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Variation in bird diversity in relation to habitat size in the urban landscape of Seoul, South Korea

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Abstract. This study was carried out to find what factors could affect bird diversity in green areas in an urban landscape. We selected 83 sites of different size and type of urban landscapes in Seoul, South Korea and surveyed bird diversity. Urban green patches were grouped into three subclasses: < 1 ha, 1–10 ha and > 10 ha. The cumulative bird diversity was greater in the subclass 1-10 ha than in < 1 ha or in > 10 ha. We suggest that bird diversity was closely related to habitat size, especially in the category 1–10 ha, and recommend this area be used to establish new bird habitats in urban landscapes. The number of bird species was significantly correlated with the number of insect species in studied patches, but was not correlated with the size of green areas or the distance to roads. Therefore, we suggest that the number of insect species is the most important factor affecting bird diversity within our urban study area.

Key words: bird diversity, urban landscape, urban planning, insects, roads, Korea

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INTRODUCTION

Urbanization is likely to overcome agriculture as the dominant factor of fragmentation at the global scale (Marzluff & Ewing 2001). Currently about 3% of the Earth's surface is covered with buildings and other urban structures (Meyer & Turner 1992). What is more important, a sprawl of buildings associated with many urban centers and the current tendency in developed countries to subdivide and settle formerly extensive wild areas (Berry 1990, Knight et al. 1995, Buechner & Sauvajot 1996) result in fragmentation of large portions of the earth by some form of human settlement (Marzluff & Ewing 2001).

With the rapid expansion of urban development, the importance of understanding the relationship between wildlife and urban habitats is obvious (Jokimäki & Suhonen 1998). Studies surveying multiple sites within urban areas (e.g. Mills et al. 1989, Jokimäki & Suhonen 1998) demonstrate variation in the capacity of differently developed sites to support bird populations. Therefore, planning and design decisions have a huge impact on the urban landscape, which in turn impact animal diversity. Traditionally though, ecologists would choose to measure some natural features in a landscape (e.g., tree patches) and ask how the distribution of these features affects the distribution of animals (Hostetler 1999). Then, a long-term goal of an urban ecologist should be able to uncover the factors regulating the success or failure of species in inhabited areas, and use these factors to develop principles for the design of urban landscapes more nature-friendly (Turner 2003).

In terms of habitat size, the value of large ecological reserves and large patches is well accepted, but more work is needed on the value of intermediate-sized reserves and patches or small area habitat features (Zuidema et al. 1996, Gilfedder & Kirkpatrick 1998, Semlitsch & Bodie 1998). Such information is critical for the development of effective and realistic conservation and ecosystem restoration strategies especially in highly modified landscapes (Fischer & Lindenmayer 2002).

The goal of this study was to compare: 1) the relationship between habitat area and bird diversity, 2) the relationship among bird diversity, patch size, the number of insect species, and distance from studied patches to adjacent traffic road. We used the results to advise a realistic and effective restoration method of existing habitats and establishment of new habitats in the city.

MATERIAL AND METHODS

In the study area, Seoul (South Korea), about 10.2 million people reside in roughly 605 km^2. There are 1,405 parks of a total area of 154.1 km^2, covering about 25% of the city. However, more than 80% of the parks are located in the outermost areas of the city and 63.4% of them are urban natural parks.

Within the city we selected 83 different sites belonging to 6 main types of urban landscape (Table 1) in which bird diversity was surveyed. All green area patches were grouped into three categories according to size: small areas (< 1 ha, n = 26), medium (1–10 ha, n = 51) and large ones (> 10 ha, n = 6). The mean (± SD) size of patches under study was 0.44 ± 0.18 ha for small, 3.08 ± 1.78 ha for medium and 24.1 ± 6.21 ha for large areas.

Birds were surveyed 3–4 times in each biotope in 2001 and 2002. To include the fall and spring migration seasons, birds were surveyed twice in each site from October to November in 2001, 2002 and from May to June in 2002. All surveys were conducted within 4 h after sunrise. We recorded all birds heard and seen in each study area. A survey route zigzagged through each plot to allow us to inspect the backyards of the houses and buildings. This kind of transect count reduces many problems associated with counting birds in urban areas, such as varying noise and visibility (DeGraaf et al. 1991). Surveys were not conducted during rainy or extremely windy conditions (greater than 20 mph).

Insect data were gathered by sweeping, beating and light trapping during daytime and night. The net size was 30 cm diameter. Sweeping and beating were carried out about 10 times in a place, and this was 3 times per season. Light trapping was conducted during 3 hours after sunset.

Table 1. Characteristics of green area patches and the number of bird species on each biotope characteristics and the factors influencing the bird diversity. N — number of studied areas.

Landscape type (N)	Landscape characteristics	Area (ha)	Total No of bird species	No of insect species	Distance to adjacent traffic road	Impermeable pavement ratio
DA (14)	Gardens whithin the building complexes	4.81 ± 8.06	2.64 ± 2.50	27.6 ± 19.4	35.4 ± 44.3	61.3 ± 30.0
FR (16)	Forests	2.87 ± 4.91	5.81 ± 2.56	42.9 ± 18.8	262 ± 232	0.00 ± 0.00
GA (12)	Parks	1.95 ± 2.06	2.92 ± 1.78	28.1 ± 14.0	51.9 ± 70.3	7.92 ±27.4
RA (16)	Gardens near the houses (1-4 floor high)	3.86 ± 4.22	3.69 ± 1.96	27.9 ± 8.96	77.0 ± 106	70.1 ± 22.3
SW (7)	High flood plain in the streams or ponds	6.72 ± 11.3	3.57 ± 3.05	33.6 ± 12.6	104 ± 153	30.0 ± 47.6
UA (18)	Undeveloped or unused areas, vacant lands	3.77 ± 6.58	3.67 ± 2.06	29.8 ± 14.8	197 ± 159	16.9 ± 34.9

The patch size and the distance from patch to adjacent traffic road were estimated using GIS. We did not include the size of traffic road into analysis. Each factor was surveyed while collecting bird diversity data and the data were derived from the report by Seoul city (For more detail, see Report of plan study ecosystem restoration and biodiversity promotion with biotope type in Seoul 2002, 2003).

Cumulative species-area curves were used to assess the contribution that small patches made to species diversity. Patch size were first ordered from large to small, and values for cumulative sizes and cumulative number of species were calculated; for comparison, the analysis was repeated with patches ordered from small to large (Quinn & Harrison 1988). In order to assess whether the contribution of small patches to species diversity was caused only by certain species, we repeated all analyses after the exclusion of waterbirds.

Multiple regression analysis was carried out in which bird diversity, size of patch, the number of insect species, and the distance from patch to adjacent traffic road were the independent variables. All analyses were carried out using the SPSS 10.0 statistical software package.

RESULTS

In total, 36 bird species were observed at 83 sites. Sixteen species used small patches, 33 species medium patches, and 12 species — large ones. Eighteen species of birds were observed only at small patches. When waterbirds were excluded, the total numbers of remaining species was 27. Ten of these species were found only at medium patches. In urban landscapes, Tree Sparrow *Passer montanus* and Black-billed Magpie *Pica pica*, were encountered most often.

The cumulative number of species for a given cumulative area was consistently higher when small sites were added first (Fig. 1). When we compared the full set (all birds) to restricted set (excluded waterbirds), peak of bird diversity occurred in stream or wetland where waterbirds were observed, forests and undeveloped areas with multiple vegetation structure. Cumulative bird diversity by size of patch increased greatest in medium sites. Bird diversity was significantly correlated with the number of insect species presence at the patch, and not related to the size of studied patch and the distance to adjacent traffic roads (Table 2, Fig. 2).

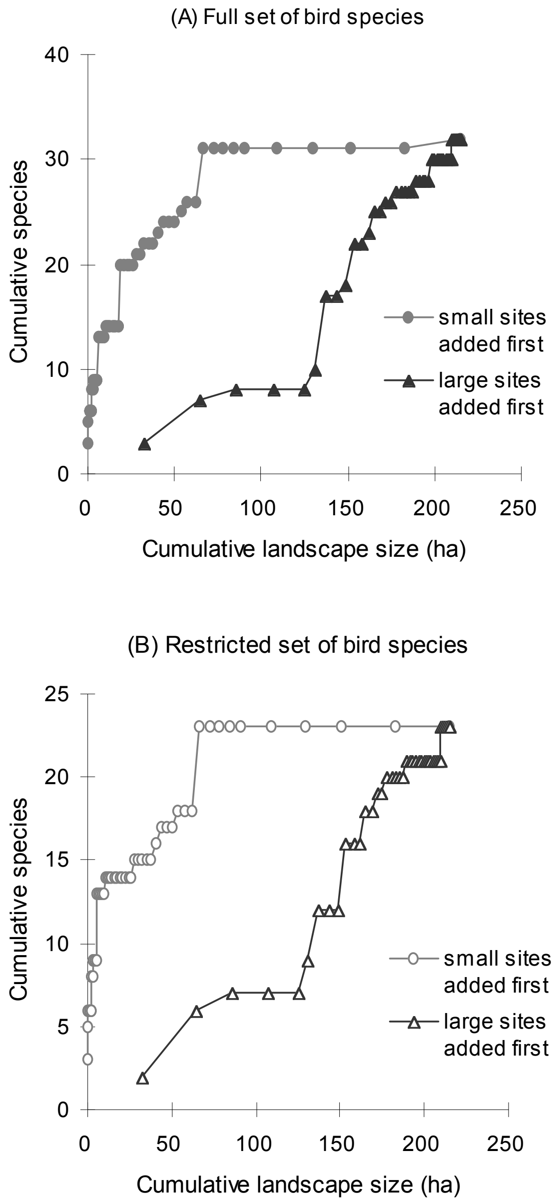

Fig. 1. Cumulative number of species versus cumulative landscape size. Part A is based on the full dataset and include all bird species; in part B waterbirds were excluded. In graphs, sites were added from large to small or small to large, respectively.

DISCUSSION

Songbird populations appeared to be more closely related to habitat quantity and structure than to habitat pattern (Donnelly & Marzluff 2006). Bird diversity varies with the amount of natural vegetation, and its converse, the amount

Table 2. Results of stepwise multiple regression analysis using the number of bird species as a dependent variable.

Variable	Coefficient	SE	Standardized coefficient	df	F	R^2	p
Area	0.059	0.039	0.150	3.79	7.866	0.230	0.135
Insects	0.050	0.017	0.328				0.003
Distance	0.003	0.002	0.183				0.095
Constant	1.622	0.544					

of urban land cover in landscape (Marzluff 2005). In this study, bird diversity increased with habitat patch size, but was not correlated with landscape size (Table 2). Also if it maintains water resources and the multiple vegetation structure, even small sites can hold high bird diversity (Fig. 2). Our results suggest that small patches can be valuable complements to large habitat patches. Therefore, we recommend that medium-sized sites of 1–10 ha are suitable size for establishing new habitat suitable for birds at least in urban landscape of Seoul.

We do not suggest that the birds we observed can maintain viable populations in such small areas, even some may not attempt to breed there. Rather, the sharp increase in cumulative species diversity (Fig. 1) suggests that small patches are used on a daily basis by many species. So they may have an important value other than providing breeding sites (Fischer 2002). For instance, well-vegetated residential areas constitute aerial corridors through their tree canopy. Such corridors are especially useful for migrating birds which use them extensively as they provide food and protection against aerial predators (Savard 1978). Greenways act not only as movement corridors (Clergeau & Burel 1997) but can also provide breeding habitats for several edge species (Noss 1993).

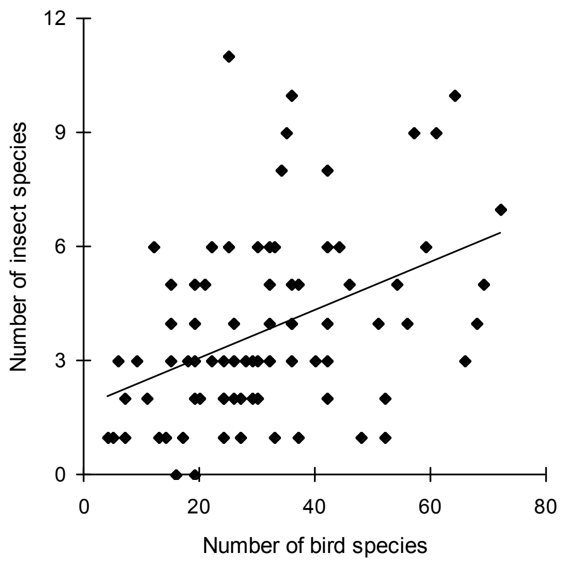

Fig. 2. Relationship between the number of bird species and the number of insect species.

Higher bird densities of only a few species have been found in several urban areas when compared to natural ones, and species composition and diversity changes as the degree of urbanization increases (e.g. Woolfenden & Rohwer 1969, Emlen 1974, Walcott 1974, Degraaf & Wentworth 1981, Blair 1996). In addition, the size of habitat patches and the intensity of surrounding urbanization were related to the presence or absence of individual species (Donnelly & Marzluff 2004). Therefore, from a policy perspective on how to manage urban areas for birds, it would be useful to know whether land use can predict whether a given area is attractive to a particular species. Such information would be important to homeowners, developers, landscape architects, and city planners as a clue to evaluate whether a piece of property (under a specific land use designation) could be designed for a given bird species (Hostetler & Knowles—Yanez 2003).

Birds are quite sensitive to changes in habitat structure and composition and are therefore excellent indicators of changes and stresses in the urban ecosystem (Savard & Falls 1982, Clergeau et al. 1998). Several studies have found that many recorded bird species have low densities and limited distribution in urban areas (Mills et al. 1989, Blair 1996, Germaine et al. 1998). Low density of many urban bird species is a common problem when attempting to ascertain which habitat variables influence the distribution of birds in urban environments. Also, many of these species may not be able to use developed urban environments and are usually absent from urban areas because necessary habitat variables are absent. In this study, birds show limited distribution similar to other urban areas. Diversity was hardly affected by the increase of habitat size, while it was strongly influenced by the presence of insect species which is their food resources (Table 2). The distance to adjacent traffic road as a surrogate of human interference, had little affect on diversity (Table 2).

Species diversity and abundance are often related to the quality of urban life (Adams 1994, Middleton 1994). In this study, bird diversity quickly increased, especially when medium sized patches were taken under consideration. Therefore, it may be possible to limit habitat size (1–10 ha) when habitat development is established for realistic and effective conservation of bird diversity. In Seoul, where land prices are very high, it is especially important to decide the minimum habitat size required to support the greatest bird diversity. In addition, due to their lower costs, small scale restoration program using small patches as a starting point are more likely to be implemented in the short term than large scale projects that can be very expensive (Fenton 1997).

On the other hand, hedgerows and natural vegetation strips act as corridors for some species of butterflies (Shreeve 1992) and birds (Johnson & Adkisson 1985, Dmowski & Kozakiewicz 1990), which move along them for foraging or simply as a route from one patch to another. Some birds and flying insects need a set of suitable neighbouring patches in which to disperse (Peterson 1985, Opdam 1990). Also, linear features for dispersal or movement can compensate for fragmentation (Saunders & Hobbs 1991, Noss 1993, Bischoff & Jongman 1993, Clergeau 1993). For that reason, patch network of designated sizes is needed for the urban environment. Small habitats with multiple vegetation structure can provide bird shelter and play a role as corridors for dispersion.

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STRESZCZENIE

[Czynniki wpływające na różnorodność gatunkową ptaków terenów zielonych Seulu].

Badania miały na celu określenie czynników wpływających na różnorodność gatunkową ptaków miejskich terenów zielonych. Wybrano 83 powierzchnie różniące się wielkością i rodzajem otaczających środowisk i odległością od dróg (Tab. 1). Badania awifauny obejmowały 3–4 kontrole w każdym z wyróżnionych płatów w latach 2001–2002, zarówno w okresie lęgowym jak i przelotów. Zapisywano wszystkie zaobserwowane lub usłyszane osobniki. Ta tych samych terenach prowadzono odłowy owadów zarówno dziennych jak i nocnych.

Na badanych terenach stwierdzono 36 gatunków ptaków. Łączna skumulowana liczba stwierdzonych gatunków była największa dla powierzchni o wielkości 1–10 ha, w porównaniu z danymi dla powierzchni < 1 ha, jak i > 10 ha. Najsilniejszy wzrost liczby gatunków obserwowano, gdy w pierwszej kolejności łączono dane dla małych powierzchni i to zarówno dla wszystkich gatunków ptaków, jak i grupy, z której wyłączono ptaki wodne (Fig. 1). Liczba gatunków ptaków była ściśle skorelowana z liczbą owadów występujących na badanych powierzchniach, podobnego związku nie stwierdzono w zależności od wielkości wybranych terenów, jak również odległości od dróg (Tab. 2, Fig. 2). Autorzy sugerują, że najbardziej odpowiednie jest zakładanie nowych terenów zielonych o powierzchni 1–10 ha.