Springtail and Ant Population from Three Western Seashore Areas of Korea

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한국 3개 서해연안에 서식하는 톡토기와 개미 개체군 분석

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Abstract - In order to investigate the population structure and dynamics of halophilous springtails and ants at seashores in Korea, we made quantitative collection from three different sites having different vegetation and environment. The pH, salinity, and electric conductivity of the three sites were measured in order to find environmental factors influencing on their species composition and distribution. In view of the results so far obtained, the species composition and distribution of springtails seemed to depend not so much on pH and vegetation as on soil texture and salinity. On the other side, ant populations seemed to depend on vegetation in sand area and on inundation in both sand area and salt marshes. In all investigated sites, the species diversity in supra littoral zones was higher than in intertidal zones, and among intertidal zones of sand beach and salt marshes it was the highest at the upper zone of the sand beach.

Key words : Halophilous arthropods, Collembola, Formicidae, Community, Biodiversity

Introduction

Ecosystem of tidelands, different from land ecosystems, contains very limited number of species, comprising halophilous community owing to seawater and accumulation of soil salt (Adams 1963), which are still quite stable (Odum 1961).

Especially, primary production of halophilous plants in the Temperate Zone mostly decomposes resulting in its direct transfer to detritus food chain, because few herbivorous animals occur there. Since, the change of soil environments and plant communities give rise to the change of species composition of animal community (Vince *et al.* 1981), the soil insects inhabiting tideland habitat there show quite different trends in species composition from those inhabiting land habitat.

Although temperature and salt concentration in tidelands are easily changeable, they are, compared with land ecosystems, quite attractive to many predators due to large amount of invertebrates feeding on organic particles from seashore plants and planktons. Therefore, the variety of communities of Apterygota along a salt marsh gradient could be indicator of different en-

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vironmental qualities (Ehrnsberger *et al.* 1977). In America, Japan, and European countries, the function of tideland ecosystems have been actively studied since mid-sixties (Odum and Smalley 1959; Smalley 1959; Teal 1962; Hopkinson *et al.* 1978; White *et al.* 1978; Long and Marson 1983).

Collembola inhabits ordinary soils and fallen rotten leaves, but they are often found in a special habitats, tidelands, caves, as well as ant and termite nests (Handschin 1924; Delamare Deboutteville 1958; Paclt 1965; Ashraf 1969; Stebaeva and Grishina 1983; Hölldobler and Wilson 1990; Greenslade 1991).

In America, Japan, and some of European countries, meanwhile, there have been some studies on halophilous springtails of seashores. Investigations were made on their systematics (Uchida and Tamura 1966; Yosii 1971; Scott and Yosii 1972; Christiansen and Bellinger 1988; Thibaud and Christian 1989, 1991), seasonal changes (Maeda and Tanaka 1982; Maeda 1988), influential effect of salinity to springtail populations (Heungens and Van Daele 1978), and morphological adaptation (Palacios-Vergas and Magdalena Vaquez 1989). Although there have been some studies reporting 15 species of Collembola from Korea (Lee and Kim 1994; Thibaud and Lee 1994; Park and Lee 1995; Thibaud and Kim 1995), they were only from terrestrial soils and sea cave, not from tidelands and they were not related to environmental and ecological factors.

All over the world about 8,800 species of ants have been reported (Hölldobler and Wilson 1990, 1994), and some 130 species were from Korea (Kim 1997). Since they are not only conducive to soil fertilization, but also predating on pest insects, they are recognized as economically important group. However, all the ants were from terrestrial soils and no species have been reported from tidelands.

Since there were many reports describing the occurrence of ants and springtails altogether as commensals from ant nests we expected to come across any case in Korea too and see some relationship between the two different insects.

Consequently, we tried to investigate the biodiversity and dynamics of halophilous springtails and ants in seacoasts and the relationship between surrounding environment and vegetation, in order to, eventually, contribute to biodiversity conservation as well as to management of seashore ecosystems.

Material and Methods

1. Site description

Investigations were made for supra littoral and intertidal zones with different plant dominant groups as shown in Table 1 and Figs. 2-4. They are Jokumdari, Songhyŏn-ri, Muan, Chonnam, 34° 59′N, 126° 21′E, Tongho, Kocha'ng, Chonbuk, 35° 23′N, 126° 29′E and Chulp'o seashore, Puan, Chonbuk, 35° 35′N, 126° 40′E (Fig. 1). Tongho is covered with sands and has slopes of 3° ~6°. Jokumdari and Chulp'o are covered with mud and has slopes of 0° ~2°, inside the bank (Table 1).

2. Sampling

For quantitative study, soil collections were made bimonthly for population change analysis for one year, from March 1998 to July 1999. Samplers of the size $10 \times 10 \times 5$ cm were used to collect soils from every two

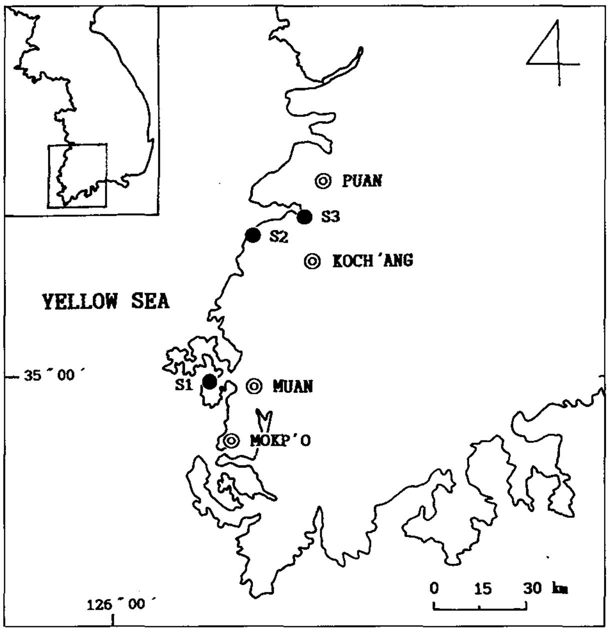

Fig. 1. A map of showing surveyed site in western coast of South Korea. (S1: Chŏllanam-do, Muan-gun, Mangun-myŏn, Songhyŏn-ri, Jokumdari, S2: Chŏllabuk-do, Koch'ang-gun, Haeri-myŏn, Tongho-ri, S3: Chŏllabuk-do, Puan-gun, Chulp'o-myŏn, Chulp'o-ri)

Table 1. Habitat and vegetation in intertidal zones of the three surveyed areas

Site	Habitat	Slope (°)	Soil texture	Vegetation		
				Dominant species	Coverage (%)	Height (cm)
Jokumdari	salt marsh	2	loamy sand	*Enteromorpha linza*	80	
Tongho	sand	6	sand	*Phacelurus latifolia*	80	120
				Zoysia sinica	35	10
Chulp'o	salt marsh	1	silty loam	*Suaeda japonica*	85	45

Table 2. Monthly precipitation and temperature in the month of collection for the period March 1998~July 1999

Site		'98 Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	'99 Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.
Jokumdari	Temperature (°C)		14.4		20.9		26.1		17.9		4.8		3.0	6.8		16.8		24.4
	(daily)		(12.3)		(21.3)		(24.9)		(20.3)		(7.1)		(1.3)	(3.4)		(16.7)		(23.6)
	Precipitation (mm)		129.6		410.8		389.7		64.1		7.0		28.0	129.7		136.7		224.4
*Tongho and Chulp'o	Temperature (°C)	6.4		17.2		25.0		21.8		8.3		0.5		11.1		19.8		
	(daily)	(7.2)		(21.4)		(24.8)		(21.1)		(4.6)		(3.6)		(14.5)		(18.0)		
	Precipitation (mm)	39.5		117.5		241.5		351.5		32.9		28.9		85.0		189.5		

*The same meterological data were used since they were available only from Puan area, near the both surveyed sites.

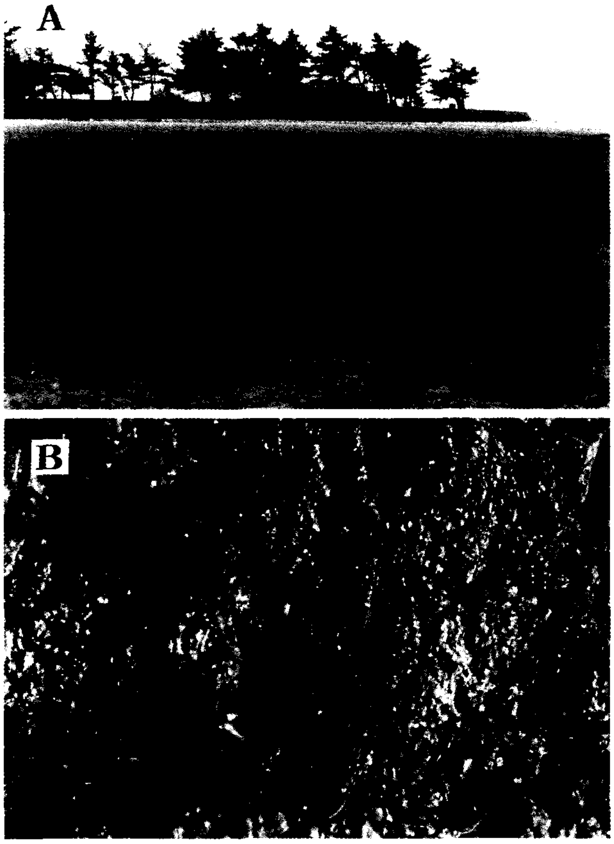

Fig. 2. Photographs showing surveyed sites of Jokumdari. A; pine tree community of supra littoral zone and *Enteromorpha linza* community of mid- and low intertidal zone, B; photograph of *Enteromorpha linza*.

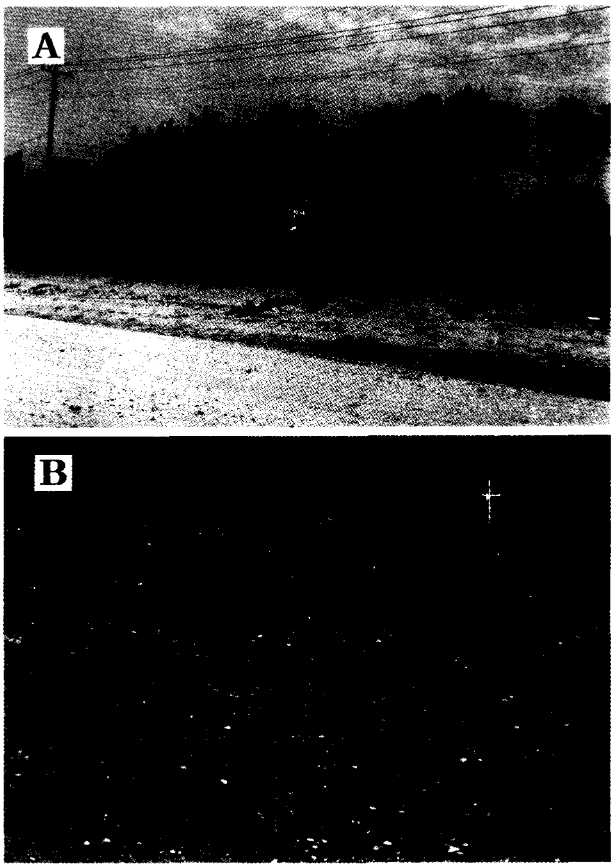

Fig. 3. Photographs showing surveyed sites of Tongho. A; pine tree community of supra littoral zone, and *Phacelurus latifolius* and Zoysia sinica community of upper intertidal zone, B; *Zoysia sinica* community of uper intertidal zone.

spots along the gradient of supra, upper, mid-and low intertidal zones. On the other hand, we checked vegetation and soil texture of the sites were identified (Table 1). Soil samples were put in polyvinyl bags and transported to laboratory. Springtails and ants were extracted using Tullgren funnels for 72 hours and were fixed in 90% ethyl alcohol. After sorting and identification of the insects, number of species were recorded from different sites of the three experimental areas.

A

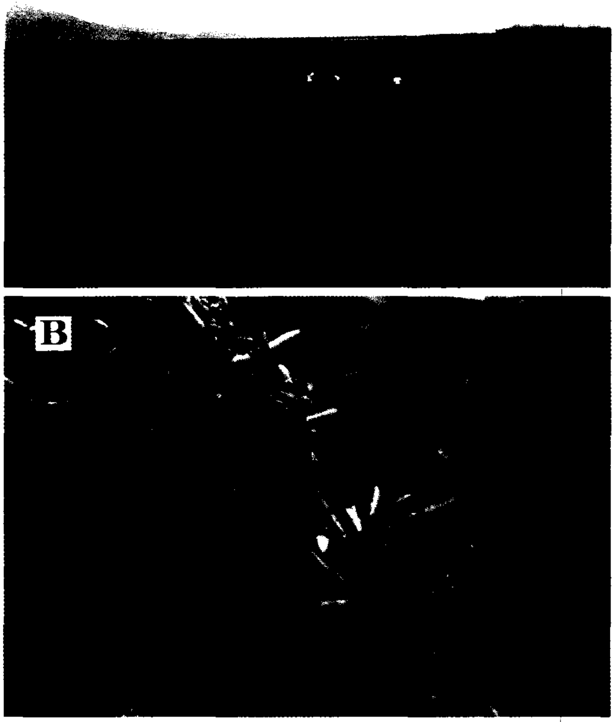

Fig. 4. Photographs showing surveyed sites of Julp'o. A; *Suaeda japonica* community in upper, mid- and low intertidal zones, B; photograph of *Suaeda japonica*.

3. Environmental properties

The bimonthly change of temperature and precipitation of the regions were obtained from the data record of the Korea Meteorological Administration (Table 2, Figs. 5, 6). pH, salinity, and electric conductivity of soils were measured along the gradient of intertidal lands. By rubbing soils and getting them through net with 1 mm sieve, and mixing the soils with distilled water in 1 : 5 (w/w) ratio and shaking them for 30 minutes. After

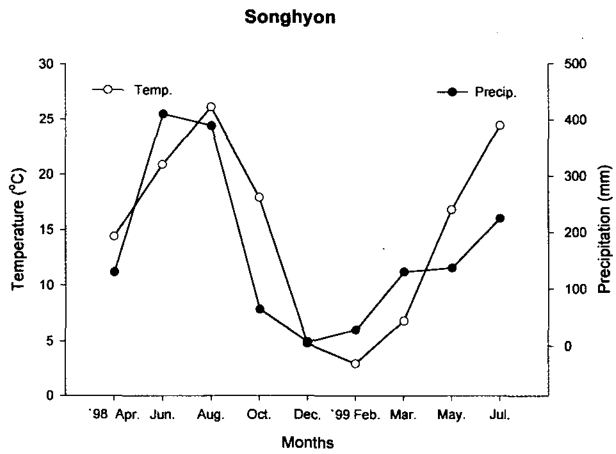

Fig. 5. Monthly precipitation and temperature change at Jokumdari (Songhyŏn) seashore for the period April 1998-July 1999.

Table 3. Characteristics of soil properties along the intertidal gradient (U: upper intertidal zone, M: mid-intertidal zone, L: low intertidal zone)

	pH									Salinity(g/l)									Electric conductivity								
	Jokumdari			Tongho			Chulp'o			Jokumdari			Tongho			Chulp'o			Jokumdari			Tongho			Chulp'o		
	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L
'98 Mar.	–	–	–	7.32	7.06	6.56	5.86	6.44	6.07		–	–	0.01	0.04	0.46	0.12	0.80	1.76	–	–	–	0.07	0.08	1.20	0.30	1.63	3.39
Apr.	6.49	6.45	6.60	–	–	–	–	–	–	0.32	0.52	1.24	–	–	–	–	–	–	0.64	1.04	2.15	–	–	–	–	–	–
May	–	–	–	7.34	7.19	6.67	6.00	6.08	5.88	–	–	–	0.02	0.03	0.57	0.10	1.27	1.53	–	–	–	0.06	0.05	1.93	0.33	2.19	3.36
Jun.	6.50	6.33	6.46	–	–	–	–	–	–	0.64	1.47	1.08	–	–	–	–	–	–	1.28	3.06	2.30	–	–	–	–	–	–
Jul.	–	–	–	6.62	6.42	6.73	6.26	6.97	6.70	–	–	–	0.04	0.66	0.76	0.65	0.66	1.10	–	–	–	0.88	1.35	1.56	0.26	1.88	3.10
Aug.	6.87	6.63	6.40	–	–	–	–	–	–	0.22	2.11	2.00	–	–	–	–	–	–	0.71	1.16	1.09	–	–	–	–	–	–
Sep.	–	–	–	6.52	6.48	6.41	6.15	6.30	6.24	–	–	–	0.71	0.66	1.00	1.29	1.38	1.89	–	–	–	1.44	1.36	2.02	1.09	2.14	3.90
Oct.	6.67	6.66	6.37	–	–	–	–	–	–	0.30	1.95	2.70	–	–	–	–	–	–	0.64	1.92	4.89	–	–	–	–	–	–
'99 Apr.	6.73	6.32	6.33	6.81	6.52	6.42	–	–	–	0.51	2.88	2.76	0.67	0.69	1.04	–	–	–	1.02	5.30	5.08	1.38	1.40	2.05	–	–	–
Jul.	6.30	6.23	6.26	–	–	–	–	–	–	1.02	2.09	1.98	–	–	–	–	–	–	1.97	2.52	2.21	–	–	–	–	–	–

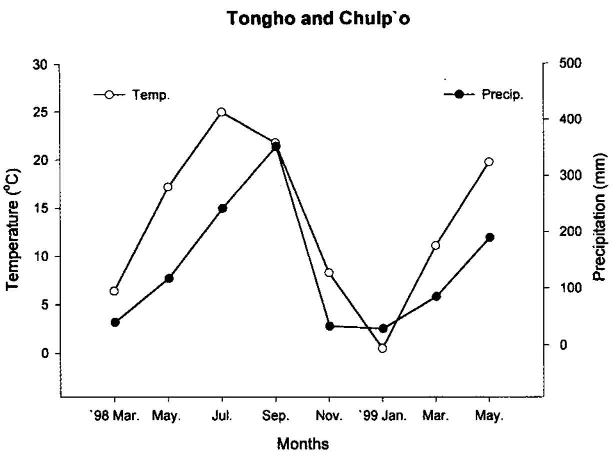

Fig. 6. Monthly precipitation and temperature change at Tongho and Chulp'o seashores for the period March 1998-May 1999.

filtering them, pH and electric conductivity were measured by pH meter (YSI 6000UPG), and conductivity meter (YSI 6000UPG), respectively. Thereupon, the soil samples, harvested for insect collections, were used for their measurements.

4. Community analysis

Collembola populations were evaluated using the following indices: abundance, McNaughton's dominance (1970), Shannon-Weaver diversity (Pielou 1975), Margalef's species richness indices (1958) and Pielou's evenness index.

Results

1. Environmental properties

Environmental properties of three sites are shown in Table 1, 2 and 3. Jokumdari was a salt marsh and its soil textures consisted of loamy sand. Mid-and low intertidal zones were covered with green algae (*Enteromorpha linza*). The pH was measured as 6.23～6.87, salinity (g/l) 0.22～2.88, and electric conductivity 0.64～5.30.

Tongho was covered with sands, and upper intertidal zone had perennial plants, *Phacelurus latifolia* and *Zoysia sinica* community, their subterranean stems were well developed. The pH was 6.41～7.34 and salinity (g/l) 0.01～1.04, and electric conductivity 0.05～2.05, respectively.

Chulp'o is a salt marsh, and its soil textures were silty loam. *Suaeda japonica* community was well developed from upper to low intertidal zones. The pH was 5.86 ～6.97 and salinity (g/l) 0.10～1.89 and electric conductivity 0.26～3.90.

The pH of Chulp'o was revealed slightly lower ranging from 5.86 even though its up to 6.97 and came Jokumdari, 6.23～6.87, and then Tongho, 6.41～7.34. Salt marsh sites were revealed more or less lower in pH than those of sand area. Especially, Tongho site showed low pH value in upper to low intertidal zone except in summer.

Salinity and electric conductivity showed high value in low zone, but low value in upper zone, and Jokumdari and Chulp'o, salt marshes, showed high salinity and electric conductivity than in Tongho which is sand area.

2. Taxa

By quantitative collecting we investigated the change in number of species and individuals per 200 cm^2. Springtails from the three sites were identified as 23 species of 7 families in total; 16 species of 6 families from Jokumdari, 15 species of 6 families from Tongho, and 14 species of 7 families from Chulp'o (Table 4, 5, 6). The species from intertidal zones were limited to 5 species in 5 families; *Oudemansia esaki, Mesaphorura yosii, Gastranurida* sp., *Axelsonia littoralis*, and *Entomobrya vigintiseta*. A great deal of difference was found in species composition between salt marshes and sand area. At Jokumdari and Chulp'o, salt marshes, *Oudemansia esaki* and *Axelsonia littoralis* were found to occur and the number of individuals grew more with increasing salinity in the gradient. On the other hand, *Lepidocyrtus* sp., *Entomobrya marginata* and *Entomobrya vigintiseta* occurred in upper zones in Tongho, sand site.

Ants from the three sites comprised 9 species of 8 genera in 3 subfamilies; 5 species of 5 genera in 2 subfamilies from Jokumdari, 7 species of 6 genera in 2 subfamilies from Tongho and 5 species of 5 genera in 3 subfamilies from Chulp'o. Most of species were found from supra littoral zones but *Tetramorium caespitum* were found on upper intertidal zone of Tongho with well-developed *Phacelurus latifolia* and *Zoysia sinica* community.

Table 4. Number of individuals per 200cm^2 of Collembola along the salt marsh gradient from Jokumdari
(S: supra intertidal zone, U: upper intertidal zone, M: mid－intertidal zone, L: low intertidal zone)

Family	Species	'98 Apr.				Jun.				Aug.				Oct.				Dec.				'99 Feb.				Mar.				May				Jul.			
		S	U	M	L	S	U	M	L	S	U	M	L	S	U	M	L	S	U	M	L	S	U	M	L	S	U	M	L	S	U	M	L	S	U	M	L
	Collembola																																				
Hypogastruridae	*Hypogastrura communis*	2	–	–	–	3	3	–	–	2	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	5	–	–	–	3	–	–	–
	Hypogastrura armata	5	–	–	–	3	–	–	–	3	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8	–	–	–	3	–	–	–
Neanuridae	*Oudemansia esaki*	–	3	15	20	–	10	18	31	–	–	3	5	–	2	12	22	–	1	13	5	–	–	1	2	–	1	1	17	–	2	6	20	–	1	5	6
Onychiuridae	*Mesaphorura yosii*	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Isotomidae	*Axelsonia littoralis*	–	1	5	24	–	1	3	15	–	–	–	2	–	1	1	2	–	–	–	–	–	–	–	5	–	–	–	20	–	1	3	10	–	–	–	2
	Isotomurus palustris	28	–	–	–	91	17	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	20	–	–	–	30	13	–	–
	Archisotoma sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	36	–	–
Entomobryidae	*Lepidocyrtus minuta*	1	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	2	–	–	–	3	1	–	–
	Lepidocyrtus sp.	–	–	–	–	3	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3	–	–	–	5	–	–	–	2	–	–	–
	Entomobrya marginata	8	–	–	–	6	–	–	–	3	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	3	–	–	–	6	–	–	–	–	–	–	–
	Entomobrya striatella	2	–	–	–	4	–	–	–	2	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3	–	–	–	1	–	–	–
	Homidia munda	–	–	–	–	192	–	–	–	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	10	–	–	–	1	–	–	–
	Homidia heugsanica	1	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	1	–	–	–
	Homidia bilineata	1	–	–	–	–	–	–	–	5	–	–	–	3	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	2	–	–	–	2	–	–	–
	Homidia mediaseta	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–
Sminturidae	*Ptenothrix saxatilis*	1	–	–	–	2	–	–	–	1	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	2	–	–	–	1	–	–	–
Total no. of individuals		49	4	21	45	306	31	21	46	30		3	7	10	3	13	24		1	13	5			1	7	12	2	1	37	64	3	9	30	47	51	5	8
Total no. of species		9	2	3	3	9	4	2	2	9		1	2	6	2	2	2		1	1	1			1	2	7	2	1	2	11	2	2	2	10	4	1	2
Grand total no. of individuals		119				404				40				50				19				8				52				106				111			
Grand total no. of species		12				11				11				8				1				2				10				13				13			

Table 5. Number of individuals per 200 cm^2 of Collembola along the intertidal gradient from Tongho (S: supra intertidal zone, U: upper intertidal zone, M: mid–intertidal zone, L: low intertidal zone)

Family	Species	'98 Mar.				May				Jul.				Sep.				Nov.				'99 Jan.				Apr.				Jun.			
		S	U	M	L	S	U	M	L	S	U	M	L	S	U	M	L	S	U	M	L	S	U	M	L	S	U	M	L	S	U	M	L
	Collembola																																
Hypogastruridae	*Hypogastrura communis*	4	–	1	–	2	10	–	–	–	5	–	–	–	2	–	–	–	1	–	–	–	–	–	–	–	15	–	–	–	7	–	–
Onychiuridae	*Mesaphorura yosii*	1	–	–	–	5	–	–	–	46	3	–	–	4	2	–	–	–	–	–	–	–	–	–	–	20	3	–	–	15	4	–	–
Isotomidae	*Archisotoma* sp.	–	8	–	–	–	–	–	–	10	–	–	–	1	2	–	–	–	–	–	–	–	–	–	–	3	5	–	–	2	3	–	–
	Isotomurus palustris	1	–	–	–	2	–	–	–	1	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	2	–	–	–
	Isotoma sp.	–	–	–	–	153	1	–	–	10	2	–	–	3	–	–	–	–	–	–	–	–	–	–	–	3	–	–	–	50	2	–	–
Entomobryidae	*Lepidocyrtus minuta*	–	1	–	–	5	5	–	–	7	4	–	–	3	3	–	–	2	1	–	–	1	–	–	–	3	2	–	–	5	3	–	–
	Lepidocyrtus sp.	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Entomobrya vigintiseta	–	10	–	–	–	21	–	–	–	5	–	–	–	3	–	–	–	–	–	–	–	–	–	–	–	15	–	–	–	18	–	–
	Entomobrya marginata	–	–	–	–	–	20	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13	–	–	–	–	–	–	
	Entomobrya nana	27	–	–	–	1	–	–	–	1	–	–	–	3	–	–	–	2	–	–	–	1	–	–	–	5	–	–	–	2	–	–	–
	Homidia heugsanica	5	–	–	–	6	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	3	–	–	–	2	–	–	–
	Homidia mediaseta	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Homidia bilineata	1	–	–	–	1	–	–	–	2	–	–	–	1	–	–	–	1	–	–	–	–	–	–	–	2	–	–	–	3	–	–	–
Tomoceridae	*Tomocerus kinoshitai*	1	–	–	–	1	–	–	–	3	–	–	–	2	–	–	–	1	–	–	–	1	–	–	–	3	–	–	–	4	–	–	–
Sminturidae	*Ptenothrix saxatilis*	–	–	–	–	3	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5	–	–	–	3	–	–	–
Total no. of individuals		40	19	1	–	180	57	–	–	82	19	–	–	18	12	–	–	7	2	–	–	3	–	–	–	49	53	–	–	88	37	–	–
Total no. of species		7	3	1	–	11	5	–	–	9	5	–	–	8	5	–	–	5	2	–	–	3	–	–	–	10	6	–	–	10	6	–	–
Grand total no. of individuals		60				237				101				30				9				3				102				125			
Grand total no. of species		10				13				11				10				6				3				13				12			

Table 6. Number of individuals per 200 cm^2 of Collembola along the salt marsh gradient from Chulp'o (S: supra intertidal zone, U: upper intertidal zone, M: mid-intertidal zone, L: low intertidal zone)

Family	Species	'98 Mar.				May				Jul.				Sep.				Nov.				'99 Jan.				Apr.				Jun.			
		S	U	M	L	S	U	M	L	S	U	M	L	S	U	M	L	S	U	M	L	S	U	M	L	S	U	M	L	S	U	M	L
	Collembola																																
Hypogastruridae	*Hypogastrura communis*	10	1	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6	–	–	–	5	–	–	–
Neanuridae	*Oudemansia esaki*	–	–	10	1	–	–	41	20	–	–	2	–	–	2	5	7	–	–	3	2	–	1	4	2	–	4	7	15	–	5	12	20
	Gastranurida sp.	–	2	–	–	–	3	–	–	–	1	–	–	–	–	–	–	–	3	–	–	–	2	–	–	–	5	–	–	–	1	–	–
Onychiuridae	*Mesaphorura yosii*	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–
Isotomidae	*Axelsonia littoralis*	–	6	5	20	–	9	14	–	–	–	1	2	–	–	3	2	–	1	5	6	–	2	3	2	–	4	5	7	–	1	3	–
	Isotomurus palustris	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Entomobryidae	*Lepidocyrtus minuta*	1	–	–	–	1	–	–	–	3	–	–	–	2	–	–	–	1	–	–	–	–	–	–	–	2	–	–	–	4	–	–	–
	Entomobrya marginata	–	–	–	–	6	1	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	1	–	–	–
	Homidia heugsanica	–	–	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3	–	–	–	–	–	–	–
	Homidia mediaseta	2	–	–	–	3	–	–	–	1	–	–	–	4	–	–	–	2	–	–	–	–	–	–	–	4	–	–	–	5	–	–	–
	Homidia bilineata	1	–	–	–	2	–	–	–	2	1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	3	–	–	–
	Homidia koreana	1	1	–	–	3	–	–	–	5	–	–	–	3	–	–	–	1	–	–	–	–	–	–	–	3	–	–	–	4	–	–	–
Tomoceridae	*Tomocerus liliputanus*	–	–	–	–	1	–	–	–	4	–	–	–	2	–	–	–	1	–	–	–	–	–	–	–	3	–	–	–	5	–	–	–
Sminturidae	*Ptenothrix saxatilis*	5	5	–	–	3	–	–	–	5	–	–	–	2	–	–	–	1	–	–	–	–	–	–	–	4	–	–	–	2	–	–	–
Total no. of individuals		25	16	15	21	27	13	55	20	20	2	3	2	16	2	8	9	6	4	8	8	–	5	7	4	29	14	12	22	29	7	15	20
Total no. of species		7	6	2	2	9	3	2	1	6	2	2	1	7	1	2	2	5	2	2	2	–	3	2	2	9	4	2	2	8	3	2	1
Grand total no. of individuals		77				115				27				35				26				16				77				71			
Grand total no. of species		11				12				9				9				8				3				13				11			

Table 7. Number of ants per 200cm² from three sites (Jokumdari, Tongho and Julp'o (S: supra intertidal zone, U: upper intertidal zone))

Sites	Jokumdari								Tong−ho																	Julp'o							
	'98.					'99.			'98.											'99.						'98.					'99.		
	4.	6.	8..	10.	12.	2.	3.	5.	7.	3.		5.		7.		9.		11.		1.		4.		6.		3.	5	7.	9.	11.	1.	4.	6.
Species	S	S	S	S	S	S	S	S	S	S	U	S	U	S	U	S	U	S	U	S	U	S	U	S	U	S	S	S	S	S	S	S	S
Formicidae																																	
Ponerinae																																	
Ponera japonica																											1						
Myrmicinae																																	
Pristomyrmex pungens		2	3						3																								
Solenopsis japonica	1							3														3		3		1							
Tetramorium caespitum	1	7	8	7				6	7	4	3	6	4	6	4	6	5					4	3	5	3	3	3	5	4			4	5
Formicinae																																	
Camponotus japonicus		4	2	3				3	3					2																			
Lasius alienus			6	4					2							2																	
Paratrechina flavipes																3								3			1		1			1	
Paratrechina sakurae																						2											
Plagiolepis flavescens														4													2					2	
Total no. of individuals	2	13	19	14				12	15	4	3	6	4	12	4	11	5					9	3	11	3	4	5	7	5			5	7
Total no. of species	2	3	4	3				3	4	1	1	1	1	3	1	3	1					3	1	3	1	2	3	2	2			2	2

Table 8. Abundance (N), dominance (DI), richness (RI), diversity indices (H′) and evenness (J′) index of Collembola along the intertidal gradient. (supra:supra littoral zone, up:upper intertidal zone, mid:mid−intertidal zone, low:low intertidal zone)

			'98 Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	'99 Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Total or average
N (m^2)	Jokumdari.	supra		2450		15300		1500		500					600		3200		2350	25900
		up		200		1550				150		50			100		150		2550	4750
		mid		1050		1050		150		650		650		50	50		450		250	4350
		low		2250		2300		350		1200		250		350	1850		1500		400	10450
	Total			5950		20200		2000		2500		950		400	2600		5300		5550	49450
	Tongho	supra	2000		9000		4100		900		350		150			2450		4400	23350	23350
		up	950		2850		950		600		100					2650		1850		9950
		mid	50																	50
		low																		
	Total		3000		11850		5050		1500		450		150			5100		6250		33350
	Chulp'o	supra	1250		1350		1000		800		300					1450		1450		7600
		up	1300		2700		100		100		200		250			700		350		5700
		mid	250		700		150		400		400		350			600		750		3600
		low	1050		1000		100		450		400		200			1100		1000		5300
	Total		3850		5750		1350		1750		1300		800			3850		3550		2200
DI	Jokumdari.	supra		0.73		0.92		0.50		0.50					0.50		0.47		0.70	0.617
		up		1.00		0.87		0		1.00		1.00			1.00		1.00		0.96	0.854
		mid		0.95		1.00		1.00		1.00		1.00		1.00	1.00		1.00		1.00	0.994
		low		0.98		1.00		1.00		1.00		1.00		1.00	1.00		1.00		1.00	0.998
	Tongho	supra	0.80		0.88		0.68		0.39		0.57		0.66			0.51		0.74		0.654
		up	0.95		0.72		0.53		0.50		1.00					0.57		0.68		0.707
		mid	1.00																	1.000
		low																		
	Chulp'o	supra	0.60		0.41		0.50		0.43		0.50					0.34		0.34		0.446
		up	0.69		0.92		1.00		1.00		1.00		0.80			0.64		0.86		0.864
		mid	1.00		1.00		1.00		1.00		1.00		1.00			1.00		1.00		1.000
		low	1.00		1.00		1.00		1.00		1.00		1.00			1.00		1.00		1.000
RI	Jokumdari.	supra		2.06		1.40		2.35		2.17					2.41		2.40		2.34	2.161
		up		0.72		0.87				0.91		0			1.44		0.91		0.76	0.801
		mid		0.66		0.33		0		0.39		0		0	0		0.46		0	0.204
		low		0.53		0.26		0.51		0.31		0		0.51	0.28		0.29		0.48	0.352
	Tongho	supra	1.62		1.93		1.82		2.42		2.06		1.82			2.31		2.01		1.999
		up	0.68		0.99		1.36		1.61		1.44					1.26		1.38		1.246
		mid	0																	
		low																		
	Chulp'o	supra	1.86		2.43		1.67		2.16		2.23					2.36		2.08		2.113
		up	1.80		0.78		1.44		0		0.72		1.24			1.14		1.03		1.019
		mid	0.37		0.25		0.91		0.48		0.48		0.51			0.40		0.37		0.471
		low	0.33		0		0		0.46		0.48		0.72			0.32		0		0.289
H′	Jokumdari.	supra		2.06		1.43		2.83		2.45					2.63		2.98		2.03	2.344
		up		0.81		1.49				0.92		0			1.00		0.92		1.08	0.889
		mid		1.05		0.59		0		0.39		0		0	0		0.92		0	0.328
		low		1.09		0.91		0.86		0.41		0		0.86	1.00		0.92		0.81	0.762
	Tongho	supra	1.62		1.06		2.10		2.82		2.24		1.58			2.81		2.16		2.049
		up	1.46		1.91		2.25		2.29		1.00					2.26		2.12		1.899
		mid	0																	0
		low																		
	Chulp'o	supra	2.31		2.97		2.42		2.70		2.25					3.07		2.87		2.656
		up	2.18		1.14		1.00		0		0.81		1.52			1.84		1.14		1.204
		mid	0.92		0.81		0.92		0.95		0.95		0.99			0.98		0.72		0.905
		low	0.28		0		0		0.76		0.81		1.00			0.90		0		0.469
J′	Jokumdari.	supra		0.65		0.45		0.89		0.95					0.94		0.86		0.61	0.764
		up		0.81		0.75				0.92		0			1.00		0.92		0.54	0.706
		mid		0.66		0.59		0		0.39		0		0	0		0.92		0	0.284
		low		0.69		0.91		0.86		0.41		0		0.86	1.00		0.92		0.81	0.718
	Tongho	supra	0.58		0.31		0.66		0.94		0.96		1.00			0.84		0.65		0.743
		up	0.92		0.82		0.97		0.99		1.00					0.87		0.82		0.913
		mid	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		low	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Chulp'o	supra	0.82		0.94		0.94		0.96		0.97					0.97		0.96		0.937
		up	0.84		0.72		1.00		0		0.81		0.96			0.92		0.72		0.746
		mid	0.92		0.81		0.92		0.95		0.95		0.99			0.98		0.72		0.905
		low	0.28		0		0		0.76		0.81		1.00			0.90		0		0.469

3. Biological indices

Individual occurrences were shown in Table 8. Density (N) of Collembola population in supra littoral zones was higher than in intertidal zone and high values were demonstrated from April to July and low values in winter. In salt marsh areas the density of low intertidal zones was high, but in sand area upper zone showed high value.

In supra littoral zones dominance index (DI) of springtails averaged 0.446~0.654 and at intertidal zones 0.707 ~1.000. Especially, in the intertidal zones of salt marshes it was as high as 0.854~1.000 but in upper zone of sand beach it averaged 0.707, lower than in salt marshes. Richness index (RI) in supra littoral zones averaged 1.999~2.161 and in intertidal zones 0.204~1.246 and diversity index (H') in supra littoral zones averaged 2.049~2.656 and in intertidal zones 0.328~1.899. They were shown to be generally low. These indices, however, were higher in supra littoral zones than in intertidal ones. Among the intertidal zones the upper zone of Tongho was high, RI, 1.246 and H', 1.899. In salt marshes evenness index (J') of supra littoral zones averaged 0.743~0.937 and in intertidal ones 0.284~0.913, the index of supra intertidal zones was higher than in intertidal zones, going in parallel with diversity index. In sand area, however, evenness index of upper intertidal zone was higher than that of supra littoral zones, revealing opposite to the former (Table 8).

Discussions

The present series of investigations were undertaken to see how springtails and ant community structure change along environmental gradient in the three seashore areas different in soil properties and vegetations. As a result of quantitative study, it was found that species composition and their distribution were quite different between salt marshes and sand area. In case of springtails, *Oudemansia esaki* (Kinoshita) and *Axelsonia littoralis* (Moniez) occurred in common as dominant species in spite of the differences of their vegetation between Jokumdari and Chulp'o. The two species are all cosmopolitans and were reported as halophilous, inhabiting salt marshes in Japan and U.S.A for instance (Yosii 1955, 1958, 1966; Christiansen and Bellinger 1998). In the present study, they occurred more in lower zones, having high salinity. Meanwhile, the salinity of intertidal zone of Tongho, sand beach, was lower than in other two salt marshes. Three species of Collembola were found in upper intertidal zone; *Lepidocyrtus* sp., *Entomobrya marginata* Tullberg and *Entomobrya vigintiseta* Lee et Park. Among them *Entomobrya vigintiseta* was already reported from beach of Taechŏn (South Korea) (Lee and Park 1984). Certainly, it is considered as a halophilous species.

In case of ants, they were found from supra littoral zones. Among intertidal zones they were restricted to upper tidal zone of sand area which has *Phacelurus latifolia* and *Zoysia sinica* community of perennial plants with well developed subterranean roots and little seawater inflow.

Local animal distribution may be limited by predation and ants are generally known to eat springtails when they come across them (Dejean 1985; Hölldobler and Wilson 1990). In this study, ants and springtails were found together from an ant nest in the supra littoral zones of Jokumdari area. In survey sites outside the ant nest, however, no springtail population was observed together with ants which may be ascribed to predatory habits of ants on springtails.

As regards soil properties, pH was higher in sandy area than in salt marshes. The pH of Jokumdari and Tongho decreased toward lower tidal zones. Even though pH showed a certain trend of change, it did not affect species composition and distribution of Collembola. The population density of salt marshes was affected by salinity of sea water which becomes stronger toward low tide zone. Consequently, the species composition and distribution of springtails seemed irrelevant to pH and vegetation but depend on soil texture and salinity. These relationship seem to be identical with many previous studies (Weigmann 1973; Conrad 1976; Wittenveen and Joosse 1987; Ehrnsberger 1997; Sterzynska and Ehrnsberger 1997). Ant population, meanwhile, seemed to depend on the vegetation and restricted to upper zone in sandy area irrespective of the above factors.

Individuals of the marine Collembola clump together in shape of small 'nests' which are filled with air during inundation at high tide (Josse 1966; Witteveen and Joosse 1988). The structure of the cuticle is also resistant to wetting by pressure and surfactants (King *et al.* 1990). Springtails are well adapted to the environment, which has high salinities and regular tide, because they have high osmolarity of haemolymph comparing with land springtails (Hopkin 1997). Ants, however, do not have above mechanical systems.

During the investigations springtail density was the highest from April to July and the lowest in winter. But, report from West Malaysia showed the highest from June to August (Kondoh *et al.* 1980) and in a forest of Temperate Zone in Japan it was the highest from June to July (Niijima 1971). The reason why it decreased in August remains to be studied.

Population density (N) of supra littoral zones were higher than in intertidal zones. Among intertidal zones the upper zone of Tongho, sand area, was high. Dominance index (DI) was, on the whole, high, and that of intertidal land was higher than supra littoral zone. Especially DI of salt marshes was higher than in sand area. Richness index (RI) and diversity index (H') were generally low and they were opposite to dominance index (DI). All these results support that the communities of soil insects in the areas, which were less stressed by regular inundation and salinity are characterized by high species richness, diversity and a lower contribution by dominant species (Ehrnsberger *et al.* 1997). The supra littoral lands, which are not affected by salinity and tide, in particular, were occupied by terrestrial species and showed high numbers of individual. Mid- and low intertidal lands, on the contrary, were occupied by halophilous species, showing low richness and diversity index.

All the above results support that the population structure in community varies with environmental factor gradients (Wittaker 1972; Magurran 1988) and in littoral zone, in particular, changing with intertidal gradient (Ehrnsberger *et al.* 1997).

적 요

연안생태계의 호염성 톡토기와 개미군집의 생물다양성정도와 변동에 대해 알아보기위해, 주변환경과 식생이 다른 세지역에서 정량채집을 실시하였다. 종조성이나 분포에 영향을 주는 요인을 찾기위해 pH, 염도 및 전기전도도를 측정하였다. 연구결과 톡토기의 종조성이나 분포에는 pH와 식생보다도 토성과 염도가 더 큰 영향을 주는 것으로 나타났다. 그러나 개미의 경우는 집을 지을 적당한 장소를 제공해 줄 수 있는 식생과 조수에 의한 침수에 더 큰 영향을 받는 것으로 사료된다.

모든 조사지역에서 조상대가 조간대보다 다양도가 높았으며 조간대중에서는 모래함량이 높은 동호의 상조대에서 가장 높게 나타났다.

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