CHAPTER 9

EVALUATION AND PLANNING OF WILDLIFE HABITAT IN URBAN LANDSCAPE

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Abstract. We compared the response of various taxonomic groups, birds, butterflies, ants, trees and ferns, in the large city of Osaka, Japan in order to examine relationships between the abundance and arrangement of the habitats, and life history trait of the species. We presented species specific responses to habitat fragmentation. Species richness decreased more rapidly in birds than ants from the urban to rural ends of the urban gradient, and butterflies were intermediate. Birds were influenced by the habitat area and distance to species source. In contrast, ants were less influenced by habitat area, but were susceptible to the history of the isolated habitats. In ants, trees and ferns, some rare species occurred even in small habitats and the small habitats contributed to species diversity in the urban areas. Simultaneously, variation of the life history affected the distribution of species. For example, *Parus major* could breed in urban area by using scattered trees in an urban matrix; their home range enlarged in the urban area to secure sufficient food. One of the major goals of urban landscape ecology is to use scientific information to restore and preserve biodiversity in urban ecosystems. Some examples of planning and adaptive management for wildlife habitats in urban landscapes were introduced

1. INTRODUCTION

Loss of biodiversity is one of most important problem in the global environmental issues. Although biodiversity in urban landscape does not contribute the global biodiversity very much, it has important functions for human life. The functions include improvement of urban ecosystem, remediation of urban climate, fostering culture, providing a place of environment education, etc.

Urban ecosystem studies of Japan started in 1971 as a part of a project, “human survival and environment" (Numata, 1976). He defined urban ecosystem as one of man-modified and man-made ecosystems, and he proposed three approaches to urban ecosystems; (1) Examining the flow of energy, matter, people and

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information, (2) studying the impact of an urban environment on the terrestrial and aquatic ecosystems, and (3) studying reactions to the abiotic environment (in the Clementian sense). He and his colleagues reported a series of urban ecological studies of the metropolitan Tokyo (see Numata, 1982).

Urban ecological study in Japan reaches over many fields, such as pollution of air and water, urban climates, water cycle, etc, and one of important subject is impact of urbanization on flora, fauna and biological community. Early studies focused on biological indicator of urbanization; lichen (Taoda, 1973), alien plants (Hotta, 1977), soil arthropods (Aoki, 1979), and retreat of wild animals (Chiba, 1973) were used as indicators. Through comprehensive study of urban ecology, Numata (1987) noticed importance of landscape ecology in urban ecosystem studies. He emphasized this approach as holistic/integrated approach to anthropocentric ecosystem.

Though importance of the fusion between urban ecology and landscape ecology was emphasized, only a few papers have been published in Japan. Some of them are of pattern analysis of urban landscapes (Yokohari and Fukuhara, 1988; Hasebe and Suzuki, 1997; Ochi et al., 2000), and others are of function of urban landscapes as habitat (Hamabata, 1980; Higuchi et al., 1982; Hashimoto et al., 1994; Hattori et al., 1994; Toyama and Nakagoshi, 1994; Imai and Natuhara, 1996; Natuhara and Imai, 1996; Yabe et al., 1998; Goto et al., 1999; Hashimoto et al., 2005a).

In this essay we identify effects of habitat islands on wildlife in urban and suburban areas, and test hypotheses that (1) habitat fragmentation in urban gradient generaly increase species diversity, but (2) the effects of urbanization depend on the life histories of the species, by comparative study of different taxonomic groups. We also explore methods for conservation of species diversity in the urban area.

Osaka Prefecture occupies an area of 1864 km^2 in the western region of Japan and has a human population of 8,830,000. The annual mean temperature and precipitation are 16.2°C and 1,400 mm, respectively. The monthly mean temperature varies from 5.5°C in January to 28.2°C in August and that of precipitation from 34 mm in December to 206 mm in July. Elevations in Osaka vary from sea level at the Osaka Plains to 1125 m at Mt. Kongo. The dominant potential natural vegetation types are evergreen broad-leaved forest, consisting of *Castanopsis cuspidata* var, *Sieboldii* and *Quercus glauca* from plain to hilly areas, and deciduous forest, of *Fagus crenata* in the upper mountain. Analyses of pollen in geographic strata reveal that lowland forests were cleared and changed to paddies 2000-3000 years ago.

2. HABITATS ALONG URBAN GRADIENTS

Urbanization provides an environmental gradient from a highly developed core to a rural or natural area (Numata, 1976, McDonnell and Pickett, 1990). Analysing changes in a biological community along such a gradient provides a scientific basis for planning ecological cities, but also facilitates testing of hypotheses through management of urban landscapes. In the Osaka Prefecture, as in other cities, building areas decrease from the centre of the urban core to the suburbs, while the area of cultivated field increases and then decreases with increasing forest area

(Figure 1). In urban areas, fragmented habitats appear as islands in a matrix of build, cultivated and natural areas. Many studies have used island-biogeography theory to analyse fragmented habitats in urban areas, reporting that important variables affecting the species were forest area, degree of isolation, age since isolation, and combinations of these factors (Willis, 1979; Higuchi et al., 1982; Howe, 1984; Opdam et al., 1984; Askins et al., 1987; Soule et al., 1988; Bolger et al., 1991; Haila et al., 1993; Ichinose and Katoh, 1994). The determinants of species diversity are often too complex to be modelled by area alone. The incorporation of other variables such as a measure of habitat heterogeneity or resource availability may be necessary (Boecklen and Gotelli, 1984). Another important finding was that bird species in isolated habitats tended to show high nestedness (Simberloff and Abele, 1976; Patterson and Atmar, 1986; Hashimoto et al., 2005a). Species are not distributed randomly among the isolated habitats, with their response to fragmentation influenced by their population and life-history traits (With et al., 1997; Natuhara and Imai, 1999).

At the same time, urbanization creates land mosaics (Forman, 1995; Natuhara and Imai, 1996). A gradient can be seen in the land covers, and in intermediate zone, mosaics of forest and open field are detected (Figure 1).

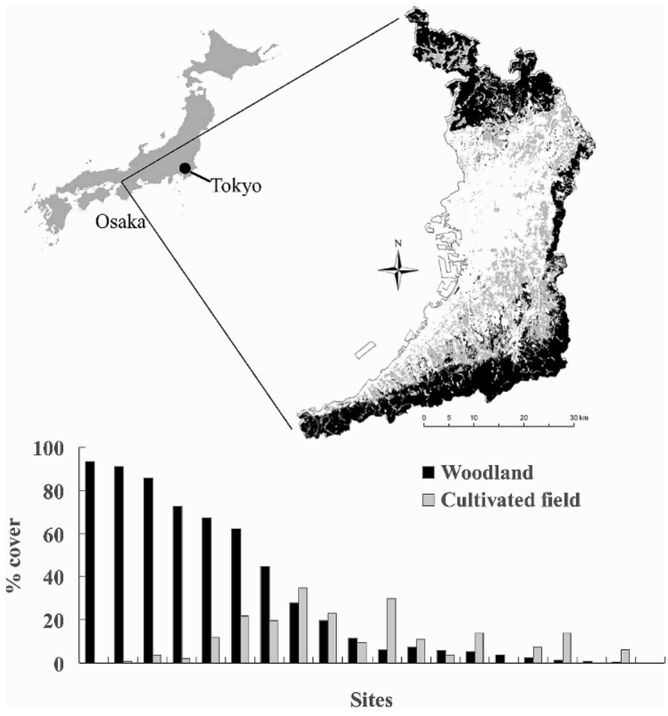

Figure 1. Urban gradient in the study site, Osaka, Japan.

Formation of the mosaic landscape sometimes increases the biodiversity, though urbanization is generally a major cause of the loss of biodiversity. We examine this mosaic model of habitat and its meaning in the urban area.

The affects of landscape mosaics on biodiversity are the result of various mechanisms, and are exerted at various spatial scales (Hansson, 1979; Helle andMuona, 1985; Yahner, 1988). Species richness may increase in a mosaic of habitats by the following mechanisms: the formation of a new habitat at a boundary between neighbouring elements, such as vegetation of forest edges with shrub layer forming the mantle and the lianas forming the veil, and the mosaic effect *per se*, i.e., a mosaic of forests and open lands can contain habitats for both forest species and open land species. Several butterflies use a set of resources in the habitat, e.g. food plants for larva, nectar source for adults, and their habitat must be a mosaic of different vegetation. However, some species may disappear from the mosaic due to the fragmentation of habitat, and less mobile species cannot move beyond a barrier between patchy habitats.

Furthermore, the quality of urban and suburban habitats are changing in the study area; the traditional coppicing in the *Satoyama* landscape (Natuhara et al., 1999; Fukamachi et al., 2001), which is a mosaic of secondary forests, grasslands, farmlands and irrigation ponds, has been abandoned over the last 40 years.

Potentially, lucidophyllous forests are developing in the southwestern Japan; most of them have changed to deciduous *Quercus* forest by human use over the past several thousand years. Furthermore, the forests had been fragmented by farmlands, and both forests and farmlands were changed to buildings and asphalt by urbanization. The gradient of urban habitats includes the following components: the reduction, isolation, mosaic formation, and the ecological succession of habitats.

3. FAUNAL CHANGE ALONG THE URBAN GRADIENT

The intensity of habitat fragmentation by urbanization changes from the suburbs to the urban core, influencing the arrangement of habitat. Forests are fragmented by farmlands in rural areas and both of forests and farmlands change to buildings and asphalt in the urban core. Examination of faunal change along this environmental gradient from continuous large habitats to habitat mosaics is important for conservation planning. In the intermediate level of forest reduction (% forest cover is from 65% to 10%), increasing farmland area forms land mosaics (Figure 1) and the number of fragmented forest increased to between 10 and 35. In this section_we focus on the effects of the habitat mosaics in Osaka on birds and butterflies assemblages at the landscape scale.

For bird assemblages, we recorded the proportion of nine types of land use (forest, scatter forest, farmland, grassland, bare ground, residence, city centre, pond and river, and sea) and the presence/absence of each of 76 breeding birds in 5-km square quadrats on a map of the Osaka Prefecture (Natuhara and Imai, 1996). For butterflies, 78 butterflies were recorded along 19 transect routes in various land covers (Natuhara, 2000)

The number of bird species is shown against percentage of forest (Figure 2). The highest richness is detected at around the 50% level. The relationship varies among species group with different habitat use. Species richness changed according to the proportion of forest in the 5-km square and it showed a unimodal curve. However, the response was different in forest-interior species from forest-edge species; the former increased approximately linearly with increasing proportion of forest.

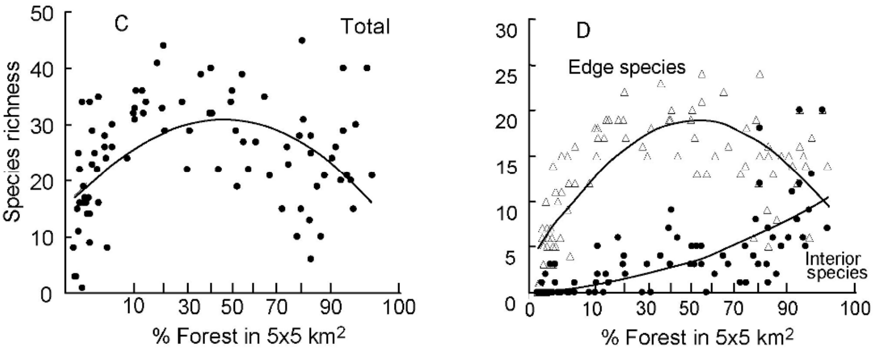

Figure 2. Relationships between percentage of forests in a grid and (C) species richness of birds, and (D) species richness of forest interior birds and forest edge birds.

The changes in bird diversity along the Osaka urban-gradients were also detected by ordination (Natuhara and Imai, 1996) and in butterfly (Natuhara, 2000). The proportion of forest and that of farmland are two major environmental gradients according to Principal Components Analysis of the nine types of land use. Ordination by Canonical Correspondence Analysis showed that breeding bird distribution differentiated along the two major clines, forest and farmland. Avifauna changed successively along those environmental gradients (Natuhara and Imai, 1999). There were no discrete boundaries of the distribution of bird-species groups. We tentatively classified five groups of quadrats on the ordination plane of the sample score and five groups of bird species in CCA-ordination plane.

The occurrence of these bird groups correlated with land use; the first group with forest area, the second one with scatter forest, the third with farmland, and the fourth had a relation to seashore. Although diversity of land use seemed to increase species richness in the third group, less diverse and forest-rich group contained as many species as the third group.

These effects of mosaics may appear on various spatial scales, and butterfly assemblages can be studied on several spatial scales, such as the region, landscape, and local habitat. On the landscape and smaller scales, the landscape mosaic enhanced the species richness of butterflies, however, the diversity indices and specialist butterflies (univoltine-tree feeder) decreased in the mosaic landscape (Natuhara et al., 1999).

4. URBAN HABITATS AS ISLANDS

We compared species-area curves among five taxonomic groups, birds, butterflies, ants, trees and ferns. Generally the relationships are summarized by the power function (1) and log function (2), although the logistic curve was also used.

$$S = c\,A^{z} \tag{1}$$

$$S = b \log A + c \tag{2}$$

where S is species richness, A is habitat area, and b, c and z are constants. Coefficient of determinants was high for all groups but ants were high in both models (Table 1). In the power function analysis, the species richness in 1-ha areas was highest in trees, followed by ants, ferns, butterflies, with the lowest in birds, though statistically significant regression could not be estimated for ants. The slope was highest in ferns, then trees, butterflies, birds and lowest in ants. The slope was highest in trees when using the log function.

Age of habitats may affect the species richness. When habitats were classified by their age since development (i.e., younger than 10 year-old, between 11 and 50, and older, Figure 3), there was no significant difference in the species richness between other age groups in birds and butterflies with the exception of the Nanko power station, by the analysis of covariance. The Nanko power station had extremely few bird species and many butterfly species. This habitat consisted of three, seven and ten year-old woods; most trees were evergreen, and shorter than 2 m in the youngest stands and grew 10 m with high density (20 / 100 m^2) in the older stands. In contrast, the species-area curve for ants varied among the three age groups.

The effect of distance to species source or continuous large forests on the species richness of birds, butterflies and ants in Osaka was analyzed using linear regression. The effect of distance was greatest in butterflies and least in ants, and there are no significant correlation in trees and ferns (Table 2). Moving ability and habitat size of the species influences differences in proportion of occurrence in urban area and the distance effect. But these figures are biased, because species-distance relationships are not linear. There are 55 forest birds bred in the Osaka, but the intercept is 13.7. This means 75% of bird species do not breed at fragmented habitats even if the location is close to the continuous habitats. The intercept of butterflies is 43.7 that is about 56% of butterfly species recorded by transect counts in Osaka Prefecture. The intercept of ants is 17.7 that is 20% of 87 ant species recorded in Osaka Prefecture (Natuhara, 1998). But the distribution of ants is random among fragmented habitats, and total number of species recorded in the fragmented habitats was 50 or 57% of total species. Possible causes of no species-distance correlations in trees, ferns and ants in Kyoto are recruitment of seeds from street trees and gardens in the urban matrix, and long dispersal distance of spores of ferns. In ants, dominance of passive dispersal with gardening materials causes long distant dispersal. Furthermore, possible metapopulation structure in urban habitats for these taxonomic groups may reduce the slope of species-distance curve (Hanski and Gyllenberg, 1997).

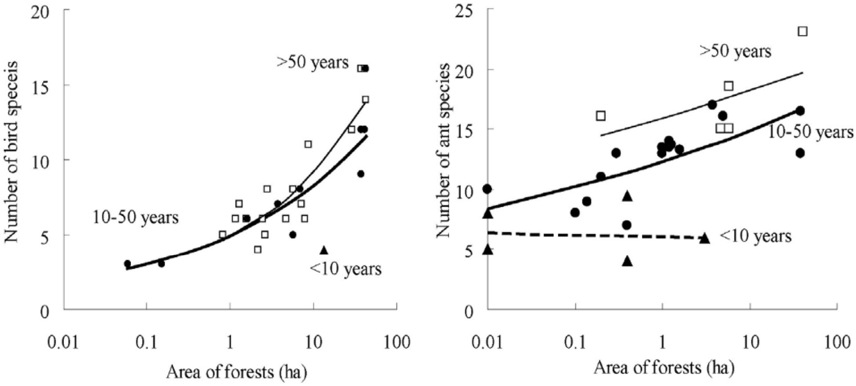

Figure 3. A comparison of species-area curves between birds and ants in Osaka, Japan. Simboles indicates years after plantation of forests; Squares and thin lines: more than 50 years, circles and thick lines: 10-50 years, and triangles and broken lines: less than 10 years.

For most bird species, urban forests are too small to keep enough large size of population for a long-term persistence. Thus, populations in urban forests are sink that are supported by source populations in mountainous area. On the other hand, many species of ants are able to keep large populations in the urban forests, and a metapopulation is formed.

In our original analysis of the butterfly data, the distance relationship was not significant (r^2 = 0.294, P = 0.0884), but when the Nanko power station site was removed from the data, a significant regression was estimated (Table 1). This site is located at a harbour far from the species source, but many butterflies were recorded at this site because Rutaceae trees, which are important food plants for butterflies, are more abundance than at other urban parks. Furthermore, some butterfly species migrate along the seacoast where the Nanko power station is located.

Table 1. A comparison of species-area relationships in taxonomic groups in Osaka, Japan.

	$S = c\,A^z$			$S = b$ Ln $A + c$		
Group	c	z	r^2	c	b	r^2
Birds[1)]	1.595	0.235	0.880	1.2962	3.7167	0.6872
Butteflies[2)]	6.580	0.293	0.762	4.0877	4.5939	0.6985
Ants (Osaka)[3)]	10.751	0.0495	0.0477	11.453	0.696	0.0832
Ants (Kyoto)[4)]	15.109	0.1011	0.1345	16.046	1.398	0.1235
Trees[5)]	37.8	0.3007	0.671	43.4	11.295	0.780
Ferns[6)]	9.387	0.4077	0.636	13.5	5.3468	0.668

1) Natuhara and Imai (1999), 2) Imai and Natuhara (1996), 3) Natuhara (1998), 4) Yui et al. *(2001), 5) Murakami and Morimoto (2000), 6) Murakami* et al. *(2003)*

The species composition of birds in smaller habitats was a nested subset of the larger habitats (Table 2). The occurrence pattern varied according to the species. Fifteen species possibly breed in urban parks. *Streptopelia orientalis*, *Hypsipetes amaurotis*, *Zosterops japonica*, *Passer montanus*, and *Sturnus cineraceus* were recorded at all forest, and increasing forest areas in the urban areas could increase the other ten species. In areas with lower amounts of forest, the numbers of carnivorous and insectivorous species decreased more rapidly than those of granivores and omnivores. Hashimoto et al. (2005a) also reported that the woodland bird species occurrence pattern in woodland of Kyoto City was highly nested.

Distribution of species in urban habitats depends on their life history. The most important trait is the variety of microhabitat use by the species. Nakamura (1988) classified the habitats in the study area into open spaces in forests, open space edges, forest edges, and forest interiors, and reported an occurrence pattern of species in those microhabitats. Species using the forest edge, *P. major*, *Aegithalos caudatus*, and *Emberiza cioides* occurred in middle size urban forest in the present study (Table 2). *Cettia diphone*, which uses not only forest edges but also open space in forests, occurred only in large forest. Forest interior species did not occur in the urban forest.

The distribution of carnivorous birds and insectivorous birds were limited to large forests. This is understandable for carnivores because they need a large home range. Canaday (1997) discussed the causes of the negative relationship between the number of insectivorous species and the degree of human impact. His list of important factors includes: microclimatic changes that have altered the insect prey base, greater habitat sensitivity among insectivores resulting from their high degrees of ecological specialization, changes in predation upon these birds, and interference competition from opportunistic, disturbance-adapted omnivores (Canaday, 1997). In California, 6 of 12 species not found in developed area were insectivores, and no insectivore persisted in developed areas (Blair, 1996). In Canada, Lancaster and Rees (1979) reported that 63% of species were insectivores in forest, in contrast to 1% of species in commercial industrial areas.

Passer major and *Carduelis sinica,* in particular, increased in occurrence as urban forest patches increased from 1 to 20 ha. Habitats for these species at forest edges or scattered forest may emerge in this size of forest. Similarly, habitats in the forest interior and open spaces in forests for *C. diphone* and *Dendrocopos kizuki* may emerge in forests of more than 20 ha. Habitat use of these species in urban parks has not been studied so far. A microhabitat use of these species in the urban parks and comparison of microhabitat structures among urban parks are needed to confirm the habitat diversity hypothesis.

Generalist or forest edge species adapt their behaviour to urban landscapes. *Parus major minor*, are found in both forests and urban parks in Japan. However the population density is very low in downtowns of Tokyo and Osaka. In our study of 85 parks in Osaka, *P. major* were present in only 12, with an additional 3 occurrences noted in areas outside of the study sites (Hashimoto et al., 2005b). Although these 3 occurrences were not study sites, we counted them in the number of surrounding habitats. The average areas of parks where *P. major* were recorded and not recorded were 26.0± 42.1 S.D and 2.1 ± 2.9 ha, respectively. The smallest park was 0.56 ha. Breeding behaviour was compared between two areas with different percentage of wood cover (Inoue et al., 2005). Interestingly, home range areas of breeding pairs were larger in the area with lower percentage of wood cover. Mean home range size was 4.70 ha at the site where the percentage of tree cover was 31.5% and 0.76 ha at the other site where the percentage of tree cover was 76.6%. *P. major* breeding in the former site probably required a larger home range to get food for their fledglings.

In comparison with birds and butterflies, ants, trees and ferns did not show nestedness, partly because they usually need smaller areas as habitats. Peintinger et al. (2003) also reported a random pattern in distributions of vascular plants, bryophytes, butterflies and grasshoppers; species richness increased with the area of habitat islands, but overlap among them was so low that even small habitat islands contributed to overall species richness.

Table 2. Nestedness of occurrence in urban habitats for bird species in Osaka, Japan.

	Area of wood lands (ha)			
	20.1-	5.1-20	2.1-5	≤2
Number of sites	8	7	6	7
Average area (ha)	38.5	7.99	3.12	0.96
Species	Percentage of occurrence sites			
Picus awokera *Parus varius*)	13	0	0	0
Phasianus colchicus *Cettia squameiceps* *Eophona personata*	25	0	0	0
Cettia diphone	63	0	0	0
Dendrocopos kizuki	88	0	0	0
Emberiza cioides	50	14	0	0
Bambusicola thoracica	38	29	0	0
Aegithalos caudatus	75	29	0	0
Corvus macrorhynchos	88	14	33	0
Corvus corone	100	43	17	14
Lanius bucephalus	63	43	33	14
Parus major	100	29	33	14
Carduelis sinica	88	29	33	29
Zosterops japonica	100	57	67	71
Sturnus cineraceus	88	100	83	71
Streptopelia orientalis *Hypsipetes amaurotis* *Passer montanus*	100	100	100	100

From the above results, we conclude that species requirements of space and mobility strongly affect their distribution in urban habitats.

The hypothesis of random immigration and extinction in the equilibrium theory of island biogeography is not realistic (Patterson and Atmar, 1986). Occurrence of bird species is not random, but each species follows a specific pattern (Lancaster and Rees, 1979; Higuchi et al., 1982; Ambuel and Temple, 1983; Blake, 1991; Hansen and Urban, 1992; Canaday, 1997), that is the nested subset pattern in which most species present in small habitats are also occurring in larger habitats. The distribution of species in urban habitats affects strategies for conservation.

Abundance in a species' source habitat, its body size (Soule et al., 1988; Bolger et al., 1991) and necessity of a forest interior (Blake, 1991) are important factors among life history characteristics that influence the nested subset pattern.

Consider two hypothetical patterns of species in habitats: nested subset and heterogeneous. In the former case, habitats holding fewer species do not contribute to species diversity at a regional scale. In the latter case, few species occur in multiple habitats because of differences in their habitat requirements, and habitats holding fewer species contribute species diversity at a regional scale. By simulating random arrangement of samples, we detected that several small habitats contain more species than a single large habitat of the same size in ants and the opposite results in birds and butterflies. However, this pattern of butterfly distribution is not universal. No nestedness was detected in butterflies inhabiting mountainous wetlands (Peintinger et al., 2003).

5. HABITATS AT FINE SCALES

Fine-scale heterogeneity also enhances the species diversity of birds (MacArthur and MacArthur, 1961). In our study, ant species diversity increased with increasing microhabitat diversity. Yui et al. (2001) reported that species richness of ants was positively correlated with the number of microhabitat types, such as stones, herbaceous patches, etc. They explained the species richness of ants at two different scales by using a Structural Equation Model (Figure 4). The area and shape index of forest affected the habitat quality at larger scales, and management intensity and microhabitat diversity in the forest were important at smaller scale. The effect of habitat quality was stronger at smaller scales than at larger scales.

The mosaic at a fine scale is also important for butterflies. The effect of gap clearance in the study area on butterfly assemblages was monitored by Chikamatsu et al. (2002). The average number of species and number of individuals were higher at the gaps (11.3 species, 40 individuals) than the interior of forest (3.2 species, 7 individuals). Among four gaps where the sky factor (proportion of open area to all-sky area observed from the forest floor) was measured using hemispherical photographs, population density and species richness with correlated with the sky rate. Pollard and Yates (1993) summarized the butterfly monitoring in Monks Wood that clearance at the edges of the ride is beneficial to butterflies. For the scale of individual movement, butterflies can sample a much more diverse array of habitat types in fine-grained landscapes (Debinski et al., 2001).

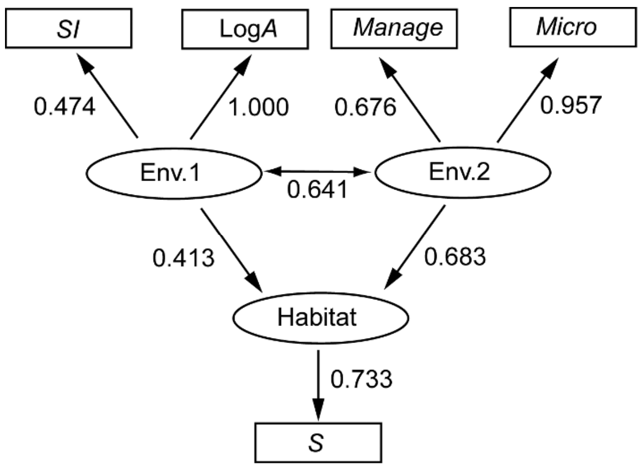

Figure 4. Structural Equation Model for species richness of ants in urban habitats. Latent variables, Env.1: Area and shape index of woodlots and Env.2: Management and micro habitat diversity of woodlots, determine species richness of ants (after Yui et al., 2001).

6. PLANNING OF WILDLIFE HABITAT IN URBAN LANDSCAPE

One of goals of urban landscape ecology is to restore ecosystems in urban areas. The latest style of regional ecosystem planning in Japan is that of the Grand Design of the Urban Environmental Infrastructure in the Metropolitan Area (Ministry of Land Infrastructure and Transport, 2004). Objectives of the plan are enhancement of the following five functions of nature: protection of biodiversity, chance to contact nature, beautify landscape, reduction of environmental load, and disaster prevention. The evaluation procedure for protecting areas of biodiversity are as followings:

(1) Extract cohesive habitat as protection area. At first ecotopes were classified to 36 types by terrain and vegetation in town block size. Then ecotope types were ranked from one to five by the incidence of wildlife species, including mammals, butterflies and freshwater fish.

(2) Evaluation of ecological networks using "guide species" which are selected so as to represent variation of habitats. Connectivity was evaluated from potential habitats of each of the guide species estimated by their home-range sizes and habitat environments.

Finally, 25 areas were selected as nature conservation areas based on the total score of five functions.

Another system is Guideline for Nature Conservation established in more than 14 prefectures. This guideline aims to grasp and evaluate the present situation of nature to identify regions to conserve, and to show the goal and course of the integrated and designed policy (Hokkaido Prefecture, 1989). Evaluation items are the degree of human disturbance of vegetation, endangered species, and the number of endangered species (Iwate prefecture, 1995) in each area, which is a 1-km grid (Okinawa prefecture, 1999), or a polygon based on ecotope classification and basin (Fukui prefecture, unpublished).

In smaler scale, fauna in urban areas are influenced by area and shape of habitat, percentage of forest in the surrounding areas, and distance to the species source. Among these, as mentioned in the previous section, area is the most important factor for most groups. An isolated forest does not perform well as a habitat for many birds. Askins et al. (1987) reported that there were no differences in population of edge species between larger forests (>187 ha) and smaller ones, but significant difference in populations of forest interior species. In particular, insectivorous interior species are the most sensitive to forest fragmentation. However, edge species can inhabit forest larger than 20 ha. If a larger area of forest cannot be supported in urban areas, increasing the percentage of forest in local areas by planting small groves can help colonization of forest edge species. It is important to realize that urban areas, which represent the fragmentation of potential habitats, can support a diversity of several groups such as butterflies, even disturbance avoider species, if we create and maintain suitable environments (Hogsden and Hutchinson, 2004). In Osaka, planted forest (age >10 years) was not inferior for birds to older forest with the same area (Natuhara and Imai, 1999). Vale and Vale (1976) reported that garden plantings seem most influential in determining the distribution and density of birds. The horticultural plantings are typically more luxuriant and provide more diverse habitats than the pre-suburban environments. This is also true for insects; distribution and abundance are more likely to be limited by the availability of suitable habitat than by their migration ability (Wood and Pullin, 2001). Several methods for increasing urban biodiversity were tested with replication (Gaston et al., 2005), and they found some of the methods, such as bamboo sections as a nesting site for solitary bees and wasps.

From an ecological viewpoint, it is better to design habitats for individual species than for species richness or abundance as a whole. Hashimoto et al. (2005b) focused on *P. major* for reasons mentioned in the previous section? By reason of mentioned previous section, and found the best fitting logistic regression model for describing the distribution of *P. major* in Osaka was

$$\text{logit P} = -18.144 + 3.799\,A_{250} + 0.688\,N_1$$

Where P is the probability of occurrence, A_{250} is the area of tree cover within a radius of 250 m, and N_1 is number of other habitats within 1 km (Figure 5). More tree cover is needed for Great Tits if the number of nearby habitats is small. By applying the model it was found that to achieve a probability of occurrence of 0.5 when the number of habitats within a 1 km buffer was 0, 1, 2 and 3, tree areas of 6.0 ha (31%), 4.0 ha (20%), 2.6 ha (13%) and 1.8 ha (9%) are required.

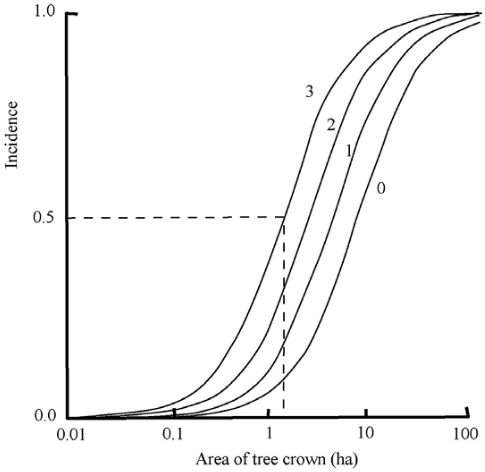

Figure 5. Estimation of incidence probability of P. major by area of tree crown within and number of neighboring habitats. When there are three neighboring habitats within 1 km, incidence probability is 0.5 at habitat of 1.2 ha. (after Hashimoto et al., 2005b).

From the model and its examination (Hashimoto et al., 2005b), a minimum of 1.8 ha tree cover in a radius of 250 m or 9% of the area, with at least 3 other habitats within 1 km are factors necessary to provide habitat for *P. major* in urban areas. Thus, more than 10 % of tree cover is a realistic target figure for an ecologically sustainable environment for urban areas. The tree cover of Osaka City in 1991 was only 4.1 %, but its target figure for 2005 is 15% (Osaka City, 1995), which includes trees in large parks. A target of 10% tree cover for areas outside of large parks is required to maximize avian biodiversity. The target of 10% tree cover is rather high and difficult to achieve in the urban area of Osaka, but there will be chances to create habitat for *P. major* by using combinations of park networks, roadside trees and rooftop gardens.

7. ADAPTIVE MANAGEMENT OF WILDLIFE HIBITAT IN URBAN LANDSCAPE

Ecosystems are unpredictable and it may be useful to modify plans in response to the results of biodiversity monitoring. Adaptive management is a useful method for conservation of biodiversity in urban landscapes.

An attempt of the adaptive management for an urban wildlife habitat was reported (Natuhara et al., 2005). Wild Bird Park in Osaka Port was established on the reclaimed land in 1983 by the City of Osaka, and has been managed by the Port and Harbor Bureau and Osaka Port Development and Technology Association. The park has a planted area of 6.5 ha and a sandy area of 12.8 ha, which includes two pools (4.6 ha comprise the north pool and 3.8 ha comprise the south pool) of rainwater and a lagoon (1.4 ha). The lagoon connected with the sea through six

Hume concrete pipes and six steel pipes that pass through the dike. A tidal flat of only 0.2 ha has emerged at the east side of the lagoon. Two pools did not connect with sea and were filled with rainwater. The park functions as a sanctuary for ducks. However, fewer shorebirds came to the site than we expected.

We assumed that the area of tidal flat is too small to attract shorebirds and concluded to restore one of pools to a tidal flat for shorebirds. The north pool had been separated from the lagoon by a mound of soil. The mound between the lagoon and the north pool was breached in 1995 to restore tidal flat that provides habitat for shorebirds (Figure 6). The north pool became to be affected the tide through the Hume concrete pipes and to be filled with sea water at high tide and dry at ebb tide. Thus, the area of tidal flat increased to 2.6 ha one of the ponds was restored to a tidal flat in 1995 after consultation among the manager, NPO, and scientist as a result of the monitoring. The area of tidal flat increased from 0.2 to 2.6 ha, and the number of shorebirds increased from 205 (the average of 1991–1995) to 1042 (1996). The species composition of benthic animals had also changed; the dominant group was Chironomid larvae before the repair and Polychaetes after the repair, and the species richness increased. Natural ecosystems are often unpredictable and are difficult to manage.

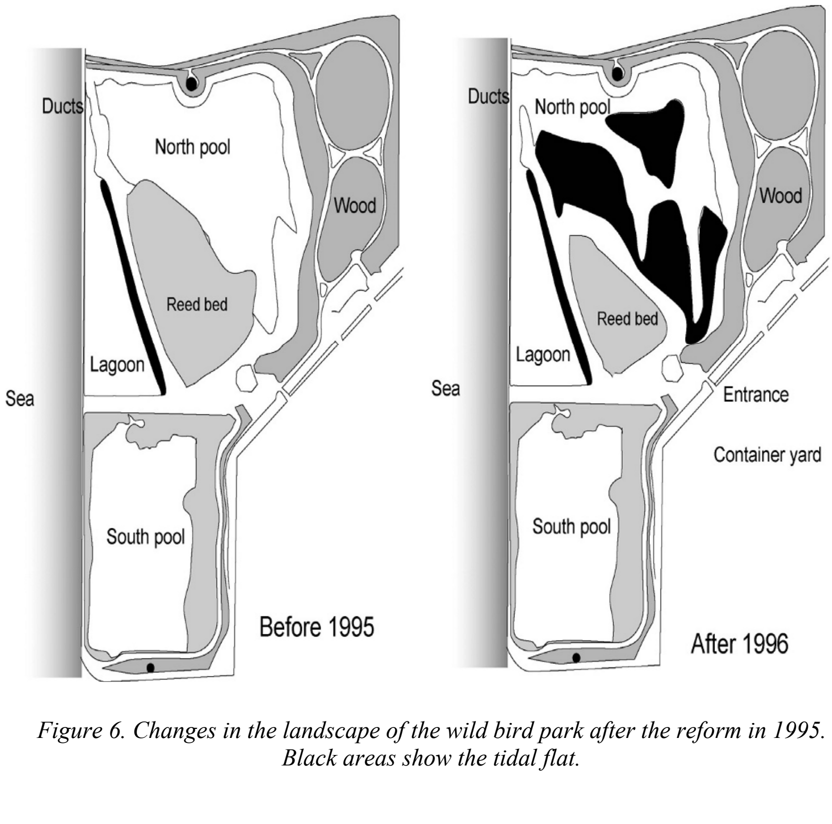

Figure 6. Changes in the landscape of the wild bird park after the reform in 1995. Black areas show the tidal flat.

An artificial tidal flat that we constructed at the wild bird park in Osaka has not been a good habitat for shorebirds for 13 years. However we could change the management plan and restored the tidal flat in 1995, and which made the park attractive for shorebirds. The success of this plan depended on continuous monitoring and on the council system among the manager, the citizen's group and scientists. The adaptive management is a management-asexperiment in dynamic situations where controls and strict replication are not possible (Holling, 1978). General process of the adaptive management is setting goal(s), building models, planning, carrying out the plan, and adapting the plan according to monitoring and evaluation of the result. Modelling habitat change is important for restoration of salt marshes (Boumans et al., 2002). The Wild Bird Park was designed taking account to the habitat change by subsidence. However the actual change was not as same as the estimate, and the management was modified. Our experiment demonstrates the efficacy of the approach of the adaptive management.

Table 3. Changes in spring shorebird numbers in the wild bird park.

	Period				
	1950-56	74-80	84-89	90-95	96-2001
Charadrius. dubius	20	19	35	26	56
C. alexandrinus	200	360	397	30	700
C. mongolus	15	7	6	5	20
Pluvialis fulva	31	4	10	2	15
P. squatarola	10	5	1	1	4
Arenaria interpres	250	80	9	3	33
Calidris ruficollis	283	155	67	31	1450
C. acuminata	21	58	9	4	10
C. alpina	107	500	133	51	678
C. tenuirostris	4	6	1	1	10
Limicola falcinellus		1	1		1
Tringa erythropus	75	31	1	1	1
T. nebularia	1	11	1	1	3
T. glareola	1	33	2	2	3
Heteroscelus brevipes	100	153	8	7	60
Actilis hypoleucos	2	3	1	1	3
Xenus cinereus	8	10	6	2	5
Limosa limosa	1	1		3	17
L. lapponica	50	40	13	3	4
N. phaeopus	400	6	30	28	25
Gallinago gallinago	3	1	2	10	7
Phalaropus lobatus	49	21	633	1	6
Other species	35	12	17	23	44
Total	1665	1516	1381	226	3148
Species richness	33	31	30	29	36

Maximum numbers observed at a census day in each period of years are shown.
Species that recorded more than 10 individuals at least once are shown
Source: Kobayashi 1959; Takada 1998, 2002.

Another example of adaptive management is that of an urban forest. In 2001, 6- artificial gaps (15 x 15 m) were created in an urban forest (98.5 ha) at the Expo'70 Commemorative Park in an urban area of Osaka. Thirty years have passed since the completion of land reclamation and the planting of broad-leaved evergreen trees that were established at the reclaimed land by planting of broad-leaved evergreen trees. Planners thought the broad-leaved evergreen forest was the potential natural vegetation of the site. However, low penetration of solar radiation to the forest floor seemed to restrict the diversity of forest floor vegetation (Nakamura et al., 2005) and the effect of gap clearance on butterfly assemblages was monitored (Chikamatsu et al., 2002; Yamamoto and Natuhara, 2005). Butterflies were recorded in 15 x 15 m quadrats for 10 minutes at six gaps, six plots of interior forest adjacent to the gaps, a vegetable garden, and an area of turf. Average number of species, *S* and number of individuals, *N* were 13 and 55, respectively at a vegetable garden, 11.3 and 40 at gaps, 3.2 and 7 at forest interiors, and 2 and 6 at the turf site. Five species, including *Papilio bianor* were recorded only at the gaps, and the gaps changed the species composition of butterflies and increased the species diversity in the park as a whole. Future monitoring and a clearance program are planned because population density of some species of butterflies and birds change with years after coppicing (Fuller et al., 1989; Warren, 1987).

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