

Bird community patterns in response to the island features of urban woodlots in eastern China

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Abstract Many studies have demonstrated the changes in the spatial patterns of plant and animal communities with respect to habitat fragmentation. Insular communities tend to exhibit some special patterns in connection with the characteristics of island habitats. In this paper, the relationships between richness, assemblage, and abundance of bird communities with respect to island features were analyzed in 20 urban woodlots in Hangzhou, China. Field investigations of bird communities, using the line transect method, were conducted from January to December, 1997. Each woodlot was surveyed 16 times during the year. Results indicated that bird richness was higher, per unit area, in the smaller woodlots than the larger ones, and overall bird density decreased with the increase in the size of woodlot. However, the evenness of species abundance increased with the area, and small woodlots were usually dominated by higher density species and large woodlots by medium density species. Most species occurring in the small woodlots also occurred in larger woodlots. Also, bird communities among urban woodlots showed a nestedness pattern in assemblage. These patterns implied that the main impacts of woodland habitat fragmentation are: (1) species are constricted and thus species number will increase at a given sample size; (2) as surface area decreases, the proportion of forest edge species as to interior species will increase; (3) community abundance will therefore increase per unit area but most individuals will be from a few dominant species; and (4) overall species diversity will decrease at a habitat level as well as at a region level. These patterns of community in response to the island features were therefore summarized as “island effects in community”. The underlying processes of such observations were also examined in this

paper. Woodlot area, edge ratio, isolation, and habitat nestedness were considered as the important factors forming the island effects in community. High heterogeneity between habitats usually contributed most to the maintenance of regional biodiversity, especially in urban woodlots.

Keywords urban woodlot, bird community, island habitat, island effect

1 Introduction

The theory of Island Biogeography (MacArthur and Wilson, 1967) triggered great attention to insular communities. Many studies have demonstrated the changes in the spatial patterns of plant and animal communities with respect to habitat fragmentation. Insular communities tend to exhibit some special patterns in connection with the characteristics of island habitats, such as island area, shape, isolation, and configuration, etc. (MacArthur and Wilson, 1967; Forman et al., 1976; Hanski, 1983; Opdam et al., 1985; Boecklen, 1986; Patterson, 1987; Robinson et al., 1992; Wiggins and Moller, 1997).

So far, widespread attention has been paid to the insular bird communities, especially to the impacts of habitat fragmentation on bird communities. Nevertheless, there are not enough insights to the bird community patterns in response to the island features.

Firstly, the bird community patterns in response to the island features still lack systematic survey. Among the three basic parameters (species richness, abundance, and assemblage) of community structure, the species – area relationship of insular communities has been most popularly studied, and gained most severe debates as well (Thompson, 1978; Gilbert, 1980; Margules et al., 1982; Ambuel and Temple, 1983; Williamson, 1989). In community assemblage,

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studies showed that most species present on small islands also occur on larger, more species-rich islands (Galli et al., 1976; Ambuel and Temple, 1983; Patterson and Atmar, 1986; Patterson, 1987; Blake, 1991). Such a non-random distribution pattern was termed as “nested subset pattern” or “nestedness” (Patterson and Atmar, 1986; Patterson, 1987). Although a lot of studies on the nestedness topic have paid their attention on the process of explaining nestedness, it still remains questionable (Chen, 2004). Whereas, the abundance patterns of insular communities are relatively less studied.

Secondly, how the island features influence the bird communities still remains unclear. As island habitats, habitat patches in the continent are different from real islands in some features, especially in isolation. The influences of habitat fragmentation at large scale level on breeding bird communities have been well recognized (Lynch, 1984, 1987; Blake, 1991); however, the influence of those small-scaled habitat patches on breeding, even non-breeding bird communities, need further confirmation.

Urban woodlots are small-scaled patchy habitats for birds. Chen et al. (2002a, 2002b) analyzed the richness patterns and the processes of urban woodlot bird communities, and the selectivity of birds to urban woodlots. At these bases, we aim to further analyze the bird community patterns in assemblage and abundance in response to the island features of urban woodlots. We will focus on the following questions: (1) Are there any special patterns for bird communities of small-scaled patchy habitats, such as urban woodlots, in species richness, abundance, and assemblage? (2) If such patterns exist, is there any difference between breeding seasons and non-breeding seasons? (3) Based on the results and existing studies, what are the potential processes

underlying these patterns and their implications in conservation biology?

2 Methods

2.1 Study area and urban woodlots

Hangzhou, the capital of Zhejiang province, is located in eastern China, 200 km from Shanghai City. The area is about 150 km², which is surrounded on the northern and eastern side by farmland and the southern side by the Qiantan River. Its west part is the West Lake and to the west of West Lake, there is an extensive mixed forest. Within the area, 20 urban woodlots, ranging in size from 0.5 ha to 92 ha, were selected (Fig. 1). They are well separated from one another, forming isolated patches in urban matrix. The most distant woodlots are separated by 10 km and the closest by 200 m. There are great differences among them in size, shape, the degree of canopy, leaf-height diversity, horizontal heterogeneity, connectivity, disturbance level, surrounding, etc. They include: a) large parks (1, 4, 5, 6, 10); b) small parks at the edge of city (8, 9, 11); c) small parks in residential area (7, 15, 16, 17, 20); d) forested hills (2, 3); e) plantations (18, 19); f) nurseries (12, 13); f) native woodlots (14).

2.2 Bird surveys

The surveys were conducted from January to December 1997. Each woodlot was visited twice per month during the birds' migration seasons in April, May, October, and November,

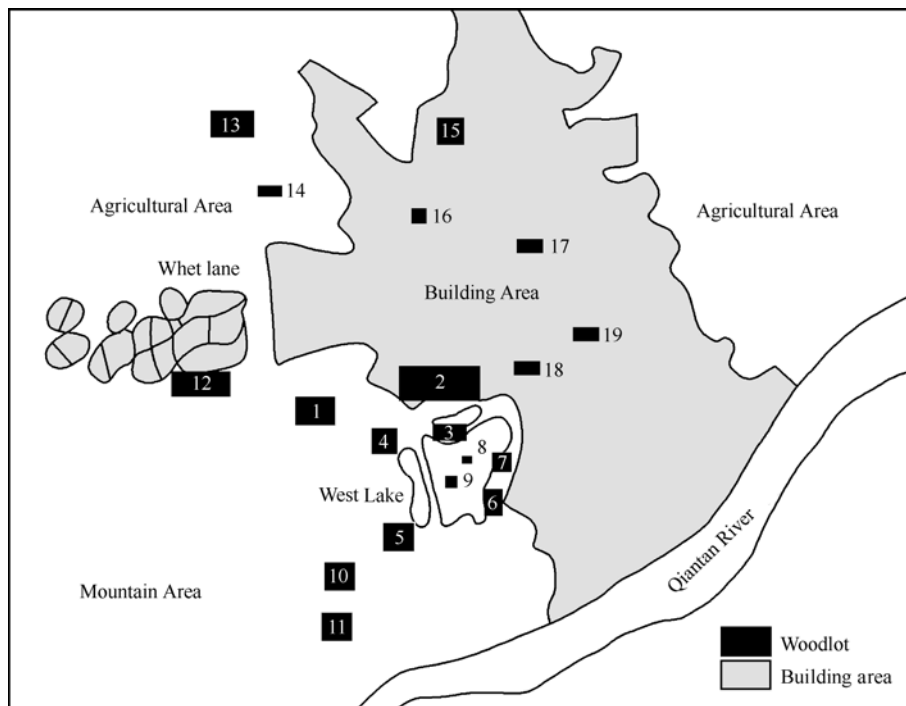


Fig. 1 The distribution of the 20-woodlot samples that were surveyed.

and once in the other months, therefore, each woodlot was visited 16 times the whole year. Visits were made during times of peak bird activity mostly between dawn and 10:00 a.m.; however, days with rain and strong winds were avoided. The method of transect lines was used to sample birds within woodlots. Along transect lines, all birds that were heard or seen were recorded, except for those that were just flying over. To maximize efficiency of visits, the time spent on each occasion was not fixed, but was long enough to make a thorough search of the whole woodlot for all species. Therefore, the length of visit varied according to the size of the site, intensity of bird activity, and density or complexity of vegetation.

2.3 Data analyses

Because “area” is one of the typical island features, we detected the relationships of species richness and abundance of bird communities with the area of urban woodlots through Multivariate Statistical Analyses. Also, the aim was to document the community patterns in species richness and abundance in response to island features. Then, we examined nestedness patterns of bird distributions among these urban woodlots, and documented the community pattern in assemblage in response to island features.

2.3.1 Urban woodlot bird community patterns in species richness

Chen et al. (2002a) indicated the significant regression relationships between species richness and area among these 20 urban woodlots. In this paper, we further determined and compared the relationships between species richness and woodlot area during the breeding season, winter season and migration seasons by Curve Estimation Analysis. Then we determined and compared the relationships between species number per sample area (a circle with the radius of 100 m, its area is 3.14 hm²) and the areas of the 20 woodlots also in three different seasons by Curve Estimation Analysis.

2.3.2 Nestedness patterns of urban woodlot bird community

Twenty woodlots ranked by species richness and all species ranked by woodlot occurrences formed a distribution matrix. If most species' distributions concentrate at the top left corner of the matrix, the distribution generally shows the characteristics of nestedness. Nevertheless, nestedness is a non-random distribution pattern which needs to be tested by a null model. Complete nestedness supposes that each species in an assemblage show a perfectly ordered occurrence sequence with respect to species richness. Deviations from complete nestedness occur when species are found where they are not expected (“outliers”) or are absent where they are expected (“holes”). The sum of outliers and holes indi-

cated the extent of nestedness. This metric can be compared to values expected from randomly assembled matrices (Patterson, 1986). We adopted the “biogeographic temperature” described by Atmar and Patterson (1993, 1995) to measure the nestedness of matrix, in which the system temperature was defined to vary from 0° (perfect nestedness) to 100° (complete randomness). We calculated nestedness temperature by the Nestedness Temperature Calculator (Atmar and Patterson, 1995). With the program, we used the matrix temperature (T) to measure the extent of nestedness of each matrix, including that for all year and the three seasons. Also, to measure the probability (P) to test whether these nestednesses were random or non-random.

2.3.3 Urban woodlot bird community patterns in abundance

We documented urban woodlot bird community patterns in abundance from two aspects. (1) Individual number and individual density in one census. Individual number and individual density in one census for all year and the different seasons were from the mean values of individual numbers and individual densities in each census of all year, breeding season, winter season, and migration seasons. Then, we determined their relationships with woodlot area through Curve Estimation Analysis; (2) Evenness of species abundance in the woodlots and their relationships with woodlot area. Evenness of species abundance was measured by the Evenness in Shannon-Wiener diversity index: $E = H / H_{\max}$. In which, H is the Index of Diversity of Shannon-Wiener and H_{\max} is the maximum theoretical diversity, $H_{\max} = \log_2 S$ (S is the species number). Then, we determined the relationships between Evenness of species abundance and woodlot area in all year, breeding season, winter season, and migration seasons by the Curve Estimation Analysis.

3 Result

3.1 Urban woodlot bird community patterns in species richness

Chen et al. (2002a) indicated that species richness of urban woodlot bird community in Hangzhou, China increased with the increase of woodlot area. There was significant regression relationship between them, but the species number per sample area significantly decreased with the increase of woodlot area. The relationship of species number per sample area with woodlot area is the real community pattern in species richness in response to island features, which has eliminated the effect of passive sampling.

Furthermore, results from the breeding season, winter season, and migration seasons were the following: Species richness in one census for all three seasons significantly increased with the increase in woodlot area (breeding season: $F = 14.21$, $P = 0.003$; winter season: $F = 15.90$,

$P=0.002$; migration seasons: $F=14.56$, $P=0.002$) (Fig. 2a), and species richness per sample area in one census for all three seasons significantly decreased with the increase in woodlot area (breeding season: $F=7.09$, $P=0.021$; winter season: $F=10.74$, $P=0.007$; migration seasons: $F=9.74$; $P=0.009$) (Fig. 2b).

3.2 Nestedness patterns of urban woodlot bird community

Eighty-two species were recorded in all the urban woodlots for the whole year. There was a significant difference ($P=1.93 \times 10^{-43}$) between the observed matrix of all year

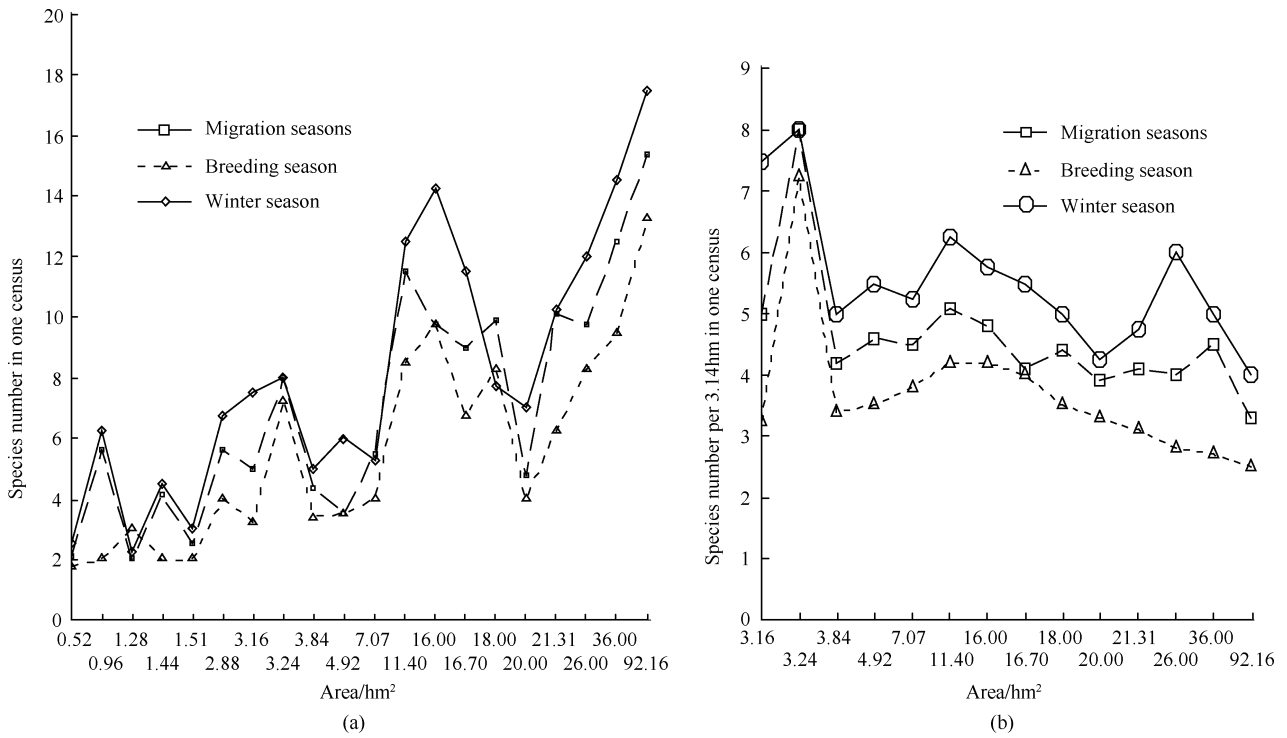


Fig. 2 Comparisons of species-area relationship and species density-area relationship among different seasons

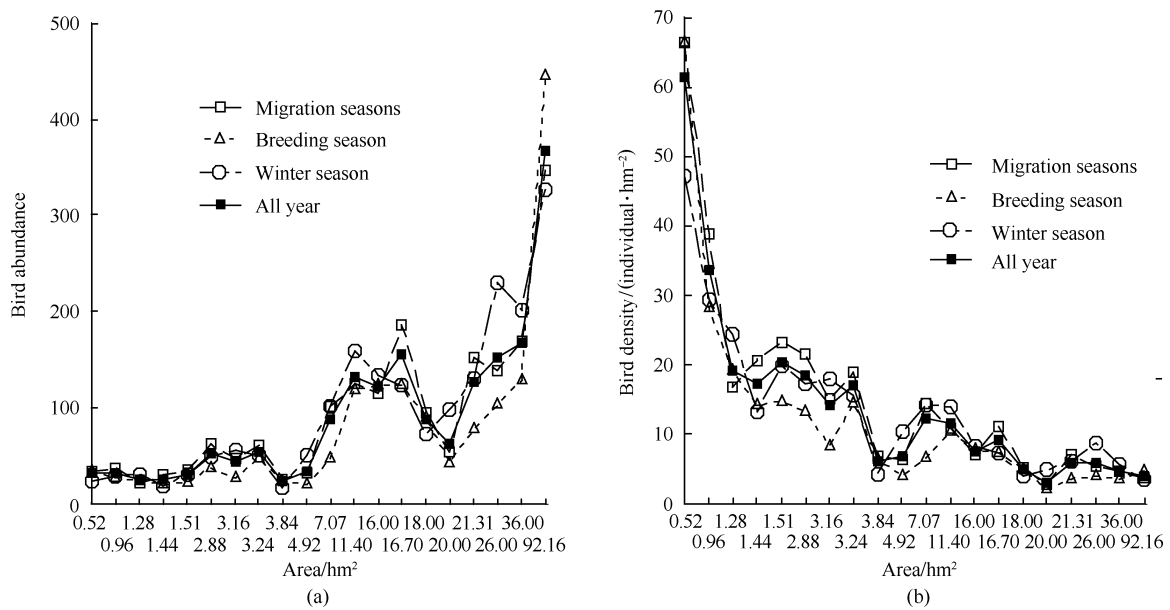


Fig. 3 Comparisons of the relationship of bird overall abundance and overall density with urban woodlot area among all year and the three seasons

($T=12.77$) and the randomly assembled matrices ($T_{\text{average}}=63.79$, standard deviation=3.41). The results indicated the nestedness pattern of urban woodlot bird community for all year existed. The results for the breeding season, winter season, and migration seasons were as follows:

Breeding season:

$T=9.79$ standard deviation: 5.61 $P=1.18 \times 10^{-15}$

Winter season:

$T=14.23$ standard deviation: 3.40 $P=4.37 \times 10^{-39}$

Migration seasons:

$T=13.28$ standard deviation: 3.48 $P=2.36 \times 10^{-37}$

3.3 Urban woodlot bird community patterns in abundance

Figure 3a shows the relationships of individual number in one census of all year and the three seasons with woodlot area. Individual number of all year and the three seasons all significantly increased with the increase in woodlot area (all year: $F=72.73$; $P=0.001$; breeding season: $F=44.75$; $P=0.001$; winter season: $F=78.05$; $P=0.001$; migration seasons: $F=53.71$; $P=0.001$). Figure 3b shows the relationships of individual density in one census for all year and the three seasons with woodlot area. Individual density of all year and the three seasons all significantly decreased with increase in woodlot area (all year: $F=65.92$; $P=0.001$; breeding season: $F=41.30$; $P=0.001$; winter season: $F=46.81$; $P=0.001$; migration seasons: $F=60.59$; $P=0.001$).

The relationships of evenness of species abundance with woodlot area (Fig. 4) showed that the evenness of species abundance in these woodlots significantly increased with the increase in woodlot area (all year: $F=25.56$; $P=0.001$; breeding season: $F=4.51$, $P=0.048$; winter season: $F=8.53$, $P=0.009$; migration seasons: $F=10.31$, $P=0.005$). These patterns implied that the bird communities of larger woodlots have more even abundance distributions.

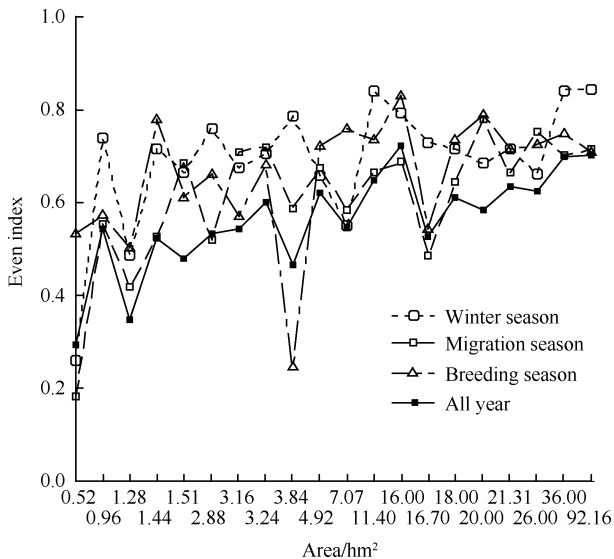


Fig. 4 Comparisons of the relationship of bird abundance evenness with urban woodlot area among all year and the three seasons.

4 Discussion

4.1 Bird community patterns in response to the island features of urban woodlots in Hangzhou

Our results demonstrated that bird community patterns in response to the island features of urban woodlots in Hangzhou, China did exist. With the same sample area, species richness increased with the increase in woodlot area (Chen et al., 2002a). Larger woodlots had higher species number, but smaller woodlots had higher species density (species number per unit area). The results of Chen et al. (2002a) were in accordance with the studies of lake-dependent birds in inland lakes (Nilsson, 1986) and birds in a farmland (Loman, 1991). The equilibrium theory popularized by MacArthur and Wilson (1967) assumes that island populations have a high extinction probability because of the small population size. On the other hand, islands usually have a low colonization rate because of the high isolation. The island species richness is supposed to be a balance between the rates of colonization from a mainland source pool and island extinctions of established populations, and therefore should be relatively low. The equilibrium theory indeed partially accounts for the species richness pattern of island biotope, in which the “islands” obviously do not cover all habitat islands, including those inland patchy habitats. The urban woodlots in our studies, the habitat islands in Nilsson (1986) and Loman (1991) all belong to small inland habitat islands. Why were the patterns negative with the equilibrium theory among these small inland habitat islands? Loman (1991) suggested the following mechanisms to explain these patterns: (1) The smaller island possesses the higher proportion of border zone and is on the average suitable for more species; (2) There is a higher intraspecific competition in smaller island that may increase species number above that expected by chance. Not all resources increase with increasing area; the border zone suitable for some birds will reversely decrease. Besides, the inland habitat islands have lower isolation than those real islands, community patterns among them thus dominated mainly by dispersal, not extinction (Chen et al., 2002a, 2002b). A high rate of dispersal usually makes the inland habitat islands possess more species.

The assemblages of the bird communities showed the nestedness patterns. This meant that most species present on the small woodlots also occurred on those larger, more species-rich woodlots. Most species on small woodlots were the habitat generalist. With the increase in woodlot area, the habitat specialists increased, such as birds restricted in wetlands and large forest found only on large woodlots. Nestedness is thought to be a non-random ordered structure. Some ecological hypotheses have been proposed to account for this pattern of insular assemblages: (1) The selective extinction hypothesis, species with large minimum-area requirements or species found in small populations have higher extinction risks, so species will disappear from sites in a predictable sequence (Patterson, 1987; 1990); (2) The

selective colonization hypothesis, a differential in dispersal ability leads strong dispersers to occupy most sites because local extinction will be quickly reversed for these species, whereas poor dispersers will be encountered in the largest sites where extinction rates are low (Cook and Quinn, 1995); (3) The habitat nestedness hypothesis, the nestedness of a species assemblage is a consequence of their close association to habitats that have a nested distribution (Cook and Quinn, 1995). As the bird habitats, the urban woodlots in Hangzhou, China are lower isolated, and there is a high fluid of bird individuals among them. Moreover, bird distributions among Hangzhou urban woodlots were significantly related to microhabitats within them (Chen et al., 2002b). Therefore, instead of selective extinction or selective colonization, habitat nestedness seemed to be the most plausible process underlying the bird assemblage nestedness patterns in Hangzhou urban woodlots.

Most species in Hangzhou urban woodlots deviated from perfectly nestedness. There were only 13 species (15.9%) with perfectly nested distribution. The number of absences from woodlots with more species accounts for 23% of the total presence/absence matrix. The nestedness of bird assemblage in Hangzhou urban woodlots is not so strong as that of Patterson (1987) in real islands (24.6% species with perfectly nested distribution, the number of absences from woodlots with more species accounted for 20.8% of total matrix) and Blake (1991) in farmland woodlots (48%~53% species with perfectly nested distribution, the number of absences from woodlots with more species accounted for 16%~17% of total matrix). Hangzhou urban woodlots include large parks, small parks, forested hills, plantations, nurseries, native woodlots, etc., in which there is high heterogeneity in habitat structure and microhabitat assemblage. High heterogeneity between woodlots results in a great deviation of bird assemblage from perfect nestedness.

Individual densities significantly decreased with woodlot area increasing. Like the explanations about the patterns in species richness, small islands usually possess a higher proportion of edge habitats, and therefore, can support more individuals per unit area (Loman, 1991). With woodlot area increasing, the evenness of species abundance in these woodlots increased, indicating that the proportion of the species with medium abundance increased, but the proportion of dominant species decreased. The increase in proportion of the species with medium abundance actually enhanced the species diversities of urban woodlot bird communities.

Our results also demonstrated that all the patterns that were discussed existed in the breeding season, winter season, and migration seasons and there were no significant variations among different seasons. It is commonly thought that bird communities during the breeding season are more stable than in the winter seasons, and migration seasons. Do the special patterns in response to the island features also existed in those relatively unstable communities? Our results have confirmed it and indicated that there were no definite relationships between the stabilities of communities

and their responsive patterns to island features. The relations between species and their habitats dominated their responses to habitat changes. Those species closely related with their habitats are usually more sensitive to habitat changes, and tend to form special patterns in response to island features. Bird communities in the winter season and migration seasons usually have higher individual fluids, which might decrease their stabilities, but do not weaken their close relations to their habitats.

4.2 The influences of habitat islanding on bird communities

Island habitats have the following similar structural features: relatively fixed area and shape, difference in quality between the interior zone and the edge zone, isolation from other similar habitats, etc. The island features will definitely influence the communities. How the island features influence the communities depends on two aspects—the specific taxon and the specific habitat island. For a specific island habitats, different taxa might form different responsive patterns, but for a specific taxon, such as bird, might form similar responsive patterns to different habitat islands (Galli et al., 1976; Butcher et al., 1981; Whitcomb et al., 1981; Opdam et al., 1985; Boecklen, 1986; Patterson and Atmar, 1986; Temple, 1986; Patterson, 1987; Blake, 1991; Robinson et al., 1992; McCollin, 1993; Wiggins and Moller, 1997). Based on our results and existing studies, we suggest following influences of habitat islanding on bird communities:

(1) Habitat islanding will lead to species number per unit area increase;

(2) Habitat islanding will enhance the proportion of edge species and reduce that of interior species;

(3) Habitat islanding will result in the increase in bird individual density, and most individuals of the communities come from some dominant species, thus resulting in the decreasing of the diversity of local community;

(4) Habitat islanding, at the regional level, will result in the decreasing of species richness and abundance evenness, and then species diversity. The heterogeneity between island habitats will enhance the species diversity at the regional level.

In this paper, we term the bird community patterns in response to the island features as “island effect of community”. The island effects of community for a specific taxon much rely on the relationship with its habitats. Birds are sensitive to changes in their habitat and then the island effect of community. The extent of island effect is closely related to the extent of habitat islanding, but not definitely related to community stability. The results warn us that the influence of habitat islanding on bird communities could exist in any season.

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