A study in the relationship between greenery of urban parks and bird diversity in Tainan City, Taiwan

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Abstract

Green space is important for the maintenance of the ecological dimension of a sustainable urban landscape. Therefore, in order to figure out the relationship between the greening of urban parks and bird diversity, we used 5 avian ecological diversity indexes, such as Species richness, Abundance, Shannon-Weiner diversity index, Evenness, and Margalef's richness indices, to evaluate the functionality of different types of urban parks. Therefore, birds in 17 parks were surveyed with the circular-plot method from August of 2004 to April of 2005; meanwhile, the greening level of urban park of Tainan city in Taiwan was measured by remote sensing method. As the result, overall there was higher bird species richness in higher greening level parks. Our findings emphasize the importance of urban park with abundant greening to maintain high ecological diversity. Thus, we suggest that increasing greening level of urban parks can promote the bird diversity in urban area.
Keywords: urban habitat, biodiversity, normalized difference vegetation index.

1 Introduction

According to governmental statistics, 77.7% of the nation's population dwells in urban area which only occupies 12.5% of the country's area. In order to accommodate such high population density, urban expansion is inevitable. Without appropriate consideration of the ecosystem during urban planning, such expansion will transform natural habitat into all sorts of man-made constructions, thus destroying the urban ecological environment.

Urban habitats differ from natural environments in several aspects. For example, urban areas dwell large amount of population, the traffic impact is

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intense, the microclimate is influenced by urban heat island effect, the planting of decorative lawns and exotic tree species, etc. These environmental change caused by human may play an important role in the urban ecosystem. However, most bird-habitat relationship studies have been made in natural ecosystems, while urban areas were much less focused on (Tilghman (1987); McDonnell et al. [12]). Studies have been implemented to investigate the response of avifauna to urban environment. Some focus on how the avian community responds to local habitat structure or landscape structure of urban parks, woodlands, or wooded streets (Emlen [6]; Tilghman [15]; Fernandez-Juricic et al. [7]). Many of these studies point out that species richness decreases with the degree of urbanization, and that total avian density increases with urbanization (Emlen [6]; Beissenger and Osborne [1]; Blair [2]). In addition, species of different guild respond differently to urbanization (Lim and Sodhi [10]).

Other than the increase of buildings, urbanization also brings about the fragmentation of natural woodland and the decrease of urban green area. However, owing to difficulties of measuring urban green area, few studies focus on the effect of the decrease of urban green area. The development of satellite imagery at various resolutions has generated interest among scientific community regarding the potential of remote sensing to measure and monitor variables that affect biodiversity (Nohr and Jorgensen [13]; Seto et al. [14].

Of the numerous vegetation indices, the normalized difference vegetation index (NDVI), which is defined as (NIR – RED)/(NIR + RED), where NIR and RED represents surface reflectance in the red and near infrared region of the spectrum, has been the most widely used index in global vegetation studies. High positive value of NDVI corresponds to dense vegetation cover, whereas negative values are usually associated with bare soil, snow, clouds or non-vegetated surfaces. The NDVI has been empirically shown to relate strongly to vegetation seasonal dynamics, leaf area index measurement, green vegetation cover and biomass estimation (Tucker et al. [16]; Gould [8]).

In this study, we investigate how avian community responds to human activities, park structure, and urban environment. We correlate, through a multivariate method, the environmental factors with the avian community, including overall avian composition, species, and biodiversity indices.

2 Method

2.1 Study area

This study was conducted in Tainan city (120°11’E, 22°58’N) in southern Taiwan. Tainan is a city of 749,807 people and covers about 175.64 km^2. The average population density is 4,269 people/km^2, and the average population density in the main areas of the city varied between 14,000 and 15,500. The average temperature throughout the year is 24.4°C, and the mean annual precipitation is 1347.7 mm. With such high population density, however, the total park area in Tainan is 1.76km^2, which is approximately 1% of the city’s area. This indicates that Tainan is an over-developed, highly-urbanized city. In such over-developed city, bird census is conducted in highly-vegetated area lest we count no birds. Therefore, the bird census was conducted in urban parks.

17 parks, ranging from 0.6 to 14.3 ha, with the total area of 635,197 m^2 were selected as the samples of this study. All parks that are larger than 1 ha in Tainan were all included in this study. In order to increase the sample size, 2 other parks that are smaller than 1 ha were also selected. The reason for choosing these two parks is that, according to previous study, they had relatively high species richness, thus made it more suitable for this study than other small parks.

2.2 Avian assemblage surveys

Birds in 17 parks were surveyed with circular-plot method from August, 2004 to April, 2005. Bird censuses were conducted twice every season, in other words, 8 censuses were conducted for every park. Censuses last 8 min per point, and were conducted within three hours after sunrise (approximately 6-9 a.m.), in good weather only. All surveys were conducted by the same person. Birds flying over the canopy were not included. Scientific names and the individuals counted of the birds were included in Appendix A.

10 to 15% of the park area was selected as the survey area. Since the radius of census point is 15 m, we place one census point for every 0.7 ha of park area. A total of 78 points were established in 17 parks. Census points were placed 50 m apart to reduce the possibility of double counting. They were also placed at least 25 m away from the edge of the park to avoid traffic disturbance. Species abundance was calculated for each park as the sum of the number of individuals recorded from each point divided by the number of census points.

2.3 Environmental variables measured

2.3.1 Environmental variables within the park

Environmental variables within the park (including park area, edge index, human activity, and vegetation structure) and urban variables (including building area and vegetation area) were measured for each park (Table 1). The formula of the edge index is $DI = P/(2\sqrt{A\pi})$, where P is the perimeter of the park and A is the area. The area and perimeter of the park is derived from GIS map by the Urban Development Bureau. To correctly determine the dynamic human activity is difficult, for different types of activities affects the avian community differently. For example, feeding the bird and jogging in the park have different impacts on birds. Therefore, instead of counting the number of people in the park, we indirectly evaluate human activity by measuring the area of the building and pavement within the park; the increase of these facilities will increase the range of human activity and, at the same time, eliminate the area that can be planted with vegetations, which adversely influence bird survival and reproduction.

Vegetation structure includes measures of the density of trees, foliage height diversity (FHD), and plant species diversity. These vegetation structure variables are determined by a thorough survey of all plants higher than 0.9m in height in the park. The presence of the following foliage height intervals: <0.9 m, 0.9-1.5 m, 1.5-3 m, 3-5 m, >5 m, is recorded. The values of each height levels are then converted to FHD by using the Shannon-Weiner's diversity index. The plant species diversity is determined by the Simpson's diversity index: $SDI = 1 - \sum_{i=1}^{S} 1 - Pi^2$, where pi is the proportion of the observations in the ith category.

Table 1: Variables measured.

Variable code	Description
AREA	area of the park
DI	edge index
VEGAREA	vegetation covered area of the park
FHD	foliage height diversity
PLANTSPE	species richness of plants within the park
PLANTDIV	Simpson's diversity index of plants within the park
PLANTDEN	number of plants per hectare
WATER%	percentage of area covered with water (eg. Pond, river)
PAVEMENT%	percentage of area covered with pavement
BUILD%	percentage of area covered with building
BUILD500[a]	area covered with buildings within a 500m radius range
BUILD1000[a]	area covered with buildings within a 1000m radius range
BUILD 2000[a]	area covered with buildings within a 2000m radius range
VEG50[b]	the number of pixels with a NDVI value higher than 0.2 within a 50*50 pixels range
VEG100[b]	the number of pixels with a NDVI value higher than 0.2 within a 100*100 pixels range
VEG150[b]	the number of pixels with a NDVI value higher than 0.2 within a 150*150 pixels range
VEG 200[b]	the number of pixels with a NDVI value higher than 0.2 within a 200*200 pixels range
VEG250[b]	the number of pixels with a NDVI value higher than 0.2 within a 250*250 pixels range

a. the center of the circle coincide with the center of the park.
b. the center of the square coincide with the center of the park.

2.3.2 Urban environmental variables

Landscape changes at different scales have the potential to affect different organisms, depending on the range of scales that is relevant to a particular species. Because environmental change at different scales may affect different species, we measure urban environmental variables at several different scales, in order to find out at which scale the avian community respond to.

According to the study of Hostetler and Holling (2000), many bird species were correlated with the amount of tree canopy cover from such broad scales as 0.2 – 85km^2. But to carry out such large scale study in parks of Tainan city is not practical. The distances between parks are short; therefore, investigating variables beyond the scale of 25 km^2, one would come up with similar value of variables. Therefore, the maximum scale adopted in this study is approximately a radius of 2 km set from the center of the park.

In this study, we measured two categories of urban environmental variables: building area and vegetation covered area surrounding the park. To assess the degree of urbanization, we measure the building area around the park. At the center of each park, we drew circles of 3 different radiuses: 500, 1000, 2000 m, and measured the area covered with buildings. The information of the building coverage area was derived from the GIS map by the Urban Development Bureau.

NDVI has been related to ground vegetation cover in the past studies (Lillesand et al. [11]). There are some studies that focus on how avian community respond to broad scale vegetation structure, and applied NDVI on their researches (Nohr et al. [13]; Seto et al. [14]). In this study, we counted the number of pixels with a NDVI value higher than 0.2 as an index for vegetation covered area (figure 1). In other words, pixels with NDVI higher than 0.2 is considered as vegetated land, and the more such pixels surrounding the park, the "greener" the environment. The reason of selecting 0.2 as the threshold value is that the NDVI value of soil is between -0.1~0.2 (Carlson and Ripley [3]), other urban ground man-made objects, such as buildings, pavement, have spectral characteristics similar to soil. The satellite image used in this study is based on a Formosat-2 level 4 product scene. The resolution of the image corresponds to 8*8 m^2 per pixel. The scene was recorded on 12 July, 2004, and was geometrically corrected.

0.33	0.44	0.44	0.44	0.48
0.34	0.37	0.38	0.38	0.39
0.38	0.33	0.31	0.23	0.10
0.26	0.11	0.04	0.04	-0.07
0.08	0.06	0.03	-0.04	-0.03
0.13	0.09	0.04	-0.05	-0.04
0.08	0.03	0.06	0.03	-0.05

In this 6 * 7 pixels sample, we view the pixels with a NDVI value higher than 0.2 (grey color boxes) as vegetated land, and count the number of such pixels.

Figure 1: An example of measuring the vegetation covered area.

2.4 Data analysis

Multivariate analyses were undertaken using PRIMER V.5.0 (Clarke and Gorley [4]) to assess overall changes in avian composition. Non-metric multi-dimensional scaling (MDS) was used to indicate the similarity of avian composition among parks. These were iterated at least 10 different starting values to ensure that a global optimum was achieved (indicated by no decline in the stress value) (Clarke and Gorley [4]). A log-transform was used on the species abundance data to give an equal weighting to common and rare species (Clarke and Warwick [5]). The BIOENV procedure in PRIMER was used to examine the relationships between avian community and environmental factors (Clarke and Gorley [4]). In the BIOENV procedure the among-site species similarity matrix was constructed only once, whereas the environmental matrix was computed for every possible combination of environmental variables.

Spearman's rank correlation coefficients (Pw) were calculated for the every match between the species matrix and each of the possible environmental matrices. The set of variables that has the highest Pw-value is that best explain the species data (Clarke and Gorley [4]).

For species richness, abundance, diversity, we employed stepwise multiple regression method to examine their relationship with environmental variables. Considering the high auto-correlation between the environmental factors, we performed a correlation analysis to eliminate variables that highly correlate (R>0.85). The correlation matrix is shown as table 2. The different scales of urban variables (BUILD500, 1000, 2000, and VEG50, 100, 150, 200, 250) highly correlate to each other, thus when proceeding statistical analysis, it is difficult to ascertain a particular scale that avian species respond to. We select the BUILD2000 and VEG50, VEG100, VEG250 as the final urban environmental factors. As a result, 12 factors were selected from the analysis. Only these factors are then put in the statistic analysis: AREA, DI, FHD, PLANTDIV, PLANTDEN, WATER%, PAVEMENT%, BUILD%, BUILD2000, VEG50, VEG100, VEG250.

Table 2: Correlation matrix of environmental variables.

Variables	AREA	DI	VEGAREA	FHD	PLANTSPE	PLANTDIV	PLANTDEN	WATER%	PAVEMENT%	BUILD%	BUILD500	BUILD1000	BUILD 2000	VEG50	VEG100	VEG150	VEG 200
AREA																	
DI	-0.202																
VEGAREA	.980(**)	-0.147															
FHD	-0.04	-0.216	-0.054														
PLANTSPE	.862(**)	-0.138	.868(**)	0.133													
PLANTDIV	0.456	-0.018	0.436	0.254	.752(**)												
PLANTDEN	-0.042	0.133	0.069	-0.318	-0.144	-0.331											
WATER%	0.345	0.129	0.379	-0.117	0.199	-0.097	0.001										
PAVEMENT%	-0.225	-0.255	-0.384	0.17	-0.332	-0.07	-0.264	-0.281									
BUILD%	-0.019	-0.14	-0.123	-0.013	-0.125	-0.296	-0.177	-0.088	0.262								
BUILD500	0.186	-0.244	0.111	0.26	0.369	0.432	-0.403	-0.432	0.073	0.4							
BUILD1000	0.263	-0.222	0.201	0.158	0.45	0.471	-0.33	-0.401	-0.026	.503(*)	.901(**)						
BUILD 2000	0.253	-0.318	0.19	0.086	.491(*)	.563(*)	-0.378	-0.405	-0.02	0.396	.889(**)	.953(**)					
VEG50	.772(**)	0.097	.808(**)	-0.3	.628(**)	0.343	0.216	.542(*)	-0.272	-0.272	-0.26	-0.149	-0.131				
VEG100	0.27	0.274	0.319	-0.351	0.152	-0.028	0.161	.670(**)	-0.227	-0.207	-.618(**)	-.487(*)	-0.473	.744(**)			
VEG150	0.062	0.169	0.091	-0.377	-0.062	-0.161	0.094	.490(*)	-0.033	-0.218	-.647(**)	-.597(*)	-.533(*)	.571(*)	.924(**)		
VEG 200	-0.073	0.172	-0.035	-0.371	-0.224	-0.311	0.165	0.426	0.002	-0.297	-.667(**)	-.713(**)	-.635(**)	0.45	.810(**)	.949(**)	
VEG250	-0.153	0.196	-0.135	-0.421	-0.324	-0.314	0.162	0.311	0.098	-0.323	-.626(**)	-.702(**)	-.633(**)	0.371	.740(**)	.904(**)	.965(**)

* p<0.05; ** p<0.01.

3 Results

3.1 Community composition

A total of 5970 bird records, comprising 29 species were obtained from the 17 parks during the survey period (Appendix A). Of the 29 species recorded, 26 are breeding birds, 3 are migratory. Of the 26 breeding birds, 6 are water birds (including the two unidentified species). 9 species occurred in only one park, and 4 species were recorded in all 17 parks. Only 13 species were observed in more than 5 different parks or more (Appendix A). The average bird species per park is 11.4 (SD=3.4), and 135.98 birds/ha were counted in all parks (SD=45.15). The abundance of each species varied among parks. The most common species are eurasian tree sparrow, light-vented bulbul, japanese white-eye, they were found in every park, and was accounted for 22.66%, 32.50%, and 24.57% of the total bird abundance respectively. The three species take up 79.73% of the total bird abundance. Besides the three species, pacific swallow also occurred in all parks, and accounted for 3.28% of the total abundance.

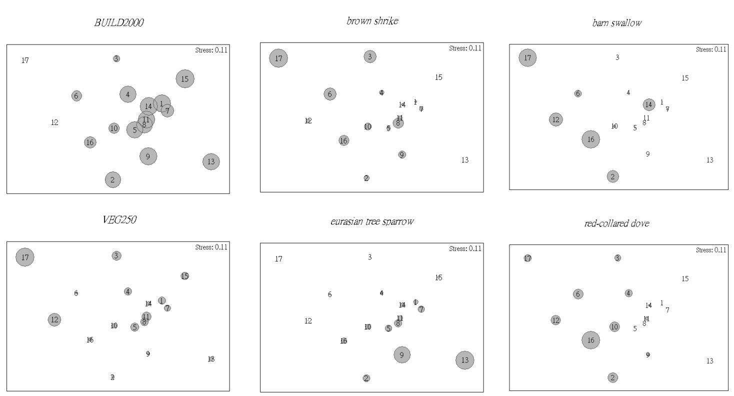
Table 3: Result of BIOENV analysis used to test the greatest contribution to differences in the avian community of 17 parks.

No.	number of variables	Pw	selections
1	2	0.571	9.12
2	3	0.558	3,9,12
3	3	0.549	4,9,12
4	3	0.545	2,9,12
5	4	0.537	3,4,9,12
6	4	0.534	3,5,9,12
7	5	0.533	3,4,5,9,12
8	4	0.523	4,5,9,12
9	4	0.522	2,4,9,12
10	4	0.522	2,3,9,12

1=AREA, 2=DI, 3=FHD, 4=PLANTDIV, 5=PLANTDEN, 6=WATER%, 7=PAVEMENT%, 8=BUILD%, 9=BUILD2000, 10=VEG50, 11=VEG100, 12=VEG250.

Table 4: Multiple regression model for avian species and abundance. The abbreviation of each variable is given in Table 1.

Biodiversity indices	Regression model	Adj_R^2	P
species richness	5.907E-05 * AREA + 22.999 * WATER% + 8.361	0.808	<0.001
species abundance	1.487E-05 * BUILD2000 + 81.128	0.233	0.029



The number in the plot indicates the park number, and the size of the bubble indicates the value of each variable.

Figure 2: MDS plots of avian composition in 17 parks of Tainan City and their relationships with environmental factors and avian species.

3.2 Responses of avian assemblage to environmental changes

3.2.1 Environmental variables that affect the avian composition

The MDS plot of avian composition in 17 parks is shown in figure 2. The distance between park 13 and 17 is the furthest, which implies that the avian compositions of the two parks have the lowest similarity. As can be seen, brown shrike is most abundant in park 17, and least abundant in park 13. Whereas rock pigeon and eurasian tree sparrow show an opposite trend to brown shrike. Spearman's rank correlation coefficients (Pw) of 10 variables have been calculated in the BIOENV procedure (table 3). Result number 1, which include building area (at R=2000m scale) and vegetation covered area (at 250*250 pixels scale) surrounding the park, best explain the overall pattern in avian composition: (Pw = 0.571). The abundance of brown shrike, barn swallow, and red-collared dove correlated negatively with BUILD2000, and eurasian tree sparrow positively; eurasian tree sparrow correlated negatively with VEG250 (figure 2). This indicates that different bird species respond differently to environmental changes.

3.2.2 Variables that affect avian richness and abundance

As table 4 indicates, 3 variables, including park area (AREA), percentage of area covered by water (WATER%), and building area (at R=2000m scale, BUILD2000) surrounding the park, out of the 12 were chosen in the regression models. AREA, explain 64% of the variations, is the most important variable affecting the avian species richness. The largest park had more than twice as many species as did the smallest park. WATER% also affected species richness positively; adding this factor in the regression model increased the amount of variation explained by 17.4% and 14.7%, respectively.

The increasing degree of urbanization, measured by the number of building area surround the park, increased the abundance of birds observed in the park, and reduced the diversity index. Regarding individual species, eurasian tree sparrow, rock pigeon correlated positively with BUILD2000, and brown shrike negatively (figure 2). However, the adj_R2 value of the abundance regression model is only 0.233, indicating that there is still 76.7% of the variation unexplained.

4 Conclusions

Owing to the low density and limited observation, to ascertain which environmental variable affect the rarely seen birds is difficult. However, we found that rarely seen birds (observed in less than 2 parks) occurred in either the largest park or the park surrounded by large vegetation covered area. And the increasing degree of urbanization tends to decrease the occurrence of rarely seen birds, and increase urban common species, such as eurasian tree sparrow, and rock pigeon.

The result of our study demonstrated that wide scales of urban environmental variables, including the building area and vegetation covered area, significantly affect avian composition. In addition, the main factor influencing the avian species richness is the park area. Therefore, in order to increase the avian richness, we should increase the park area as much as possible. To attract more species, the land use around the park should also be considered.

Appendix A

Common name	Scientific name	Total counts	Number of parks occurred in
eurasian tree sparrow	Passer montanus	1535	17
light-vented bulbul	Pycnonotus sinesis	2389	17
Japanese White-eye	Zosterops japonica	1631	17
barn swallow	Hirundo rustica	60	13
pacific swallow	Hirundo tahitica	207	17
house swift	Apus affinis	33	11
spotted dove	Streptopelia chinesis	100	14
red-collared dove	Streptopelia tranquebarica	132	11
rock pigeon	Columbia livia	259	5
grey treepie	Crypsirina formosae	42	9
black-naped monarch	Hypothymis azurea	56	9
black drongo	Ddicrurus macrocercus	24	2
black-billed magpie	Pica pica	94	4
crested myna	Acridotheres cristatellus	15	6
brown shrike	Lanius cristatus	215	16
crested goshawk	Accipiter trivirgatus	4	1
black-crowned night heron	Nycticorax nycticorax	22	1
little egret	Egretta garzetta	7	2
common teal	Anas crecca	13	1
scaly-breasted Munia	Lonchura punctulata	103	3
plain prinia	Prinis subflava	5	2
grey-cheeked fulvetta	Alcippe morrisonia	15	3
common kingfisher	Alcedo atthis	4	2
scaly-breasted munia	Turdus pallidus	2	1
pigmy woodpecker	Dendrocopos canicapillus	6	1
black-headed shrike	Lanius schach	3	1
dauruan redstart	Phoenicurus auroreus	1	1

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