CHAPTER 11

A HIGHER-TAXON APPROACH WITH SOIL INVERTEBRATES TO ASSESSING HABITAT DIVERSITY IN EAST ASIAN RURAL LANDSCAPES

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Abstract. Rural biodiversity in East Asia is at risk due to the loss of habitat diversity, and good indicators are needed to evaluate diverse habitats in rural landscapes. We examined whether the higher taxa (classes and orders) of soil invertebrates discriminated among several types of secondary forests such as broad-leaved deciduous forests, conifer forests and bamboo forests, primary forests, grasslands and/or wetlands, better than species assemblages of a well-established indicator, ground beetles (Coleoptera, Carabidae and/or Staphylinidae), in three East Asian regions (Japan, South Korea and the Russian Far East). We collected soil invertebrates with pitfall traps and used community composition and an ordination technique to test their performance as indicators. In Japan, the higher taxa of soil invertebrates discriminated finely among a wide range of habitats, and soil moisture seemed to be an important factor underlying habitat arrangement by these taxa along an ordination axis. While species assemblages of ground beetles detected large faunal differences among grasslands, wetlands and a composite group of three forest-type habitats (oak, conifer and bamboo forests), it failed to discriminate among any of the three forest-type habitats. When the analysis included only these types of forests, ground beetles were found to be able to discriminate finely among them, indicating limited performance in relation to the range of habitats

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covered. In the other two countries, the higher taxa of soil invertebrates showed a performance similar to that of species assemblages of ground beetles, possibly because of the narrow range of habitats analyzed. We conclude that the higher taxa of soil invertebrates are an effective tool for assessing the diversity of rural habitats across the East Asian region, where taxonomic knowledge at the species level is still insufficient. Our results may be applied broadly to other regions where agricultural intensification and land abandonment have caused quantitative and qualitative changes in rural landscapes.

1. INTRODUCTION

Identification of present and future threats to biodiversity is an important first step in realizing effective conservation (Margules and Pressey, 2000). Human-modified landscapes in rural areas have received little attention for conservation planning, but have recently become a matter of great concern due to a widespread decline in biodiversity (Benton et al., 2003; Kato, 2001; Krebs, 1999; Pykälä, 2000; Washitani, 2001). Nevertheless, an overall picture of threats to rural biodiversity remains obscure in many regions of the world because of a very restricted understanding of the losses in rural biodiversity sometimes referred to as the 'second Silent Spring' (Krebs et al., 1999). Figuring among such regions is East Asia, where rural landscapes have suffered conspicuous changes due to rapid industrial and economic development (Hong, 1998; Nakagoshi and Hong, 2001). Undoubtedly, rural landscapes in East Asia are of high priority and biodiversity-oriented research is essential to understand and put the current status of rural landscapes and their biodiversity on the front of real planning process.

A decline in rural biodiversity results from a loss of habitat diversity across various spatial scales through agricultural intensification with the attendant removal of non-cropped habitats (Benton et al., 2003), through the abandonment of traditional management, which causes qualitative changes in semi-natural habitats (Buckley, 1992; Hong, 1998; Nakagoshi and Hong, 2001; Washitani, 2001), or through the total loss of habitats due to changes in land use. In East Asia, the loss of habitat diversity due to the abandonment of traditional land use has emerged as a threat to biodiversity in only a few countries such as Japan and South Korea (Hong, 1998; Kato, 2001; Washitani, 2001). In Japan, where information on rural biodiversity is much more readily available than in other East Asian countries, a large number of species previously common to rural areas are now on the national red list and this situation characterizes the current crisis of biodiversity in Japan (Kato, 2001; Washitani, 2001). It is highly likely that this threat is also present in other countries where rapid agricultural modernization has strangled the traditional agriculture that has sustained agricultural life over centuries.

Assessing habitat diversity is an integral part of any conservation effort (Hughes, 2000; O'Neil, 1995). In general, there are various kinds of human-modified habitats in rural landscapes, including ponds, wetlands, grasslands, fallow lands, plantations and woodlands as well as cultivated fields. Differences in the methods and histories of management of these habitats may enhance further habitat diversity in rural areas. A priori land classification based on types of vegetation or habitats is a useful tool for reserve selection but requires biological survey to examine the relationships between fauna and land classes before applying the classification to reserve selection (Pressey, 1994). As a result, conservation planning of rural landscapes needs good indicators of habitat type across rather heterogeneous habitats. The search for such indicators across a wide range of habitats has been limited, even on a spatially restricted scale such as a rural landscape.

Invertebrates are ubiquitous, taxon-rich and dominant organisms throughout the world (Wilson, 1987), and there has been a recent increase in awareness of their usefulness as indicators in conservation planning (Kremen et al., 1993; McGeoch, 1998). Soil invertebrates living in and on the ground have proved to be effective in assessing various kinds of human disturbances (Paoletti and Bressan, 1996). Identification at the species level represents a major obstacle to the use of soil invertebrates as indicators (Oliver and Beattie, 1996), however, higher-taxon indicators of soil invertebrates often show a performance similar to that of species-level indicators (Paoletti and Bressan, 1996) and thus can be potential surrogates for soil invertebrates in practical conservation. Furthermore, such a higher-taxon approach can greatly reduce the costs necessary for biodiversity surveys in terms of money, time and labor (Balmford, 1996).

We examined the performance of soil invertebrates in higher taxonomic resolutions (classes and orders) as indicators of habitat diversity in rural areas across the northern part of East Asia, including Japan, South Korea and the Russian Far East. To evaluate the effectiveness of such higher-taxon indicators in comparison with species-level indicators, we selected ground beetle assemblages (Coleoptera, Carabidae and Staphylinidae) as a control group. Ground beetles have been widely used as indicators (Luff, 1996; Niemelä, 2001; Rainio and Niemelä, 2003) and provide rich information for the assessment of habitat diversity on various spatial scales (Niemelä et al., 1992; Luff et al., 1989, 1992; Rykken et al., 1997; Blake et al., 2003; Gutiérrez et al., 2003; Scott and Anderson, 2003). We used community composition and multivariate analysis as a measure and a method to test performance (Luff et al., 1989, 1992; O'Neil et al., 1995; Blake et al., 2003; Scott and Anderson, 2003). Recent studies validate the use of community composition in evaluating indicator performance (Howard et al., 1998; Oliver et al., 1998; Su et al., 2004).

2. METHODS

2.1 Study Areas and Habitat Types

We defined rural areas as being situated between urban and mountainous areas and focused primarily on rural habitats consisting of secondary woodlands, grasslands and wetlands near human settlement (Takeuchi et al., 2003). We selected several habitat types typical of rural areas in each country under consideration (Table 1).

In Japan, we established 50 study sites, which were distributed across 16 localities in Ishikawa Prefecture, Central Japan (Figure 1) and represented five types of rural habitats: oak forests, conifer forests, bamboo forests, grasslands and wetlands (Table 1). Conifer and bamboo forests were man-made plantations, which are usually not regarded as typical rural habitats but which were included in the present study because of their prevalence (conifer) and their rapidly increasing area (bamboo). There are few secondary grasslands in Ishikawa as in many other parts of Japan due to succession after abandonment (Takeuchi et al., 2003), resulting in our selection of mostly secondary grasslands, including two man-made grasslands, in public areas as study sites (Table 1).

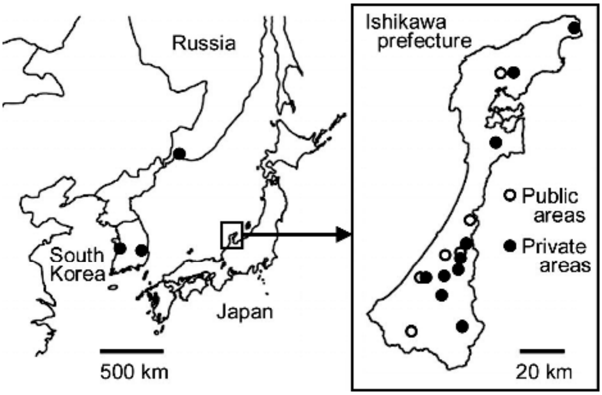

Figure 1. Map of study localities in Japan, South Korea and the Russian Far East.

In South Korea, we established 21 sites in the suburbs of two cities 200 km apart from each other, Jeongeup (100 km southwest of Daejeon) and Yeongcheon (35 km east of Daegu) (Figure 1). We selected six habitat types: pine forests, oak forests, pseudoacacia forests, bamboo forests, shrubs and grasslands (Nakagoshi and Hong, 2001) (Table 1). In the Russian Far East, we established seven sites in the suburbs of Vladivostok (Figure 1), including primary forests, oak forests, mixed deciduous forests and grasslands; one mixed deciduous forest was situated in a city park (Table 1). In addition, we established one site in a primary forest near the Ussuriisk Nature Reserve to evaluate the effect of urbanization on primary forests.

2.2 Sampling

We used pitfall traps to collect ground-active soil invertebrates. In Japan and South Korea the traps consisted of plastic bottles (500 ml, diameter 9 cm, depth 11 cm), partly filled with a 50% solution of ethylene glycol and covered with rims to prevent flooding due to rain. Each site contained one to four plots, with a distance between plots of 20-30 m, and five traps were placed linearly at 5-m intervals in each plot at each site. In total, there were 480 and 105 traps in Japan and South Korea, respectively. We collected invertebrate samples for two weeks from mid to late September 2003 in Japan and from 22 July to 5 August 2004 in South Korea. In the Russian Far East, we used plastic cups (volume 250 ml, diameter 7 cm, depth 9.5 cm) with water and a few drops of detergent as a collecting medium; there were no lids on the traps. In seven of eight study sites, we placed 15 traps linearly at 5-m intervals and carried out sampling for one day in mid June, early August, early September and mid October 2003. In the primary forest near the Ussuriisk Nature Reserve, we placed a set of five traps arranged in a 3 x 3 cross at 0.5-m intervals between traps as a

Table 1. Summary of habitat types in Japan, South Korea and the Russian Far East.

Habitat type	No. of sites	Elevation (m)	Habitat description
Japan			
Oak forest	13	40 to 250	secondary mixed oak stand (*Quercus serrata* and *Quercus variabilis*)
Conifer forest	13	40 to 400	plantation of Japanese cedar (*Cryptomeria japonica*)
Bamboo forest	9	20 to 220	bamboo plantation (*Phyllostachys pubescens*)
Grassland	9	50 to 130	one humid[a] and eight xeric[b] secondary grasslands
Wetland	6	5 to 200	beside irrigation ponds, beside small creeks or in fallow paddy fields
South Korea			
Pine forest	9	20 to 260	secondary pure pine stand (*Pinus densiflora*) with oak saplings
Oak forest	2	210 to 240	secondary mixed oak stand (*Quercus* spp.)
Pseudoacacia forest	3	220 to 250	secondary pure pseudoacacia stand (*Robinia pseudoacacia*)
Bamboo forest	2	20 to 50	bamboo plantation (*Phyllostachys nigra*) in farmyards
Shrubs	3	20 to 50	dense stand of tree saplings (*Robinia pseudoacacia, Quercus* spp., and pinus sp.)
Grassland	2	20 to 50	xeric secondary grassland beside traditional graveyards
Russian Far East			
Primary forest	3	80 to 210	mixed pine (*Abies holophylla* and *Pinus koraiensis*) -oak (*Quercus mongolica*) stand in Vladivostok or near the Ussuriisk Nature Reserve
Oak forest	2	55 to 130	secondary oak stand (*Quercus mongolica*)
Mixed deciduous forest	2	20 to 90	secondary mixed deciduous stand in the Nagornii park (*Acer* spp., *Fraxinus* sp., *Betula* sp., and *Syringa amurensis*) or in a valley of the Bogataya River (*Betula platyphylla*, *Alnus hirsuta*)
Grassland	1	20	humid secondary grassland in a valley of the Bogataya River

[a] a managed artificial lawn in the Kanazawa University

[b] one managed artificial lawn and two secondary grasslands in the Kanazawa University, two secondary grasslands in the Kanazawa Castle Park, and two secondary grasslands in nature parks

secondary trapping unit and collected specimens for two days from 30 June to 1 July2003, for one week from 13 to 19 July 2003, and for eight days from 22 to 29 August 2003.

We identified first centipedes (Chilopoda), millipedes (Diplopoda), land snails (Gastropoda), earthworms (Oligochaeta) and leeches (Hirudinoidea) at the class level and other invertebrates at the order level, as well as carabid beetles at the species level in all three countries. In the Russian samples from the Ussuriisk Nature Reserve, we identified all Coleopteran specimens at the species level (Storozhenko et al., 2003); in the Korean samples, we also identified 85% of rove beetles (Staphylinidae) at the species level and other rove beetles (15%) at the subfamily level (Aleocharinae, Pselaphinae, Scaphidiinae and Tachyporinae). For specimens in Tachyporinae, we were able to distinguish one species, *Lordithon aitai*, from the others, Tachyporinae spp. We treated these subfamilies and Tachyporinae spp. as a single species and, as in the case of the species data of rove beetles, combined them with the carabid dataset in subsequent analysis. We eliminated springtails (Collembola) and mites (Acarina) from the Japanese samples during sorting because of the considerable amount of time needed to sort a significant number of such very tiny specimens.

2.3 Data Analysis

We used an ordination technique to examine the performance of two datasets, one based on the higher taxa of soil invertebrates (hereafter referred to as the invertebrate dataset) and the other on species of ground beetles (carabid dataset), with regard to the classification of study sites according to habitat types (Luff et al., 1989, 1992; Oliver et al., 1998; O'Neil et al., 1995; Scott and Anderson, 2003; Basset et al., 2004). We employed unconstrained ordination methods, such as principal components analysis (PCA) and detrended correspondence analysis (DCA), to analyze datasets from South Korea and the Russian Far East. For the Japanese datasets, we adopted constrained methods, such as redundancy analysis (RDA) and canonical correspondence analysis (CCA), with altitudes, longitudes, latitudes and habitat types as environmental variables, because these datasets consisted of samples collected across a wide range of localities (Figure 1) and altitudes (Table 1). In both the unconstrained and constrained methods, we finally selected either an ordination technique for species response to an underlying environmental gradient to be linear (PCA and RDA), or unimodal (DCA and CCA) based on simple criteria. After carrying out DCA on each dataset and checking the length of the largest gradient among the resultant ordination axes, we selected PCA and RDA if the largest gradient was shorter than 2.0, and DCA and CCA if it was larger than 4.0 (Jongman et al., 1995; Lepš and Šmilauer, 2003). Regardless of the length of the largest gradient, we chose DCA over PCA in those cases in which we visually confirmed an artifactual distortion of the ordination diagram due to the arch effect, in which the second axis was an arched function of the first axis (Jongman et al., 1995; Lepš and Šmilauer, 2003). If necessary, a partial RDA or CCA was carried out using one or several environmental variables as a covariable or covariables in order to help to interpret results obtained by the constrained method. Partial constrained methods enable us to examine effects of environmental variables of interest after partialling out the effect of covariables (Gutiérrez et al., 2003; Lepš and Šmilauer, 2003). We carried out these analyses using CANOCO version 4.5 (ter Braak and Šmilauer, 2002). When necessary, we standardized abundance data for each site with the number of traps and days because the sampling effort varied among sites or because some trap samples were lost due to flooding, especially in wetlands, and wildlife disturbance. For the purposes of analysis, we pooled trap samples in each site, excluded study sites whose total number of individuals collected was < 10 and transformed abundance data to $\log_{10}(x + 1)$. Where possible, we carried out non-parametric analysis of variance using the Kruskal-Wallis *H*-test or the Mann-Whitney *U*-test on site scores, derived from ordination analyses, along the first and second axis to evaluate the classification of study sites among habitat types or localities (Jongman et al., 1995). For constrained ordination in Japan, we analyzed the statistical significance of the ordination by Monte-Carlo randomization *F*-test with 499 permutations.

3. RESULTS

In total, we collected 29865, 14142 and 9270 invertebrates, including 24, 21 and 21 higher taxa (classes and orders), and 1423, 612 (116 carabids and 496 rove beetles) and 733 ground beetles, comprising 43, 38 (21 for carabids and 17 for rove beetles) and 59 species, in Japan, South Korea and the Russian Far East, respectively. In the Japanese fauna, the most abundant higher taxa were Hymenoptera, Coleoptera and Isopoda, which comprised 68% of the invertebrates collected. Two carabid species, *Carabus maiyasanus maiyasanus* and *Synuchus nitidus*, dominated beetle samples at 47% of collected specimens. In South Korea, Hymenoptera, Collembola and Aranea comprised 77% of invertebrate specimens, and slightly over half (58%) of ground beetle specimens consisted of a single species of rove beetles, *Oxytelus* sp. In the Russian Far East, Collembola, Hymenoptera and Coleoptera comprised 67% of invertebrates collected and approximately half (49%) of carabid specimens consisted of four species, *Agonum mandli*, *Carabus venustus*, *Pterostichus vladivostokensis* and *Nebria coreica*.

Ordination analysis showed that while the carabid dataset in Japan detected large faunal differences among grasslands, wetlands and a composite group of three forest-type habitats (oak, conifer and bamboo forests) (Figure 2A; $F = 3.1$, $P = 0.002$; $H = 21.6$, $P = 0.0002$ for the first axis; $H = 9.9$, $P = 0.04$ for the second axis), it failed to discriminate among any of the three forest-type habitats (Figure 2A; $H = 4.0$, $P = 0.13$ for the first axis; $H = 2.3$, $P = 0.32$ for the second axis). The first and second axes explained 21.3% and 9.7% of the variation in carabid faunal composition and 53.3% and 24.6% of the variance in the relationship between carabid species and the environment, respectively. After excluding grasslands and wetlands from the ordination analysis, however, this dataset effectively discriminated among the three forest habitats (Figure 2B; $F = 1.51$, $P = 0.006$; $H = 10.5$, $P = 0.005$ for the first axis; $H = 13.7$, $P = 0.001$ for the second axis), separating oak forests from conifer and bamboo forests.

On the other hand, the invertebrate dataset successfully classified study sites among the forest habitats without exclusion of any habitats (Figure 2C; $H = 15.6$, $P = 0.0004$

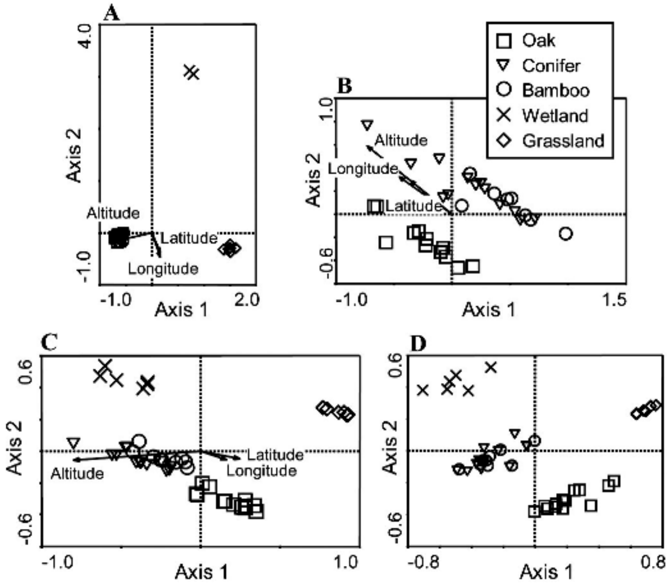

Figure 2. CCA ordination plots of all study sites (A) and sites in forest-type habitats (oak, conifer and bamboo forests: B) based on species assemblages of ground beetles and RDA (C) and partial RDA (D) ordination plots, the latter using altitude, latitude and longitude as covariables, of all study sites based on the higher taxa of soil invertebrates in Japan.

for the first axis; $H = 9.7$, $P = 0.008$ for the second axis), separating oak forests from conifer and bamboo forests, as well as among all habitats (Figure 2C; $F = 3.14$, $P = 0.002$; $H = 31.4$, $P < 0.0001$ for the first axis; $H = 20.4$, $P = 0.0004$ for the second axis). The first and second axes explained 23.3% and 6.3% of the variation in invertebrate faunal composition and 67.7% and 18.5% of the variance in the relationship between higher taxon and the environment, respectively. Two types of man-made plantation (conifer and bamboo, Table 1) showed quite similar invertebrate fauna. Soil moisture seemed to be an important factor underlying the arrangement of habitat types in the invertebrate ordination along the first axis, changing leftward from grasslands as a dry extreme to wetlands as a wet one (Figure 2C). Altitude had a large effect on invertebrate fauna, indicated by a long arrow in the ordination diagram, while the effect of geographical location (latitude and longitude) was small (Figure 2C). The partial RDA, using altitude as an environmental variable and the remaining ones as covariables, revealed that the effect of altitude was significant ($F = 2.92$, $P = 0.02$), although altitude explained only 5.7% of the variation in invertebrate faunal composition. In addition, the pattern of habitat classification based on the invertebrate dataset were nearly the same even after partialling out the effects of altitude, latitude and longitude in the ordination analysis (Figure 2D), indicating the significant effect of habitat types on invertebrate fauna ($F = 3.07$, $P = 0.002$).

For South Korea, the carabid dataset detected faunal differences between two localities and among habitat types in one locality, Yeongcheon, along the first axis (Figure 3A; U = 14.0, P = 0.018 for the former; H = 7.58, P = 0.023 for the latter). Similarly, the invertebrate dataset discriminated not only between two localities along the first axis (Figure 3B; U = 2.0, P = 0.0004) but also among habitat types in Yeongcheon along the second axis (Figure 3B; H = 8.14, P = 0.017, after excluding one grassland site from analysis). However, the differences among habitat types in Yeongcheon were larger and clearer in the ordination plot of the invertebrate dataset than in that of the carabid dataset. Ordination results in the Russian Far East showed a similar performance between the carabid and invertebrate datasets, both of which classified sites among grasslands, mixed deciduous forests and the others with oak and primary forests along the first axis (Figure 4A and B). We performed no statistical tests on the Russian ordination results because of the small sample sizes in most types of habitats.

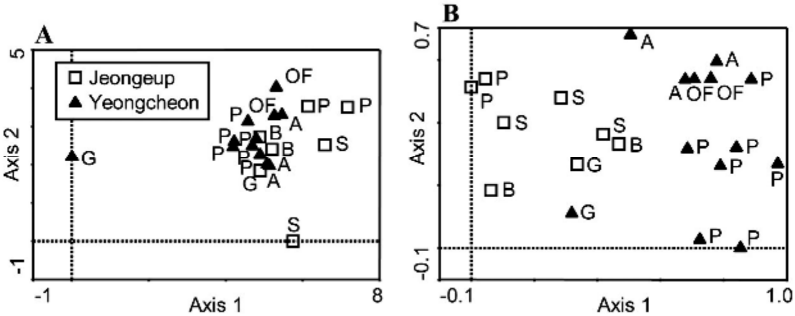

Figure 3. DCA ordination plots of study sites based on species assemblages of ground beetles (A) and the higher taxa of soil invertebrates (B) in South Korea. Capital letters indicate habitat types: pine forests (P), pseudoacacia forests (A), oak forests (OF), bamboo forests (B), shrub (S) and grasslands (G).

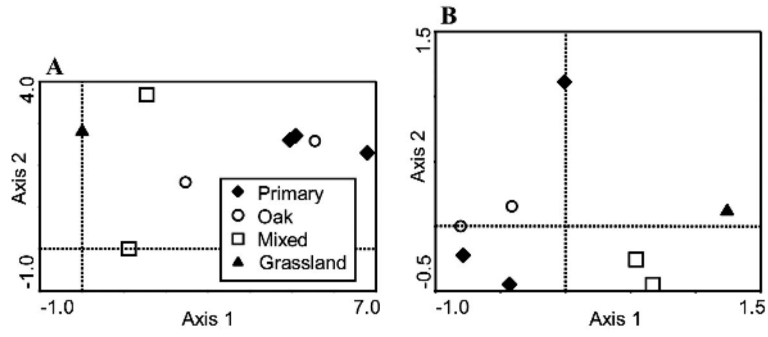

Figure 4. DCA and PCA ordination plots of study sites based on species assemblages of ground beetles (A) and the higher taxa of soil invertebrates (B), respectively, in the Russian Far East.

4. DISCUSSION

4.1 Indicator Performance

As a whole, the present study showed better performance in the higher taxa of soil invertebrates than in species assemblages of ground beetles as an indicator of diverse rural habitats. In Japan, while ground beetles identified major differences among grasslands, wetlands and forests, they failed to discriminate among several types of forest habitats and classified all of such types into a single group. On the other hand, the higher taxa of soil invertebrates effectively classified study sites among not only the forest-type habitats but also the other habitat types. After excluding the major differences among grasslands, wetlands and forests, ground beetles were found to be able to successfully discriminate among the forest-type habitats. These results clearly indicate the limited performance of ground beetles in relation to the range of habitat types: ground beetles can discriminate finely among similar habitats or within a limited range of habitats but only roughly among heterogeneous habitats or within a wide range of habitats. There is considerable evidence supporting fine resolution in the classification of similar habitats by carabid fauna, for example, in grasslands (Rushton et al., 1991; Luff et al., 1992; Asteraki et al., 1995; Luff, 1996; Dennis et al., 1997; French and Elliott, 1999), woodlands (Niemelä et al., 1988; Niemelä et al., 1992; Baguette, 1993; Coll et al., 1995; Niemelä et al., 1996; Humphrey et al., 1999; Jukes et al., 2001; Koivula et al., 2002; Similä et al., 2002), heathland (Gardner, 1991), moorland (Holmes et al., 1993; McCracken, 1994; Sanderson et al., 1995) and a limited range of habitats (Thiele, 1977; Bedford and Usher, 1994; Butterfield et al., 1995; Niemelä et al., 1996; Fahy and Gormally, 1998; Ings and Hartley, 1999; Fournier and Loreau, 2001; du Bus de warnaffe and Lebrun, 2004;). In contrast, few studies have examined a wide range of habitats; nevertheless, there is some evidence for the rough distinction of heterogeneous habitats by carabid fauna (Luff et al., 1989; Turin et al., 1991; Blake et al., 2003; Scott and Anderson, 2003).

In South Korea, both ground beetles and invertebrate higher taxa differed between the two localities, while no such local differentiation was detected in either fauna of Japan. The number of localities studied was much larger (15 in Japan and two in Korea) and the arrangement of localities was geographically more continuous, with a shorter range between the two most distant sites in Japan (170 km) than in Korea (200 km). The discrepancy in the results between the two countries may be attributable primarily to these differences in study design. In addition, the composition of the studied habitats differed greatly between the two localities in Korea and this may also have contributed to faunal variation between the two localities. For habitat classification in Korea, the higher taxa of soil invertebrates were found to show a performance similar to that of ground beetles in discriminating some types of forest habitats in Yeongcheon region. This is consistent with the present results for classification of forest-type habitats in Japan, which show fine classification among similar habitat types by carabid fauna and similar performance in discriminating among the habitat types between the invertebrate and the carabid datasets. The Korean ground beetles consisted largely of rove beetles, which represented 81% of the total number of individuals collected; in addition to carabid beetles, rove beetles can also be a potential indicator of habitat type (Bohac, 1999). We have no explanation for the scarcity of carabids in the Korean samples. However, if this represents a decline in their population in rural areas, it indicates high conservation value for carabids in Korea.

Many of soil invertebrates have proven to be closely associated with moist habitats such as damp soil, mud and decomposing organic matter and be sensitive to changes in moisture and relative humidity of their habitats (e.g. Coleman et al., 2004; Lensing et al., 2005). In the present study, the ordination analysis revealed that faunal composition of invertebrate higher taxa collected in Japan gradually changed from grasslands through forests to wetlands along the first axis. Although we measured no abiotic factors in this study, soil moisture may be an important factor that underlies the arrangement of habitat types based on the invertebrate dataset. Ground beetles are also known to respond well to soil moisture in terms of species abundance, diversity and composition (Baguette 1993; Asteraki et al., 1995; Sanderson et al., 1995; Koivula et al., 1999; Jukes et al., 2001). However, no such response of ground beetles to soil moisture was detectable in the ordination plot based on the carabid dataset, implying the relatively minor effect of soil moisture on species distribution of ground beetles across highly heterogeneous habitats in rural landscapes.

4.2 Implications for Conservation

Invertebrates are numerous everywhere and perform various ecological functions and essential roles in all ecosystems on earth. Species identification poses a crucial limitation for using invertebrates as indicators in conservation planning. For assessment of habitat diversity, however, the present study clearly shows that the higher taxa of soil invertebrates can finely discriminate among diverse types of rural habitats, even based on samples from a relatively short-term survey. This result highlights the importance of invertebrate higher taxa in assessing the habitat diversity of rural areas across the East Asian region, where taxonomic knowledge of soil invertebrates at the species level is still insufficient and abandonment of traditional management has caused qualitative changes in habitats. Our results may be applied broadly to other regions under similar conditions of land use, for example Europe (Buckley, 1992; Pykälä, 2000).

Ground beetles may be less useful than the higher taxa of soil invertebrates in classifying rural habitats, if such a wide range of habitat types as that covered in this study is taken into account. Rather, we suggest using the higher taxa of soil invertebrates as surrogate indicators for assessing the conservation value of various habitats. Habitat classification based on the present carabid datasets was rough but consistent with that based on invertebrate datasets. Such a higher-taxon approach can effectively save money, time and labor (Balmford et al., 1996) and should be one of options in designing biological surveys for conservation planning, especially in regions where available resources are severely limited.

We need additional studies on other taxa and types of rural habitats, especially on habitats under management, to refine our results. Temporal variation in structure of invertebrate communities may occur through seasonal changes in both abiotic and biotic environments and thus seasonal replication can also improve the reliability and consistency of the results over time.

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