Analysis on Bird Communities Response to Different Urban Land-Cover and Land-Use Types in Greater Manchester

Yihao Liu(✉)

School of Environment, Education and Development, University of Manchester, Manchester M13 9PL, UK
yihao.liu@postgrad.manchester.ac.uk

Abstract. Nowadays the process of global urbanization is unstoppable, leading to a serious threat to local biodiversity. Urbanization may result in biodiversity decline or even species extinction, while sometimes help maintain species abundance in some developed countries. Different land-cover and land-use types affect species diversity in different aspects and directions, so it's important to understand the pattern of species distribution across different characteristics of urban landscape, which helps city-designers and decision-makers to mitigate detrimental influences of urbanization on local biodiversity by rational urban planning and effective conservation protection. This study uses bird, which are highly sensitive to environmental changes, as the ecological indicators.

This paper studies the differences of species richness, abundance and community composition from five urban land-cover and seven land-use types, and analyses patterns of bird distribution in different land use purposes on the same land cover landscape. This study used bird species richness, Shannon and Simpson diversity index across Greater Manchester to evaluate bird diversity. This study also used Generalized Linear Model to model the relationship between bird species richness and land-cover or land-use density, and used Redundancy Analysis (RDA) to interpret the response of bird communities to land-cover and land-use density. Green spaces (especially for public parks land use) and water bodies have relatively higher bird species richness. Built areas have the lowest species richness, especially the institutional land use (including religious grounds, school grounds, and institutional grounds). Considering different land-use purposes, public parks and recreation have the highest bird diversity in green spaces land-cover, followed by amenity land and domestic gardens. In built-up areas, species diversity in institutional land use is higher than previously developed land use. Clear understanding the relationships between land-cover and land-use types and bird species diversity and communities composition will help better policy making for potential future land-cover and land-use planning.

Keywords: Spatial ecology · Avian · Greater Manchester · Species richness · Land cover · Land use

K. Ujikawa et al. (Eds.): ACESD 2021, ESE, pp. 393–402, 2022.
https://doi.org/10.1007/978-981-19-1704-2_36

1 Introduction

Nowadays because of the widespread of COVID-19 pandemic, people gradually realize the importance of ecosystems to human beings' health, which motivate them to protect and maintain the nature environment [1]. Intergovernmental science-policy Platform for Biodiversity and Ecosystem Services (IPBES) reports that the spread of infectious diseases will be caused by less abundant biodiversity and dysfunctional ecosystems [1, 2]. Therefore, protecting and restoring biodiversity and nature can be beneficial for people's physical and mental health, and further help human beings to better face future challenges.

Global urbanization is a great threat to ecosystems and biodiversity, because of the fragmented natural habitats caused by rapidly changing urban land use purpose, leading to the decline or extinction of ecological communities [3]. Green spaces are the most important and principle land-cover types as habitats for species in cities, because of their dense tree cover providing essential food and living resources [4]. Birds are sensitive to habitat, human-caused changes or environmental contaminants, have relatively lower monitoring costs, are wide-spread across various habitats, and have been well-developed [5], so they are viewed as a useful tool for environmental monitoring.

Greater Manchester is under an intense urbanization caused by development pressures, but it's impressively biodiverse. However, few urban ecological studies especially land-cover and land-use studies have been carried out in this region.

This paper will detect the changes of bird species diversity and community composition in Greater Manchester across different land-cover types, and analyse different relationships between land-cover types for different land use and bird species. Clear understanding of these relationships will help better policy making for potential future land-cover and land-use planning.

2 Methodology

2.1 Research Area

Greater Manchester, located on the North West England, 53°30'N, 2°19'W, consists of more than 50% high-density urban areas (dominated by built up areas), transitional areas, and peri-urban areas (Fig. 1). Although natural habitats have been fragmented by intense urbanization, numerous small fragmented areas of different habitats can help support small populations of a wide variety of species. There are some protected species detected in Greater Manchester, including little ringed plovers, barn owls, badgers, kingfishers, peregrine falcons, water voles, great crested newts, and even some European Protected Species [6].

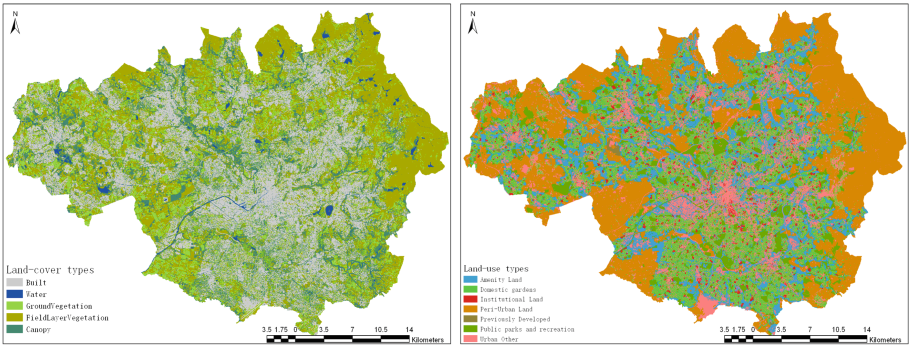

Fig. 1. Land-cover and land-use types in Greater Manchester [7].

2.2 Research Design

Greater Manchester was digitally overlaid by 1 × 1 km grids by ArcGIS Pro [8], and their locations were represented by the centroid coordinate of grids. Occurrence records data of bird species were from National Biodiversity Network, focusing on records detected after 2015, and were sampled in different grids based on their locations. Species records data occurring at less than 20 grids were removed from the analysis because of the distortion multivariate patterns from rare species [9]. 230 bird species found in study area were classified into five dietary guild according to the species-level dataset built by Wilman et al.: plant and seed eaters, fruit and nectar eaters, invertebrate eaters, vertebrate and fish and carrion eaters, and omnivore [10].

To identify land-cover and land-use types composition inside each grids, the focal density with a Gaussian filter of land-cover and land-use were calculated within a 500-m buffer and 100-m sigma, which means cells inside sigma were given more weight.

2.3 Statistical Analyses

In order to analyse bird species richness and diversity, the study summarized species detections records, species richness index, Shannon diversity index, and Simpson diversity index across different land-cover and land-use types. Then the analysis used general linear model (GLM) of the Poisson family [11], which is suitable for count data, to model the relationship between bird species richness and land-cover or land-use density inside each grids.

This study also used Redundancy Analysis method (RDA), which can interpret the response of bird communities to land-cover and land-use density and explore their relationships [12]. Before computing RDA of bird communities, bird abundance data were pre-transformed using Hellinger transformation method to avoid Euclidean distance, and plotted into biplots based on bird species scores and grid scores. Finally, this study compared bird communities composition inside different land-cover and land-use types to investigate bird communities structures.

3 Results

3.1 Species Richness and Diversity

As Table 1 shows, three green spaces layer have relatively higher species richness and diversity indexes, followed by water layer. Built areas have the lowest diversity index. Considering different land-use purposes, public parks and recreation have the highest bird diversity in green spaces land-cover, followed by amenity land and domestic gardens. In built-up areas, species diversity in institutional land use is higher than previously developed land use.

Table 1. Bird richness and diversity index within different land-cover and land-use types

Land-cover type	Total species richness	Total number of detections	Shannon diversity	Simpson diversity
Field layer vegetation	191	37,703	70.65	51.38
Water	150	14,844	66.87	49.99
Canopy	171	44,252	61.31	45.92
Ground vegetation	172	19,692	60.40	42.47
Built	167	42,243	54.63	39.99
Land-use type				
Peri-urban	192	47,700	74.37	55.02
Public parks and recreation	171	26,715	70.84	54.26
Amenity land	166	32,643	62.69	48.09
Urban other	158	25,041	53.48	38.56
Institutional land	96	2,313	50.63	37.85
Domestic gardens	155	34,304	46.03	33.34
Previously developed land	15	18	14.29	13.50
Total	230	168,735		

GLM analysis (Table 2) shows an encouraging positive relationship between water-body and bird species richness, an unexpecting negative (although weak) relationship between ground and field vegetation with species richness, and an significant negative relationship between built areas and richness. Among land-use types, public parks and recreation have a weak positive relationship with bird richness, others have a negative influence. The negative correlation between domestic parks, amenity land and Institutional land with bird richness are much weaker than the negative correlation between previously developed land and other urban land use with bird richness. There is no linear relationship between canopy and peri-urban land with bird richness.

Table 2. Summary of GLM

	Estimated coefficients	Standard errors	z-value	p-value
Intercept	3.324	0.014	227.112	<0.001
Water	1.412	0.086	16.327	<0.001
Field layer vegetation	−0.095	0.059	−1.620	0.105
Ground vegetation	−0.409	0.077	−5.335	<0.001
Built	−0.804	0.061	−13.218	<0.001
Canopy	NA	NA	NA	NA
Public parks and recreation	0.122	0.033	3.670	<0.001
Domestic gardens	−0.220	0.035	−6.368	<0.001
Amenity land	−0.314	0.033	−9.388	<0.001
Institutional land	−0.366	0.108	−3.375	<0.001
Urban other	−0.731	0.041	−17.826	<0.001
Previously developed land	−0.740	0.187	−3.947	<0.001
Peri-urban	NA	NA	NA	NA

3.2 Bird Community Composition

Figure 2 plots the explanatory variable which pass the permutation test at 95% confidence level [12]. According to the length of arrows, canopy, domestic gardens, field layer vegetation, and built areas have the most significant influence on bird distribution. Less sites are distributed in the third quadrant, which are related to built and urban other areas. Several bird species are distributed far away from others, especially in the third quadrant (*Columba livia* and *Apus apus*) correlating to some human-related land-use types, while most of others are clustered together in the right part with short projection, showing that they are related to either green spaces and water land cover or intermediate ecological conditions.

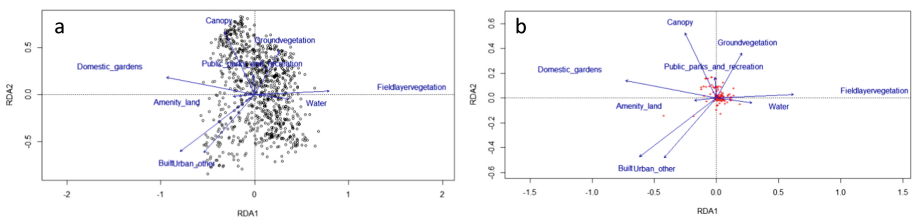

Fig. 2. RDA in different land-covers and seven land-use types (a) site scores, (b) species scores.

All dietary guilds can be found in Greater Manchester, though fruit and nectar dietary only includes one bird species: *Psittacula krameri*. Omnivore eaters have the highest proportion in the study area, Omnivores account for the largest proportion in all land-cover and land-use types, followed by invertebrate eater, plant and seed eaters, vertebrates, fish and carrion eaters, in turn.

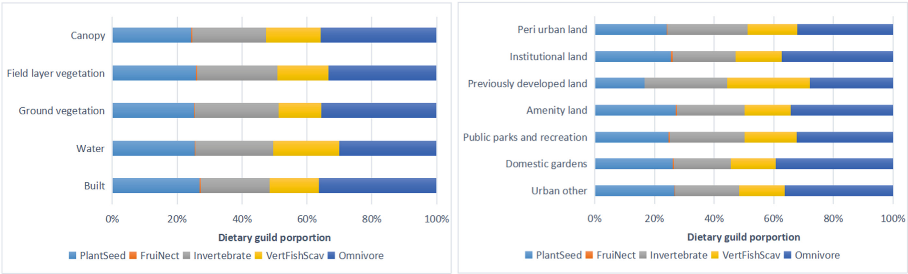

Fig. 3. Composition of birds dietary guilds in Greater Manchester.

4 Discussion

4.1 Species Richness and Diversity

In Greater Manchester, urban regions play an essential role in protecting and restoring bird diversity, since they sustain higher bird species richness and more bird individuals (total bird detections within city areas occupy more than 70% through comparing peri-urban with other regions). There are even some globally vulnerable species inside Red List [13] (e.g., *Anser cygnoides*), and European Protected Species [6] (e.g., *Falco peregrinus*, *Charadrius dubius*) recorded inside cities. Some bird species (e.g., *Xema Sabini*, *Calidris pugnax*, etc.) are only distributed within city regions, which strongly demonstrates that urban landscape is a suitable habitat for both high-density bird species and conservation species [14].

Species richness in green spaces are relatively higher, which has been proved by many other studies. Field layer vegetation has higher diversity index and less negative impact on species richness than ground vegetation, partly because the area of ground vegetation is smaller and more dispersed, leading to less abundance of bird species [15]. Some researches prove that establishing corridors between small green spaces can accelerate birds' movement and regularly interaction with connecting green spaces, therefore facilitating the growth number of bird species and individuals [16]. Considering different land-use purposes in green spaces, species diversity in public parks and recreation is much higher than others, and they have a positive influence in richness. The most important reason is that vegetation in public parks are much more complex and heterogeneous in structure, which can provide diverse habitats and dietary for multiple bird species [17]. Amenity land and domestic gardens are designed and maintained for safety, visual, or environmental purposes with less structural changes are more homogeneity, so they are less suitable for different species survival [18]. Therefore, city designers should consider the vegetation structure, including diverse trees species, woods, forbs and shrubs, while make the future land-use plan.

Waterbodies have encouragingly high species diversity and significant positive relationship with bird species richness. Waterbirds get food and shelters from waterways, and nest and breed near water, although waterways within cities are under high human-related pressure [19]. This can be demonstrated by some studies, which prove that waterbird diversity are not influenced by the level of urbanization, so they can survive in not only natural habitats but also human-built areas [20]. Potential future land-use planning cannot ignore the essential role of urban water in optimizing habitats.

The lowest species richness and most negative impact occur in built up regions as expected, influenced by intense artificial pressure, barren vegetation, heavy pollution and noise, high collision risks and mortality [3]. Some researches find the highest number of species and individuals occurring in built areas, especially in residential areas [21], because of common bird feeders and enough edible garbages for food. However, this analysis is unable to show this trend because we did not classify finer land-use types. Nowadays urbanization and the displacement of natural habitats by building are unstoppable, sufficient quantity and quality of green spaces between buildings, or sufficient bird feeders in the built areas, can help to protect, sustain and restore bird abundance.

4.2 Bird Community Composition

The characteristic of urban bird communities in Greater Manchester is classical. Several dominate species (e.g., *Passer montanus*, *Columba livia*, etc.) account for more than 75% of total individuals inside cities. These abundant species, which adapt to complex urban habitats better than others, are mostly distribute near buildings and make use of human refuse [22].

Only one bird species (*Psittacula krameri*) mainly eats fruit and nectar. This is an invasive alien species, which is original from Africa and Asia. *Psittacula krameri* prefer to live in built regions, public parks, and domestic gardens, and negatively affect other cavity nesters. The European Community notes invasive species cause serious damage to both biodiversity, economy and health [23], therefore weighing the pros and cons of invasive alien species before developing suitable strategies is important to control the spread and reduce biodiversity loss.

Omnivores (e.g. *Chroicocephalus ridibundus*) and granivores (e.g. *Columba livia*) tend to distribute in highly urbanized areas, since they can benefit from anthropogenic food sources (garbage, feeders, or human-source seeds) [22, 24]. Some scientists also find that omnivores have an advantage in temperate regions, because they can live based on human-related resources in winter when there is limited natural sources comparing to tropical regions [25]. Dietary composition in Greater Manchester can show this trend, which omnivores and granivores are dominate inside cities.

Invertebrate eaters (mainly insect) and vertebrates, fish, and carrion eaters occupy the rest, and bird species based on invertebrate dietary are slightly more. More invertebrate eaters are distributed in regions where have more vegetation cover (e.g., canopy, public parks, ground vegetation or field layer vegetation), possibly because tree species in study area are suitable for arthropods and provide rich food for insectivores [26]. In addition, insectivores in abundant waterways also have higher proportion than human-related land cover, which is consistent with former studies [27]. The analysis clearly shows that the highest proportion of vertebrates, fish, and carrion eaters are located near waterways, where have the most suitable nesting sites and corresponding food resources. Most of these waterbirds have a positive relationship with water variable according to Fig. 3. Therefore, carnivorous and insectivorous distributed in Greater Manchester will decline if the rapid urbanization influence and reduce the area of water and vegetation cover.

5 Conclusion

This paper clearly reveals the important role of cities in sustaining bird species diversity and shows the relationship between bird diversity and community composition with urban landscape. Green spaces (field layer vegetation, ground vegetation and canopy in turn) and water land cover have the highest species richness. Considering different land-use purposes, public parks and recreation have the highest bird diversity in green spaces land-cover, followed by amenity land and domestic gardens. This is determined by their vegetation structural complexity. The lowest species richness, diversity, and most negative contribution to species diversity are in built-up regions. Previously developed land use has a lower diversity and more negative influence because of the high intensity of artificial pressure, barren vegetation, heavy pollution and noise, high collision risks and mortality.

There are 230 bird species distributed in Greater Manchester, and more than 70% of them live inside cities. Several dominate species account for more than 75% of total urban individuals, which is the classical characteristics of urban bird communities. Omnivores and granivores tend to distribute in the most highly urbanized areas (e.g. built-up areas), since they can benefit from anthropogenic food sources. More insectivores are distributed in regions where have more vegetation cover (e.g., canopy, public parks, ground vegetation or field layer vegetation) or near abundant waterways. The highest proportion of vertebrates, fish, and carrion eaters are located near land-cover type.

To protect and maintain biodiversity inside cities, city designers should consider the vegetation structure, including diverse trees species, woods, forbs and shrubs, while make the future land-use plan, establishing some corridors between small green spaces can also facilitate the growth number of bird species and individuals. What's more, future land-use planning cannot ignore the essential role of urban water in optimizing habitats and supporting healthy waterbird communities. In highly urbanized areas, decision-makers can design more green spaces between buildings, or sufficient bird feeders in the built areas, to help protect and sustain bird abundance.

Acknowledgements. I would like to express my thanks to Dr. Matthew Dennis for his patient professional and logistical guidance and Dr. Gail Millin-Chalabi for her useful practical advice. I also would like to express my thanks to every professor in the University of Manchester, who gave me essential associated knowledge background and writing skills. Lastly, I want to thank my parents who supported me for further learning and my friends who encouraged and accompanied me when I was in trouble.

References

1. EC (2020): EU Biodiversity Strategy for 2030. Bringing Nature Back Into Our Lives. Brussels. https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1590574123338&uri=CELEX:52020DC0380#footnote2. Accessed 8 Aug 2021
2. IPBES (2019): Global Assessment Report on Biodiversity and Ecosystem Services. Available at: https://ipbes.net/global-assessment. Accessed 14 Aug 2021
3. Seress, G., Liker, A.: Habitat urbanization and its effects on birds. Acta zoologica Academiae Scientiarum Hungaricae (Budapest, Hungary : 1994) **61**(4), 373–408 (2015)
4. Kong, F., et al.: Urban green space network development for biodiversity conservation: identification based on graph theory and gravity modeling. Landsc. Urban Plan. **95**(1), 16–27 (2010)
5. Pertti, K.: Birds as a tool in environmental monitoring. Ann. Zool. Fenn. **26**(3), 153–166 (1989)
6. AGMA: An Ecological Frameworkfor Greater Manchester (2008). https://www.lancswt.org.uk/sites/default/files/2018-08/An%20Ecological%20Framework%20for%20Greater%20Manchester.pdf. Accessed 13 July 2021
7. Dennis, M., et al.: Mapping urban green infrastructure: a novel landscape-based approach to incorporating land use and land cover in the mapping of human-dominated systems. Land (Basel) **7**(1), 17 (2018)
8. Esri: (2021) ArcGIS Pro. The world's leading GIS software. https://www.esri.com/en-us/arcgis/products/arcgis-pro/overview. Accessed 14 Aug 2021
9. Braak, ter.: Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. Ecology (Durham) **67**(5), 1167–1179 (1986)
10. Wilman, H., et al.: EltonTraits 1.0: Species-level foraging attributes of the world's birds and mammals. Ecology (Durham) **95**(7), 2027–2027 (2014)
11. Borcard, D., Gillet, F., Legendre, P.: Numerical Ecology with R. 2nd ed. 2018. Cham: Springer International Publishing (2018)
12. Fletcher, R., Fortin, M.J.: Spatial Ecology and Conservation Modeling: Applications with R. 1st ed. 2018. Cham: Springer International Publishing (2018)
13. An, A., et al.: Changing abundance and distribution of the wintering swan goose Anser Cygnoides in the middle and lower Yangtze river floodplain: an investigation combining a field survey with satellite telemetry. Sustain. (Basel, Switzerland) **11**(5), 1398 (2019)
14. Beninde, J., et al.: Biodiversity in cities needs space: a meta-analysis of factors determining intra-urban biodiversity variation. Ecol. Lett. **18**(6), 581–592 (2015)
15. Khera, N., Mehta, V., Sabata, B.: Interrelationship of birds and habitat features in urban greenspaces in Delhi India. Urban Forestry Urban Greening **8**(3), 187–196 (2009)
16. Sodhi, N.S., et al.: Bird use of linear areas of a tropical city: implications for park connector design and management. Landsc. Urban Plan. **45**(2), 123–130 (1999)
17. Silva, C.P., et al.: Bird richness and abundance in response to urban form in a Latin American city: Valdivia, Chile as a case study. PLoS ONE **10**(9), e0138120–e0138120 (2015)
18. Ferenc, M., Sedláček, O., Fuchs, R.: How to improve urban greenspace for woodland birds: site and local-scale determinants of bird species richness. Urban Ecosyst. **17**(2), 625–640 (2013). https://doi.org/10.1007/s11252-013-0328-x
19. Ma, Z., et al.: Managing wetland habitats for waterbirds: an international perspective. Wetlands (Wilmington, N.C.) **30**(1), 15–27 (2010)
20. Andrade, R., et al.: Waterbird community composition, abundance, and diversity along an urban gradient. Landsc. Urban Plan. **170**, 103–111 (2018)
21. Sandström, U., Angelstam, P., Mikusiński, G.: Ecological diversity of birds in relation to the structure of urban green space. Landsc. Urban Plan. **77**(1), 39–53 (2006)

22. Jokimäki, J., Suhonen, J.: Distribution and habitat selection of wintering birds in urban environments. Landsc. Urban Plan. **39**(4), 253–263 (1998)
23. Genovesi, P.: European strategy on invasive alien species. Council of Europe (2003)
24. Kark, S., et al.: Living in the city: can anyone become an ‘urban exploiter’? J. Biogeogr. **34**(4), 638–651 (2007)
25. Lim, H.C., Sodhi, N.S.: Responses of avian guilds to urbanisation in a tropical city. Landsc. Urban Plan. **66**(4), 199–215 (2004)
26. Vehviläinen, H., Koricheva, J., Ruohomäki, K.: Effects of stand tree species composition and diversity on abundance of predatory arthropods. Oikos **117**(6), 935–943 (2008)
27. Hayes, W.M., et al.: Bird communities across varying landcover types in a Neotropical city. Biotropica **52**(1), 151–164 (2020)