	
Taiwan	36,000	21°45′–25°15′ (23°30′)	205	
Rishiri-to Is.	183	(45°15′)	16	
Hirado-shima Is.	165	(33°15′)	40	S=79.58−1.36L
Iki Is.	134	(33°45′)	33	
Miyako-jima Is.	148	(24°45′)	43	

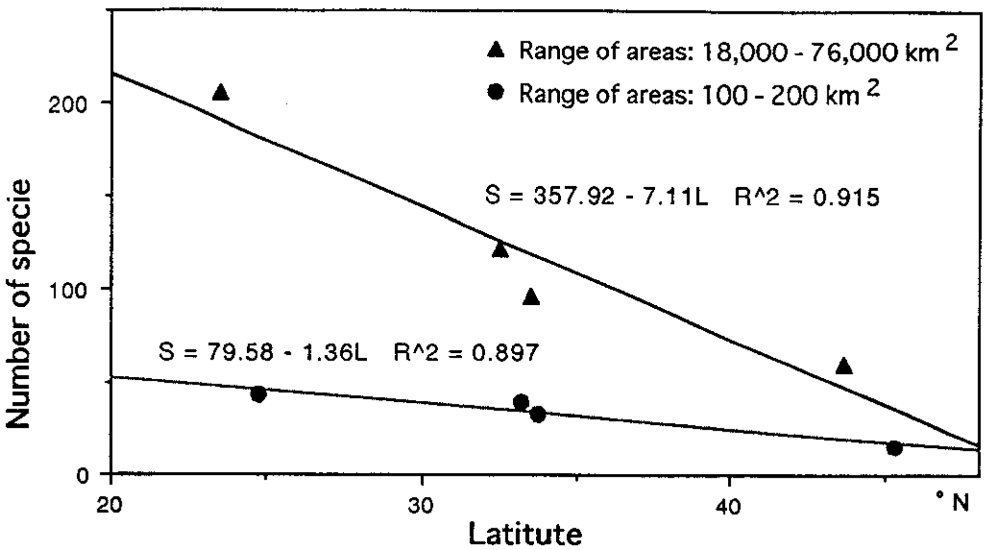

Fig. 5. Latitudinal gradients of ants at different levels of area size (from Table 3).

is poorly known.

Faunal similarity

The faunal differences in this area can be explained by the affinity of composed species. The distribution pattern of each species will be discussed in the part III of this study. Here we provisionally divide the species into two groups: those distribute in warmer temperate region and cooler temperate region. In southern Korea and adjacent islands, the former species such as ponerines and dacetines are fewer, while the latter species such as those of *Myrmica*, *Lasius*, *Formica* are richer comparing with the fauna of northern Kyushu and adjacent islands. Thus a climatic factor would affect, directly or indirectly, on the species composition. In particular, a 120°C· month isothermal line of Kira's warmth index (a kind of accumulative temperature calculated by $WI=\sum(t-5)$: t=average temperature of a month) should be noted, which runs from southwestern Japan through Tsushima to south of Cheju-do

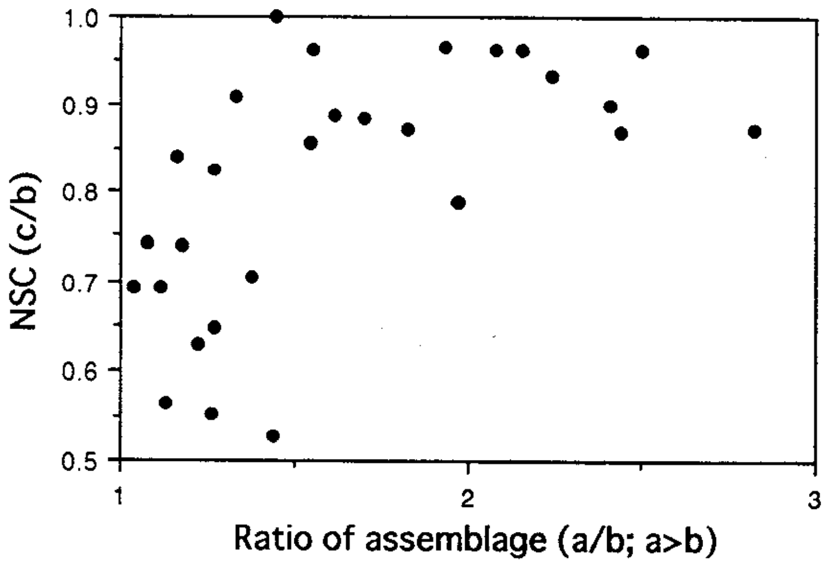

Fig. 6. Relationship between *NSC*-value and ratio of two assemblages. a & b: number of species in two areas, respectively, c: number of common species in the areas.

Island. This line almost agrees with southern limit of distribution of some Oriental or subtropical species, *i.e. Pheidole nodus*, *Cardiocondyla nuda* (Morisita, 1986), and also divides the islands and areas treated in this paper into two major faunal groups stated above.

Another possible explanation is the existence of the Korea Strait as a geographical barrier which lies between Tsushima Is. and Korean Peninsula. Tsushima Is. is located nearer to the Korean Peninsula than the mainland of Kyushu, 52 km far from Korea while 92 km far from Kyushu. But the present analysis shows higher faunal similarity of Tsushima Is. to the mainland of northern Kyushu rather than to the northern Korea. A similar results was obtained by Makihara (1976) in a study of the faunal comparison of Cerambicidae. He concluded that the higher faunal similarity between Tsushima Is. and Kyushu was due to the difference of completion periods of two straits lying north and south of the islands: the Korea Strait and the Tsushima-Kaikyô. The Tsushima-Kaikyô, is 120 m in maximum depth while the Korea Strait is 140 m in maximum depth. So the former connected with the mainland of Kyushu, while the latter was already forming a strait during the last glaciation (Wülm; ca. 20,000 years ago) (Ijiri, 1979). Thus the Korea Strait is more effective barrier than the Tsushima-Kaikyô. The effect of the Korea Strait as a distributional barrier will be further discussed in the part III.

These hypotheses would be examined by more detailed study of ecological and/or physiological characteristics of each species and historical inference of dispersal.

Pattern of increase in species

Hölldobler & Wilson (1990) described a pattern of growing assemblages as follows:

"...on extremely small islands only species A-C might be present, on somewhat larger islands A-F, on still larger islands A-H, and so on. The sequence is seldom if ever of the form A-C, D-I, K-X, and so forth." (p. 420)

This pattern of species occurrence sequences, or nested sets of growing assemblage, can be examined by several methods (Schoener, 1988). Here we use the Nomura-Simpson's Coefficient again to see this regularity. If the increase of species is caused by a newly additive species set, the *NSC* is constantly expected as 1.0 because the index implies the ratio of common species in a smaller assemblage. Using a data set of Table 2, the relationship between *NSC* and growing

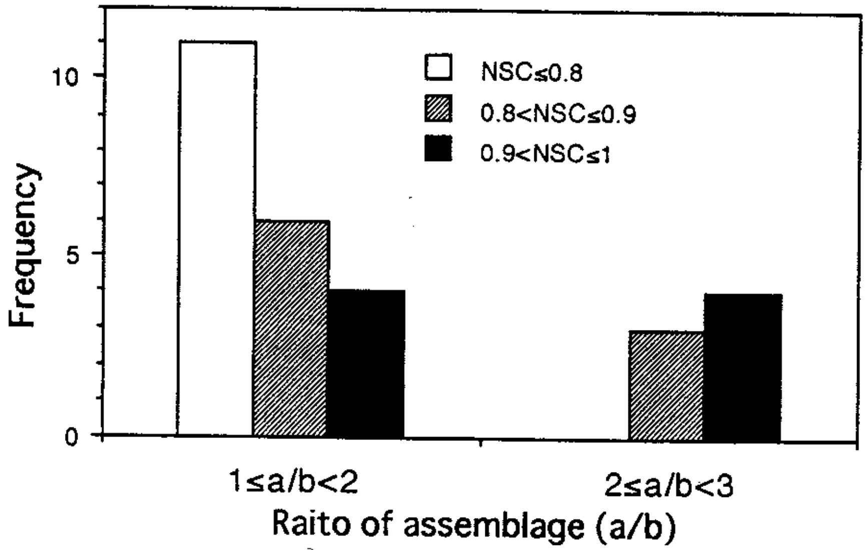

Fig. 7. Frequency distribution of *NSC*-value in different assemblage ratios.

rate of assemblage size was examined. A size of an ant assemblage is expressed by the number of species in an island and the growing rate is shown by a ratio of a/b (a & b: number of species, $a>b$).

Fig. 6 shows that the regularity is not claer when the ratio of assemblages is low. But as a size of an assemblage is twice as large as smaller one, or more, the *NSC*-value is getting close to 1.0. Fig. 7 summarizes the frequency distribution of the *NSC*-values. This examination shows as follows: when a ratio of size in two assemblages is high enough (twice as large as, or more), more than 80% of the species on a smaller island can be expected to occur in the larger islands. This assemblage rule would be applicable for the relatively homogenous areas biogeographically and will not be supported in the areas intercepted by major biogeographical borders. The applicable range must be one of the further subjects.

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韓国および日本のアリ相の比較研究
I. 韓半島南部島嶼および九州北部島嶼間の比較

崔　炳文・緒方一夫・寺山　守

韓国南部の島嶼と日本の九州北部の島嶼間のアリ相について計量的に比較し，生物地理学的属性を論議した．韓国と日本の間の 10 の島々での種数・面積関係は両対数で傾き 0.136，y 切片 1.256 の直線として表わされた．ただし韓国の島々のデータだけでは，傾きがこの値より低くなった．

類似度指数の一つである野村・シンプソン指数で地域間の類似性を計算し，クラスター分析によって，地域ごとのアリ相の類似性を調べた．その結果，調査した 10 の島々および韓国南部と九州北部のアリ相は類似度70%のレベルで，2つのグループに大別され，北部九州の3つの島々（対島，壱岐，平戸島）は北部九州本土と1つのクラスターを，韓国南部の7つの島々は韓国本土南部ともう1つのクラスターを形成することが明らかになった．

以上の結果より，種数・面積関係における傾きのもつ意味，2つのクラスターに大別されることの理由，およびアリ群集の大きさと種類組成のパターンについて論議した．

（崔　炳文：大韓民国清州市秀谷洞 135　清州教育大学．緒方一夫：812　福岡市東区箱崎 6–10–1　九州大学熱帯農学研究センター．寺山　守：182　東京都調布市若葉町 1–41–1　桐朋学園桐朋教育研究所）

Appendix. Distribution data of ants in study area. 1: Cheju-do Is., 2: Hong-do Is., 3: Taehuksan-do Is., 4: Tolsan-do Is., 5: Namhae-do Is., 6: Saryang-do Is., 7: Koje-do Is., 8: Tsushima Is., 9: Iki Is., 10: Hirado-shima Is., 11: Yakushima Is., J: mainland of northern Kyushu, K: mainland of southern Korea.

JFC-code*	Scientific name	Area code												
		1	2	3	4	5	6	7	8	9	10	11	K	J
10102	*Amblyopone silvestrii*	○			○	○			○			○		○
10301	*Proceratium itoi*	○			○								○	○
10302	*Proceratium japonicum*								○		○			○
10303	*Proceratium watasei*													○
10304	*Proceratium* sp. A									○				○
10401	*Discothyrea sauteri*													○
10601	*Ectomomyrmex javanus*	○	○	○	○	○			○	○			○	
10701	*Brachyponera chinensis*	○	○	○	○	○	○	○	○	○	○	○	○	○
10802	*Trachymesopus pilosior*											○	○	○
10901	*Cryptopone sauteri*	○		○		○		○	○	○	○	○	○	○
11001	*Ponera japonica*	○	○	○		○			○		○		○	○
11002	*Ponera scabra*	○				○		○	○	○	○		○	○
11003	*Ponera yakushimensis*											○		
11007	*Ponera* sp. C								○		○	○		○
11101	*Hypoponera nippona*			○									○	
11105	*Hypoponera sauteri*	○		○		○		○	○	○	○	○	○	○
11106	*Hypoponera* sp. C								○		○	○		○
11301	*Odontomachus monticola*											○		
20102	*Cerapachys humicola*								○					
20103	*Cerapachys* sp. A													○
40101	*Myrmica jessensis*	○											○	
40102	*Myrmica ruginodis kotokui*	○	○									○	○	○
40103	*Myrmica kurokii*												○	
40106	*Myrmica* sp. B	○												
40107	*Myrmica* sp. C												○	
40301	*Stenamma nipponense*													○
40302	*Stenamma owstoni*											○		○
40401	*Aphaenogaster famelica*								○	○	○	○		○
40402	*Aphaenogaster osimensis*											○		
40403	*Aphaenogaster smythiesi japonica*	○	○		○	○		○	○		○	○	○	○
40404	*Aphaenogaster tipuna*			○										
40501	*Messor aciculatus*	○			○	○	○			○	○	○	○	○
40601	*Pheidole fervens*											○		
40602	*Pheidole fervida*	○	○	○	○	○	○	○	○			○	○	○
40603	*Pheidole indica*	○					○					○		○
40605	*Pheidole nodus*	○		○		○	○	○	○	○	○	○	○	○
40606	*Pheidole pieli*									○	○	○		○
40701	*Leptothorax acervorum*												○	
40703	*Leptothorax congruus*	○				○		○			○		○	○
40704	*Leptothorax spinosior*	○	○	○		○	○	○		○	○	○	○	○
40705	*Leptothorax koreanus*													○
40709	*Leptothorax* sp. D								○			○		
40801	*Cardiocondyla nuda*											○		○
40901	*Tetramorium bicarinatum*									○	○	○		○
40902	*Tetramorium caespitum*	○	○	○	○	○	○	○	○	○	○	○	○	○
40905	*Tetramorium nipponense*								○	○	○	○		○
41001	*Strongylognathus koreanus*						○							

Appendix. (Continued)

JFC-code*	Scientific name	Area code												
		1	2	3	4	5	6	7	8	9	10	11	K	J
41101	*Monomorium chinense*	○	○	○	○	○	○	○		○	○	○	○	○
41105	*Monomorium intrudens*	○	○	○		○		○	○	○	○	○		○
41107	*Monomorium pharaonis*	○				○							○	○
41108	*Monomorium triviale*			○										
41109	*Monomorium* sp. A											○		
41202	*Solenopsis japonica*	○	○		○	○	○	○	○		○	○	○	○
41401	*Oligomyrmex sauteri*								○	○	○	○		○
41501	*Vollenhovia emeryi*	○		○	○	○	○	○	○	○	○	○	○	○
41504	*Vollenhovia* sp. C											○		○
41801	*Lordomyrma azumai*										○	○		○
41901	*Myrmecina flava*													○
41902	*Myrmecina graminicola nipponica*	○		○					○	○	○	○	○	○
42001	*Pristomyrmex pungens*	○	○	○	○	○	○	○	○	○	○	○	○	○
42101	*Crematogaster laboriosa*								○	○	○	○	○	○
42102	*Crematogaster matsumurai*	○	○	○	○	○	○		○				○	○
42103	*Crematogaster brunnea teranishii*	○	○	○	○	○	○		○		○		○	○
42104	*Crematogaster matsumurai vagula*	○									○	○		○
42106	*Crematogaster osakensis*	○	○	○	○	○		○	○	○	○	○	○	○
42201	*Strumigenys lewisi*	○	○	○	○	○		○	○	○	○	○	○	○
42203	*Strumigenys* sp. A													○
42401	*Smithistruma incerta*									○	○			○
42404	*Smithistruma rostrataeformis*													○
42405	*Smithistruma* sp. A								○					○
42406	*Smithistruma* sp. B											○		○
42501	*Pentastruma canina*													○
42601	*Trichoscapa membranifera*													○
42801	*Kyidris mutica*			○					○					○
42901	*Epitritus hexamerus*													○
42902	*Epitritus hirashimai*								○		○			○
60103	*Leptanilla morimotoi*													○
60105	*Leptanilla tanakai*											○		
70101	*Dolichoderus sibiricus*	○							○			○	○	○
70201	*Ochetellus itoi*	○	○	○	○	○	○	○	○	○	○	○	○	○
70302	*Tapinoma* sp. A											○		○
70401	*Technomyrmex albipes*											○		
70402	*Technomyrmex gibbosus*	○	○										○	○
80103	*Acropyga nipponensis*											○		
80202	*Plagiolepis flavescens*	○	○	○	○	○	○	○	○				○	○
80501	*Paratrechina flavipes*	○	○	○	○	○	○	○	○	○	○	○	○	○
80503	*Paratrechina sakurae*	○	○	○	○	○		○	○			○	○	○
80601	*Lasius alienus*	○				○		○					○	
80602	*Lasius hayashi*								○		○	○	○	○
80603	*Lasius niger*	○	○		○	○		○	○	○	○		○	○
80604	*Lasius productus*								○					○
80605	*Lasius sakagamii*												○	○
80606	*Lasius flavus*			○		○							○	
80607	*Lasius sonobei*											○	○	○
80608	*Lasius talpa*						○					○	○	○
80609	*Lasius hikosanus*													○

Appendix. (Continued)

JFC-code*	Scientific name	Area code												
		1	2	3	4	5	6	7	8	9	10	11	K	J
80610	*Lasius meridionalis*			○									○	○
80611	*Lasius umbratus*								○					○
80612	*Lasius capitatus*												○	
80613	*Lasius fuliginosus*												○	○
80615	*Lasius spathepus*	○	○			○			○		○		○	○
80616	*Lasius teranishii*												○	
80704	*Formica yessensis*					○	○	○					○	
80706	*Formica japonica*	○			○	○	○	○		○	○	○	○	○
80707	*Formica lemani*	○											○	
80709	*Formica* sp. A	○							○	○	○	○	○	○
80801	*Polyergus samurai*												○	○
80902	*Camponotus japonicus*	○			○	○	○	○	○	○	○	○	○	○
80903	*Camponotus obscuripes*								○			○		○
80904	*Camponotus yessensis*													○
80906	*Camponotus devestivus*								○	○		○		○
80911	*Camponotus kiusiuensis*	○	○			○			○			○	○	○
80913	*Camponotus keihitoi*		○											○
80914	*Camponotus quadrinotatus*	○			○								○	○
80915	*Camponotus itoi*	○				○			○	○				
80916	*Camponotus nawai*								○	○	○	○		○
80918	*Camponotus nipponensis*	○											○	
80919	*Camponotus tokioensis*	○	○	○	○	○	○	○	○	○	○		○	○
80920	*Camponotus* sp. G											○		
80922	*Camponotus* sp. H	○			○	○								
81001	*Colobopsis nipponicus*											○		○
81103	*Polyrhachis moesta*								○			○		○
81104	*Polyrhachis lamellidens*	○							○				○	○
00001	*Leptothorax* sp. 1	○		○									○	
00002	*Leptothorax* sp. 2					○							○	
00003	*Camponotus atrox*	○											○	
00004	*Lasius brunneus*	○				○							○	
00005	*Plagiolepis manczshurica*	○		○	○	○	○	○						

*: See Terayama, 1992.