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The Study on the Characteristics of Ground Beetle (Coleoptera: Carabidae) Community for Conservation of Biodiversity in Agricultural Landscape[1]

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농업경관에서의 생물다양성 보전을 위한 딱정벌레 군집 특성 연구[1]

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ABSTRACT

This study was conducted to provide basic information for development of habitat-based conservation strategies of biological diversity in agricultural ecosystem. The carabid beetle assemblages were examined at four kinds of habitats(levee, dike, forest patch remnants and streamside) from three differently stressed areas located in Paltan-myun, Hwaseong city, Korea: agricultural and forest area(site 1), industrial area(site 2), and residential area(site 3). Pitfall trap samplings were carried out 39 times from November 2000 to November 2002. Our study's findings were that the composition of carabid beetle fauna, dominance species, and pattern of carabid beetle assemblage were different among the habitats. The similarity index was highest between two levees in site 2 and 3, and lowest between hillock in site 2 and streamside in site 3, and that among habitats fragmented by road with high traffic was lower than that among any other habitat types. So, we could know that agricultural land use respectively do an important role in diversity conservation and networking. These findings will be used to establish the land use and management plans in the aspects of conservation of biodiversity.

KEY WORDS: HABITAT, ASSEMBLAGE, BIODIVERSITY, DISTURBANCE

요 약

본 연구는 농업 생태계의 생물다양성 보전에 있어 서식처 기반의 보전 전략을 수립하는데 있어 기본 정보를 제공하기 위해 수행되었다. 연구는 경기도 화성시 팔탄면에 위치한 환경압박이 서로 다른 3개 조사지(농경지와 야산으로 이루어진

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조사지 1, 공장이 많이 위치하는 조사지 2, 거주지역이 많이 차지하는 조사지 3에서 4개의 토지이용(야산, 밭둑, 논둑, 하천변)별로 2000년 11월부터 2002년 11월까지 39회의 딱정벌레 군집 조사를 통해 이루어졌다. 본 연구의 주요 결과로서 딱정벌레 군집 조성, 우점종 그리고 군집 패턴이 토지이용에 따라 다르게 나타났으며, 유사도는 조사지 2와 3의 논둑에서 가장 높게 나타났고, 조사지 2의 야산과 조사지 3의 하천변간의 유사도가 가장 낮았다. 또한 도로에 의해 파편화된 서식처간의 유사도가 서로 다른 서식처 및 조사지간의 유사도보다 낮게 나타났다. 이를 통해 생물다양성 보전과 네트워크 측면에서 농경지 토지이용은 각각이 중요한 역할을 수행하고 있음을 알 수 있다. 본 연구는 국내 농촌경관에서의 서식처별 딱정벌레 군집분석을 통하여 생물다양성 보전에 대한 기초 자료를 제공한다는 점에서 가치를 평가할 수 있다.

주요어: 서식처, 군집, 생물다양성, 교란

INTRODUCTION

There is a general consensus on the importance of reserve systems to preserve biodiversity, which is rapidly declining due to human impact(Wright, 1996; Primack and Ros, 2002). Central to this idea is the criteria for the prioritization of sites within reserves, in order to suggest particular protection plans, and maintain extant or apply new management regimes(Primack and Ros, 2002). In biodiversity surveys, bioindicators are used to assess the species richness of a community. Using only a few species groups to estimate the diversity of total biota, e.g. through extrapolation, is a quick technique(Colwell and Coddington, 1994).

Carabid beetles have been studied worldwide in ecosystem monitoring researches as a bioindicator with a sensitive reaction to anthropogenic disturbances, because they are well known both taxonomically and ecologically (Stork, 1990; Desender *et al.*, 1991; Desender, 1996; Niemelä, 2001; Johanna and Niemelä, 2003). Most of Carabid surveys have focused on the response of the species to changing environmental conditions, e.g. forest fragmentation(e.g. Niemelä *et al.*, 1988; Koivula *et al.*, 2002 and 2004), or management practices(e.g. Rushton *et al.*, 1990).

A traditional Korean agricultural landscape consists of villages, agricultural fields, small forests and streams. Because of internal and external changes in the agricultural environment, new farm village development programs have been implemented in Korea(Lee *et al.*, 2007). Thereby, farm village land use is expanding to encompass green-tourism, citizen and silver domicile space, etc. Therefore, there is a need to study whether these activities affect the biological diversity and conservation areas of traditional farm village ecosystems in Korea. In general, comprehensive ecological investigations to base conservation decisions are rarely conducted in areas for which development is planned.

Few studies on carabid beetle have been conducted in Korea. They are mostly the classification and ecology of carabid beetle in the forest. The current study was undertaken to analyze the connection between the ecological characteristics of carabid beetle and the preservation, conservation, and development of the rural landscape. The roles of habitat types of carabid beetle diversity in an agricultural landscape consisting of some small fragmented habitats were discussed in this study. Thus, we sought to define that the compositions of the carabid beetle fauna should be different according to habitat type, in order to provide the information that agricultural land use plays an important role in diversity conservation and networking.

MATERIALS AND METHODS

1. Study sites

The study sites were located in the Balan reservoir area in Paltan-myun, Hwaseong city, Gyeonggi-do, Republic of Korea(Figure 1 and Table 1). Three sites and four adjacent habitat types(levee, upland dike, hillock, and stream ridge) within each site were chosen after a consideration of the waterway, traffic, land use, and urbanization gradient (Jung, 2008).

The difference in the soil analysis result at four habitat

Figure 1. The maps of the study area and sampled sites(left upper: Site 1, right upper: Site 2, left under: Site 3, small red circle: vegetation sampling plot, large blue irregular circle: carabid sampling plot)

types in three sites was not shown(Kang, 2009). The levee soil from site 3 had the characteristic of the sandy loam, and another levee from site 1 and 2 had the characteristic of loamy soil. The dike soil from site 3 had the characteristic of the loamy soil, and another dike from site 1 and 2 had the characteristic of sandy loam. The hillock soil from site 3 had the characteristic of the silt loam, and another hillock from site 1 and 2 had the characteristic of sandy loam. The streamside soil from site 2 had the characteristic of the silt loam, and another dike from site 1 and 3 had the characteristic of sandy loam. There was no heavy metal contaminated sites based on the legal standard(Kang, 2009).

2. Carabid monitoring

Unbaited pitfall traps were used to collect carabid beetle(Jung, 2008). A total of 39 collecting were conducted at two week intervals from November, 2000 to November, 2002. The specimens collected in the pitfall traps were stored in 75% alcohol in Entomology Program, Seoul National University. The nomenclature used follows the monograph by Korea Insect Nomenclature Book(1994) and Carabidae(Park and Baek, 2001). All of the species identification was checked by Jong-Kyun Park(South Korea). We were not able to obtain confident identifications for some specimens of the genus *Agonum, Amara, Bembidion* and *Chlaenius*.

3. Statistical methods

The species composition was analyzed to determine the differences and similarities between habitats, and to ascertain whether the biocenosis was influenced by roads. The differences in species composition and abundance among the habitats were evaluated using a Multidimensional Scaling(MDS) analysis. The two- dimensional solution

Table 1. The characteristics of sampled sites

	Site 1				Site 2				Site 3			
	Levee	Dike	Hillock	Stream side	Levee	Dike	Hillock	Stream side	Levee	Dike	Hillock	Stream side
Width	<3m	<2m	>10m	5m	<3m	<2m	>10m	5m	<3m	<2m	<10m	5m
Permanence level	periodic	periodic	permanent	periodic	periodic	periodic	permanent	periodic	periodic	periodic	permanent	periodic
Disturbance level	disturbed	disturbed	undisturbed	disturbed	disturbed	disturbed	undisturbed	disturbed	disturbed	disturbed	undisturbed	disturbed
Opening level	open	open	closed	open	open	open	closed	open	open	open	closed	open
Dominant plants	Artemisia	Artemisia	Quercus	Persicaria	Artemisia	Artemisia	Quercus	Persicaria	Artemisia	Artemisia	Quercus	Persicaria

contained almost as much information as the three-dimensional solution(stress levels only 5.2% different) and was simpler to present and interpret. Also, similarity of carabid beetle community among habitat types was analyzed using Kulczinski- Quantitative similarity index. Above analyses were performed by the Community Analysis Package(3.0) software(Richard *et al*., 2004). The dominant species was seen to occupy over 3% of the total number. The ecological indices(α-diversity index and evenness index) were compared among the habitat types(Pielou, 1975).

RESULTS

1. Species composition

We analyzed the species composition to search the difference among habitats, and the similarity between habitats to search that biocenosis is influenced by road. A total of 5,787 carabid beetles were collected and total 69 species 30 genera of carabid beetles were identified (Table 2).

The number of species of carabid beetle in site 1 were less than other sites. That of hillock was small, on the other hands: there was relatively many species at upland dike and streamside. The total 37 species were common in three sites. One species was collected only in site 1, two species was collected only in site 2, and 12 species were collected only in site 3.

As a result of species composition at four habitats, two species were found only at levee: *Agonum sp*. and *Lachnocrepis prolixus*(Bates, 1873), five species were found only at dike: *Harpalus jureceki*(Jedlička, 1928), *Bradycellus subditus* (Lewis, 1879), *Calleida onoha*(Bates, 1873), *Paratachys pallescens*(Bates, 1873) and *Pristosia vigil*(Tschischérine, 1895), four species were found only at hillock: *Anomotarus stigmulus*(Chaudoir, 1852), *Cymindis daimio*(Bates, 1873), *Perigona nigriceps* (Dejean, 1831) and *Pterostichus haptoderoides* (Tschischérine, 1895), and seven species were found only at streamside: *Agomum chalcomus*(Bates, 1873), *Asaphidion semilucidum*(Motschulsky, 1862), *Bembidion morawitzi* (Csiki, 1928), *B. semiluninum* (Jedlička, 1961), *B. sp, Oodes integer*(Semenov, 1889) and *Trechus ephippiatus*(Bates, 1873). The 17 species were common species found at the four habitat types. Particularly, as to four species(*Synuchus arcuaticollis* (Motschulsky, 1860), *S. cycloderus*(Bates, 1873), *S. nitidus*(Motschulsky, 1861) and *S. orbicollis*(Morawitz, 1862)) of the genus Synuchus, many populations were noted to inhabit at the hillock in comparison with other habitats. This fact corresponds to habitat specialist hypothesis.

Table 2. The species number of carabid beetle in four habitats of three sites

Sites	Habitats	Genera	Species
Site 1	Levee	12	21
	Dike	15	35
	Hillock	7	16
	Streamside	13	25
	Sum	19	44
Site 2	Levee	13	32
	Dike	11	25
	Hillock	9	12
	Streamside	16	35
	Sum	21	52
Site 3	Levee	13	36
	Dike	15	39
	Hillock	9	15
	Streamside	17	32
	Sum	27	64
Total		30	69

2. Similarity analysis

The similarity index(Kulczinski-Quantitative similarity index) among four habitats shows up in Table 3 and 4. The similarity index was ranged with 0.040～0.745 at the habitat for each type(Table 4). The similarity index between the hillocks in three sites showed considerably higher than 0.614 in species composition, which is higher than that at any other habitat. The similarity index between

Table 3. The Kulczinski-Quantitative similarity index among four habitat types in three area

	Levee	Dike	Hillock	Streamside
Levee	-	-	-	-
Dike	0.389	-	-	-
Hillock	0.117	0.287	-	-
Streamside	0.476	0.380	0.194	-

Table 4. The Kulczinski-Quantitative similarity index among twelve sites (L: Levee, D; Dike, H; Hillock, S; Streamside, 1; Site1, 2; Site2, 3; Site3)

	L1	L2	L3	D1	D2	D3	H1	H2	H3	S1	S2	S3
L1												
L2	0.467											
L3	0.281	0.455										
D1	0.409	0.285	0.200									
D2	0.206	0.269	0.414	0.446								
D3	0.389	0.372	0.338	0.484	0.437							
H1	0.260	0.134	0.042	0.404	0.085	0.117						
H2	0.252	0.106	0.040	0.410	0.077	0.125	0.739					
H3	0.275	0.123	0.049	0.569	0.110	0.158	0.614	0.745				
S1	0.439	0.397	0.165	0.507	0.116	0.237	0.349	0.375	0.445			
S2	0.262	0.374	0.311	0.202	0.276	0.189	0.072	0.049	0.058	0.220		
S3	0.123	0.203	0.332	0.119	0.189	0.139	0.047	0.044	0.049	0.127	0.312	

the streamside in three sites showed considerably lower than 0.127 in species composition. The species composition at the paddy levee and streamside, which are damp environment, was similar, and that at the upland dike and hillock, which is dry environment, was similar.

As a result of similarity analysis between different habitats, the similarity index between levee and streamside was highest, and that between levee and hillock was lowest. Especially, the similarity index(0.569) between dike in site 1(D1) and hillock in site 3(H3), in which it is geographically not related, was highest, but the similarity index(0.040) between levee in site 3(L3) and hillock in site 2(H2), in which it is geographically not related, was lowest. The difference of the habitat type and environment seems to influence on the species composition. And a difference is even generated in the species composition and fertilization by the small difference of the habitat structure.

3. The analysis of dominance species

As a result of dominance species analysis, nine dominant species were occupied 68.2% of total individual number at the levee. Especially *Chlaenius micans* (Fabricius, 1792), *Harpalus eous*(Tschitscherine, 1901), *H. sinicus sinicus*(Hope, 1845), and *Pheropsophus javanus* (Dejean, 1825) were dominant only at the levee(Table 5). At the dike, 9 dominant species were occupied 75.3% of total individual number. Especially *Chlaenius naeviger* (Morawitz, 1862), *Curtonotus harpaloides*(Dejean, 1828), *Harpalus tridens*(Morawitz, 1862), and *H. tschiliensis* (Schauberger, 1929) were dominant only at the dike. At the hillock, 4

Table 5. The comparison of dominant species occupied 3% over of total individual numbers in four habitats between November 2000 and November 2002

Species Name	Levee	Dike	Hillock	Streamside
Amara pseudosimplicidens	0.2	0.0	0.0	**3.9***
Anisodactylus punctatipennis	0.6	0.1	0.0	**6.4**
Bembidion morawitzi	0.0	0.0	0.0	**3.1**
Chlaenius bioculatus	2.6	0.8	0.0	**4.9**
Chlaenius micans	**3.1**	0.6	0.1	1.7
Chlaenius naeviger	1.4	**6.8**	1.4	1.4
Chlaenius ocreatus	0.3	0.0	0.0	**3.9**
Chlaenius pallipes	**9.6**	0.0	0.0	**3.9**
Curtonotus harpaloides	1.7	**7.8**	0.0	0.7
Dolichus halensis halensis	**6.2**	**8.9**	0.0	2.8
Harpalus chalcentus	**4.0**	**8.4**	0.0	0.0
Harpalus eous	**11.1**	0.2	0.0	0.3
Harpalus sinicus sinicus	**4.9**	2.1	0.0	0.4
Harpalus tridens	0.5	**4.2**	0.0	0.7
Harpalus tschiliensis	2.9	**4.7**	0.0	0.7
Nebria chinensis chinensis	2.9	0.8	0.2	**3.9**
Nebria coreica	**8.5**	0.1	0.0	**9.1**
Pheropsophus javanus	**9.3**	0.1	0.0	1.4
Synuchus arcuaticollis	**11.4**	**23.3**	**23.2**	**22.5**
Synuchus cycloderus	0.5	1.0	**23.1**	0.1
Synuchus nitidus	0.2	**4.6**	**32.1**	1.3
Synuchus orbicollis	2.3	**6.6**	**19.0**	2.9

* Bold letter indicate the dominant species by habitat types

dominant species of the genus *Synuchus* were occupied 97.5% of total individual number. These species mostly preferred the forest-habitat. At the streamside, 9 dominant species were occupied 61.8% of total individual number. *Amara pseudosimplicidens*(Lafer, 1980), *Anisodactylus puctatipennis*(Morawitz, 1862), *B. morawitzi, Chlaenius bioculatus*(Chaudoir, 1856), *C. ocreatus*(Bates, 1873), and *Nebria chinensis chinensis* (Bates, 1872) were dominant only at the streamside. Especially *B. morawitzi* was collected only at the streamside.

4. The analysis of pattern of beetle assemblage

As a result of MDS analysis, a strong pattern of beetle assemblage was evident in the two-dimensional scaling, with landscape elements well separated along axis 1(stress: 15.3%, Figure 2). Especially, that at the hillock was significantly different from that at other habitats.

DISCUSSION

Pitfall trapping was used to understand the carabid beetle community structure in this study. Pitfall trapping does offer a reliable method of analyzing the daily and annual activity patterns of carabid beetles(Cochraan, 1997). These collecting activities can be carried out from spring through summer and even into autumn, but with the increasing growth of vegetation in summer new methods of collecting can be adopted. Sweeping reeds or tuffs of grass, nettles, dune grass, deciduous trees or pines with a sweep net may reveal certain species of *Amara* and *Harpalus*. These beetles climb up during the night in search of the seeds on which it is thought to feed(Forsythe, 2000). The various collecting methods should be considered in order to study a behavior and effect by the environmental disturbance of specific population.

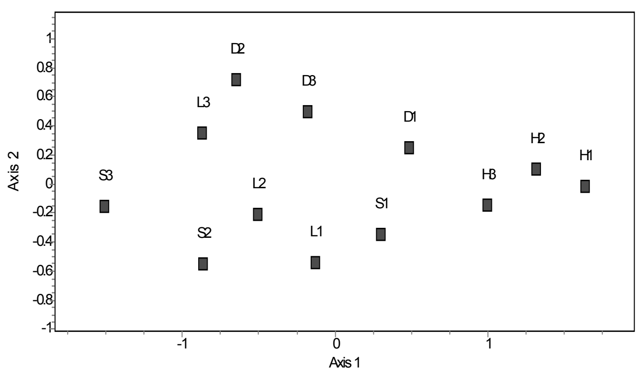

Figure 2. The Non-metric Multi-Dimensional Scaling (MDS) plots from 12 sites, based on Bray-Curtis similarity matrix(stress: Axis 1 = 0.153, Axis 2 = 0.076, L: Levee, D: Dike, H: Hillock, S: Streamside, 1: Site 1, 2: Site 2, 3: Site 3)

The composition of carabid beetle species was analyzed to study the difference and similarities between habitats and investigate if biocenosis is influenced by road location. The number of species of carabid beetle in site 1 was less than in other sites. The number of species at the hillock was small. In contrast, there were relatively many species at the upland dike and streamside locations. Total 37 species were commonly in three sites. One species was collected only in site 1, two species were collected only in site 2, and 12 species were collected only in site 3. The analytical result of the species composition at four habitats showed that two species were found only at the levee, four species were found only at the hillock, and seven species were found only at the streamside. Eighteen species were common species found at four habitat types. Particularly, regarding four species of the genus *Synuchus*, many populations were noted to inhabit at the hillock, in comparison with other habitats. This fact corresponds to the hypothesis of a habitat specialist. As a result of MDS analysis, a strong pattern of beetle assemblage was evident in the two-dimensional scaling, with landscape elements well separated along axis 1(stress: 15.3%). Especially, the assemblage at the hillock was significantly different from that at other habitats.

The composition of the carabid fauna dominance species and the pattern of group beetle assemblage were different among the land use. The results of this study reconfirmed that habitat types had an effect on carabid beetle community structure and diversity. Overall carabid beetle diversity varied among habitat types. That is, habitat type could have a treater influences on carabid beetle diversity than regional effects. In the research of Lövei and Sunderland(1996) and Spence *et al.*(1994), results similar to those obtained in this study showed that carabid diversity is more influenced by habitat structure than by the specific plant species. There has been much research regarding the correlation of environmental factors and carabid beetles. Vegetation structure and the microclimate (temperature and humidity) are the major elements which accurately indicate the distribution of the carabid population (Niemelä *et al.*, 1992). Moreover, there is a significantly positive relationship between the available food supply in the forest and the species richness. Thiele(1977) emphasized the importance of the environment, but did not consider the importance of special biological characteristics, like the food supply. Fournier and Loreau(1999) found that the density of feed played an important role in beetle distribution. Magura *et al.*(2004) reported a positive relationship with ground surface temperature and species richness; when the habitat temperature was high, the numbers of the common and open habitat species were abundant. Generally, the forest species are known to prefer habitats with high humidity(Thiele, 1977; Magura *et al.*, 2004). The appearance of fallen leaves is emphasized in some studies as a significant indication of the presence of beetle (Koivula and Niemelä, 2002). However, this sign does not seem to indicate carabid abundance or species richness at the habitat of the forest floor.

One striking result from our study is the fact that hillock are particularly poor in terms of carabid beetle conservation. There was no characteristic fauna and the species richness was relatively low at that habitat type. The hillock contained only an intermediate proportion of species with small range sizes and reduced wing development. Hillocks have been traditionally regarded as emblematic habitats for fauna conservation in rural area. These results indicate that agricultural landscape patchy remnants of ancestral habitats do no act as climax habitats like old forests for the maintenance of carabid diversity. Since they are not early succession forests, two other factors may be responsible for this pattern: (1) remnants may be too small and isolated to allow the survival of typical forest species, and (2) remnants may be highly disturbed due to edge effect(Dunning *et al.*, 1992; Saunders *et al.*, 1992). In addition the remnants may be periodically disturbed by wood-cuttings or other human perturbations. Recently, planted hedges appear to provide suitable habitats for carabids at a local scale by inducing a strong spatial reorganization around the hedge(Desender *et al.*, 1994; Fournier and Loreau, 1999). Our present study showed that such habitats are also interesting on a larger scale, in a perspective of maintenance of carabid diversity, because they may host populations that cannot establish either in remnants or in crops. However, examination of the literature(Burel, 1992; Tischendorf, 1998) leads us to believe that such a mosaic of unconnected small woody remnants and young open hedges will never be sufficient to replace true large forests. Specialized forest species that are characteristic of climax environments need a strong connectivity between suitable habitats(Burel, 1992; Scott and Anderson, 2002) and will probably remain absent from such a landscape. Our results suggest marked differences in the conservation value among habitats differing in structure and degree of human disturbance in a complex rural landscape. These findings will be used to establish landscape plans for the conservation of biodiversity.

However, there are some considerations such as the change of carabid beetle species composition according to the collecting method except the pit-ball trap and the kind of bait, a correlation between the soil contamination and a carabid beetle population, the characteristics of the carabid beetle distribution to the feeding habit, and etc. in this study. The above mentioned researches at the population level must be conducted at the same time for the efficient evaluation and decision making for conservation of biodiversity by using of arthropod in environmental disturbance area. Nevertheless, this study is valuable as a basis study that tried using carabid beetle for biological diversity preservation in a Korean rural landscape area.

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