

Bird species assemblages across a rural urban gradient around Kolkata, India

Shruti Sengupta · Moumita Mondal · Parthiba Basu

Published online: 23 October 2013

© Springer Science+Business Media New York 2013

Abstract Urban development leads to changes in habitat structure and resource base. Bird communities are known to respond sharply to such changes. Our result from study of bird community along urbanization gradient around Kolkata metropolitan city clearly separated the urban bird community from the rural and rural 3 habitats in terms of species diversity and foraging groups. Rural and rural 3 sites had more number of rare species and higher percentage of unique species as compared to the urban habitats. Functional group analysis showed higher abundance of granivores in urban habitats and absence of insectivore and carnivorous species that were found in the rural and rural 3 habitats. The bird species assemblage along the gradient was significantly nested where bird species recorded in urban areas were subset of the species rich rural areas. There was no difference in individual counts between urban and rural habitats, therefore nullifying the hypothesis that rural areas are more species rich because of higher population size. Bird community in the urban areas was less even as compared to the rural areas due to the dominance of omnivorous guild. Bird diversity was negatively correlated to the density of house lots.

Keywords Bird diversity · Urbanization gradient · Nestedness, functional group, Kolkata metropolitan area

Introduction

Urbanization is perceived as a major driving force behind habitat fragmentation and conversion, but effects of urbanization on biodiversity loss is only recently being investigated at larger detail (Blair 1996; Blair 2001a, b; Blair and Launer 1997; Hunter 2007; Kowarik 1995; Marzluff 2001; McKinney 2002; Pauchard et al. 2006). Expansion of urban areas associated with mushrooming of urban sprawls and smaller suburban habitations has been shown to have serious bearing on the local species diversities increasing the local

S. Sengupta
Madhumita Apartment, 33 BT Road, Khardah, Kolkata 700117, India

M. Mondal
8/3, Pashupati Bhattacharjee Road, Kolkata 700 034, India

P. Basu (✉)
Ecology Research Unit, Department of Zoology, Calcutta University, 35, Ballygunge Circular Road,
Kolkata 700019, India
e-mail: bparthib@gmail.com

extinction rates (McKinney 2002, Marzluff 2001) and through replacements of native species (Kowarik 1995, Blair 1996, Blair and Launer 1997, Blair 2001a, b). Many of these changes are also said to be irreversible (Pauchard et al. 2006). From another perspective, analyses of the status of biodiversity along urbanization gradients would also provide useful information on species response to structural changes in complex landscape mosaics both at population as well as community levels (Bolger et al. 1997; Crooks et al. 2004; Germaine et al. 1998; Marzluff et al. 1998).

Large parks and reserves in urban areas may support high species diversity because these protected areas are the habitat “fragments” of highly diverse ecosystems (Schaefer 1994). Some studies of birds in urban areas have focused on species richness within a patch of native habitat (e.g., a large park) in relation to patch size and the degree of isolation from other areas of habitat (Tilghman 1987, Diamond 1988, Soulé et al. 1988). A few studies have examined the effects of surrounding urbanization on bird species richness in park and riparian fragments (e.g., Saab 1999, Sodhi et al. 1999, Mörtberg 2001, and Er 2002).

The occupancy of poor-quality or marginal areas by resident birds could be influenced by the surrounding landscape (regional parks vs. high-density housing) because the surrounding habitats may act as resource areas for residential birds and as “source” areas for dispersing birds. (Melles et al. 2003)

Urban habitats are altered from their original state, but do offer foraging and cover resources and are thus not always hostile or unsuitable for all species. In a complex landscape mosaic, the presence and detection of individual birds is expected to vary with land use and with the overall composition of the landscape (Trzcinski et al. 1999, Austen et al. 2001, Fahrig 2001).

Kolkata (earlier Calcutta) is the 7th biggest city in India in terms of area and population. By 2011 its population is predicted to grow up to 16.5 million which is a 22 % leap from 13.6 million in 2001. Housing densities are also increasing around the city as areas in the city outskirts are transforming fast to accommodate the bulging population. Expansion of Kolkata city into the adjoining rural landscapes, mostly through unplanned urbanizations at various scales, has created sharp urbanization gradients and has thrown open conservation issues that need to be addressed urgently.

The aim of this study is to analyze the avian community along urbanization gradients in selected surrounding areas of Kolkata. We attempted to see whether and how the bird communities are affected by the intensity of urbanization and if there is any change in the functional groups across the gradients. We made the following hypotheses:

1. Urban areas will have less number of species compared to the rural and Rural 3 areas.
2. Urban and rural areas will have different bird community structure.
3. Bird community along the gradient will show a nested pattern.
4. Bird species diversity will be determined by the extent of built up area along the gradient.

Methods

Study site

Three urban sites characterized by high house lot density, 1 peri urban site that was a recreational area on the outskirts of an urban settlement and 2 rural sites characterized by sparse house lots and more open space were chosen for the study (Table 1);

1. Rural 1(Barbaria)—A rural patch within 3 kms from a densely populated urban conglomeration with few dispersed houses and cultivation fields.

Table 1 Characteristics of the sites chosen for bird diversity assessment and house lot densities in these sites

Site no.	Site	Site character	Site location	House lot density
1	Rural 1(Barbaria)	Least populated	220 44' 51.7"N 880 27' 32.52"E	7
2	Rural 2 (Burul)	Sparsely populated	220 21'35.93"N 880 06'46.38"E	45
3	Rural 3 (Gandhighat)	Sparsely populated	220 45' 8.02"N 880 21' 49.26"E	8
4	Urban 1(Khardah)	Highly populated	220 43'23.51"N 880 22'26.35"E	99
5	Urban 2 (Panashree)	Moderately populated	220 30' 36.12"N 880 18' 22.40"E	56
6	Urban 3(Charaktala)	Highly populated	220 29' 39.88"N 880 19.1' 36.61"E	184

- Rural 2 (Burul)—A village located 35 kms from the southern fringe of Kolkata metropolitan area. Characterised by low house lot density and had open cultivation fields with patches of thick vegetation.
- Rural 3 (Gandhighat)—A recreational area on a river bank area, adjacent to a densely populated urban conglomeration. This had good vegetation and low house lot density.
- Urban 1 (Khardah)—A congested area with several housing complexes and industries. Sparse vegetation and almost no open space.
- Urban 2 (Charkatala)—An urban area with high house lot density but with gardens attached to house lots. There were some water bodies in the area.
- Urban 3 (Parnashree)—An area with a large water body surrounded by dense housing complexes. There were patches of open fields in this area.

House lot densities (housing units per square km) and extent of open areas (% of open space per square km) for these locations were calculated from Google Earth image (Fig. 1).

Bird diversity

Relative abundances of individual bird species were estimated at 6 selected sites, by point count method. A point count is a count undertaken from a fixed location for a fixed time. It can be undertaken at any time of year, and is not restricted to the breeding season. Point counts can be used to provide estimates of the relative abundance of each species or, if coupled with distance estimation, can yield absolute densities, too (Buckland et al. 2001).

At each sites, four transect points were selected randomly within 1 sq.km. The distance between two transect points were approximately 150–200 m. The time spent at each transect was 15 min. The sampling was done twice a day (morning 6 am onwards & evening 4 pm onwards), once in a month for consecutive 3 months (February 2009 to April 2009).

Species falling within last quartile of the species abundance distribution were considered rare and the rest were considered common (Davidar et al. 1996). Uniqueness of a site was calculated as % of unique species of the total number of species in a site (Savitha et al. 2008).



Fig. 1 Landscape and Google Earth images of the study sites. **a)** Rural 1, **b)** Rural 2, **c)** Rural 3, **d)** Urban 1, **e)** Urban 2 and **f)** Urban 3

Functional diversity

The bird species were categorized into six foraging groups. The categories were a) frugivore, b) insectivore, c) carnivore, d) granivore, e) nectarivore and f) omnivore. Omnivores were species that feed upon more than two types of food items. Some species e.g. Chestnut tailed Starling, Golden Oriole, Indian Koel, Orange Headed Thrush, Rufous Treepie, Red Whiskered Bulbul and Red-vented bulbul were considered both as frugivore and insectivore. White breasted water hen was considered both as insectivore and carnivore.

Weighted averages of species abundances were calculated for different functional groups. This was done by weighting the abundances of different functional groups with the house lot density in each area and then dividing the term with total abundance of all species in that functional group (Jongman et al. 1995; Fraterrigo and Wiens 2005).

Nestedness

Nestedness among the six sampling sites representing urban, peri urban and rural sites was calculated using Nestcalc (Atmar and Patterson 1993). Nestedness occurs when species recorded from a fragment is a subset of a larger (more species rich) fragment. Values of N_c and C were calculated and statistical significances estimated from species presence absence matrix using Nestedness Calculator (Wright and Reeves 1992). N_c is a count of number of times a species presence in a fragment correctly predicts its presence in a richer or larger fragment. C is a measure of the relative degree of nestedness that is not affected by matrix size (Wright and Reeves 1992).

Results

A total of 48 bird species were recorded from 2858 individuals pulled across sites. The Shannon-Weiners' diversity index (H') was highest in the Rural 2 (Burul) site and lowest in Urban 3 (Charkatala) site (Table 2). There was no significant difference in individual count between urban and rural areas.

Rural sites and the peri urban site had higher number of rare species compared to the urban sites (Fig. 2). Rural sites also had higher uniqueness compared to urban sites. Two of the urban sites (Urban 1-Khardah and Urban 2-Charkatala) did not have any unique or rare species. Thirty five percent of the species were unique to the rural and Rural 3 areas and were urban avoiders.

There was a highly significant correlation between house lot density and bird species diversity (Spearman rank correlation), $r = -0.886$, $p < 0.01$. Regression analysis shows a linear fit between house density and bird species diversity (Shannon Weiner's diversity index) at different sites (Fig. 3). The best fit regression model was $y = -0.0297x + 17.17$, $R^2 = 0.51$.

Cluster analysis clearly groups Urban sites (Khardah, Charkatala and Parnashree) rural sites (Barbaria, Burul and Ganndhighat) as separate clusters (Fig. 3). Urban sites 1 and 2 (Khardah and Charkatala) were most similar in terms of bird community structure and this cluster had a relatively distant similarity with Urban site 3 (Parnashree). The two rural sites were closest to each other and although this cluster grouped with the rural 3 site, it was relatively at a larger distance Fig. 4.

The rank-abundance curve was steeper in urban sites (averaged for all sampling sites) as compared to the rural sites (averaged across sampling sites) (Fig. 5). Rank abundance curve was gentler for the rural areas that also had more number of species.

Table 2 Bird species richness and Shannon-Weiners' diversity index for various study sites

Site No.	Sites	Number of bird species	Shannon diversity index
1	Rural 1	36	2.9847
2	Rural 2	38	2.9776
3	Rural 3	31	2.8973
4	Urban 1	25	2.2312
5	Urban 3	21	2.5183
6	Urban 2	25	2.4565

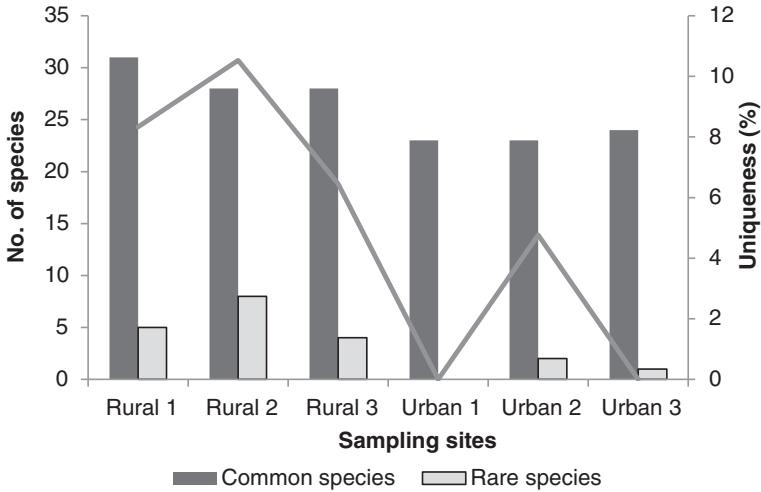


Fig. 2 Distribution of common, rare (species in the last quartile of the species abundance curve) and unique species (a species found only in a particular site) across different sites

There was significant variance among various functional groups across different sampling locations (Two way ANOVA, $F=10.36, p<0.0001$). Rural sites had more number of frugivores (Mann Whitney U test, $p<0.05$) and insectivores (Mann Whitney U test, $p<0.05$) (Fig. 6). Necatrivores were found only in the rural areas (Fig. 6). Urban areas had more number of granivores (Mann Whitney U test, $p<0.05$) Fig. 7.

Weighted averages for granivores and omnivores were highest indicating the prevalence of these feeding groups in the areas with higher house lot densities (Fig. 8).

The bird fauna was found to be significantly nested (Fig. 6) with a fill of 43.9 % ($Nc=335, C=0.54, p<0.002$) indicating that the species found in the less species rich urban areas are subsets of more species rich and larger rural areas.

Discussion

Our results were consistent with studies done previously that showed decreased bird species diversity due to urbanization (Blair, 1996, Blair 2001a, b; Blair and Launer 1997; Hunter 2007;

Fig. 3 Best fit regression model showing relationship between house density (houses per sq.km) and bird species diversity (Shannon diversity index)

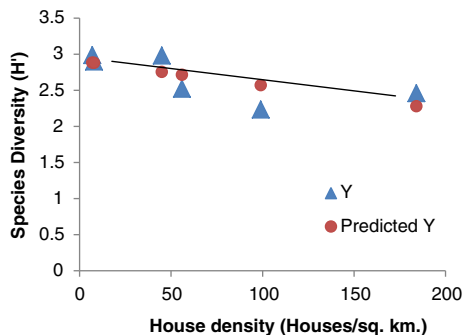
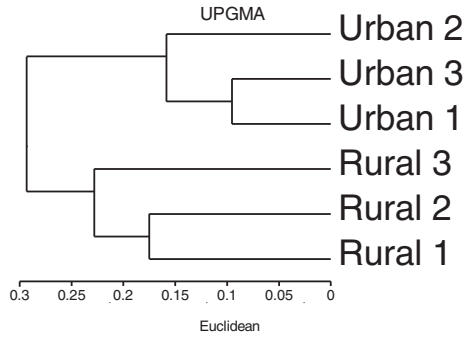


Fig. 4 Dendrogram (UPGMA, average linkage between groups) based on Euclidean distances between sites showing urban and rural sites clustering separately with respect to bird species diversity



Kowarik 1995; Marzluff 2001; McKinney 2002; Pauchard et al. 2006; Garaffa et al. 2009). Urbanization leads to changes in habitat structure and resource availability and that result into segregation of the avian community (Beissinger and Osborne, 1982; Fraterrigo and Wiens 2005). That the rural and Rural 3 sites recorded more number of species confirmed our first hypothesis.

The bird communities were clearly distinct between the rural and urban sites and this trend also confirmed our second hypothesis about segregation of the bird community along an urbanization gradient. Our analysis of the functional group matrix illustrates how the urban and rural-rural 3 bird communities segregated themselves along the resource base. There is a clear distinction between urban and rural sites in terms of various functional groups. There was preponderance of frugivores and insectivores in the rural areas which is attributed to presumably higher resource availability, e.g. trees and open areas in the rural sites as compared to urban areas. That the urban areas had more granivore birds corroborates earlier observations (Emlen, 1974; Lancaster and Rees, 1979; Beissinger and Osborne, 1982; Mills et al., 1989; Kluza et al., 2000; Fraterrigo and Wiens 2005; Chace and Walsh, 2006). Expectedly again, weighted average for granivores and omnivores abundances were found to be more which is because of their increased abundances in the urban areas with more house lot densities. Fraterrigo and Wiens (2005) also found the same pattern. Contrary

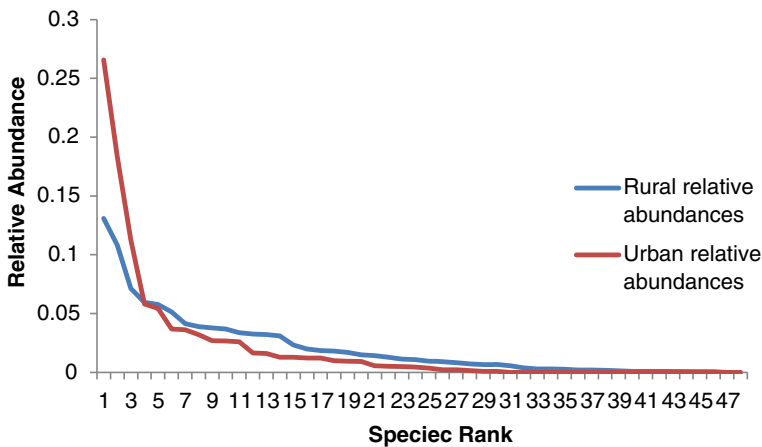


Fig. 5 Rank abundance curves for the urban and rural sites. Relative abundance values were averaged for rural and urban sites

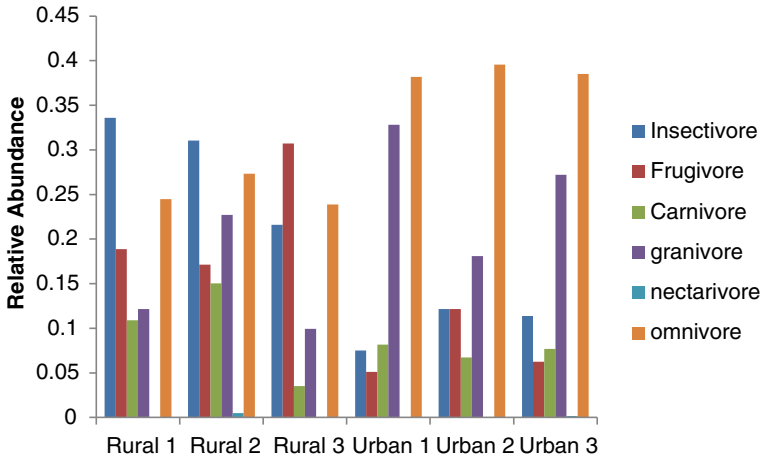


Fig. 6 Relative abundances of various functional groups across various sampling sites

to our expectation of the urban areas having more omnivore (generalist species), there was but no significant difference between the rural and urban areas in terms of omnivore species. Earlier studies had recorded more generalist species in urban areas (Boren et al. 1999). Higher abundance of house, crows, which are essentially omnivorous, in our rural and Rural 3 areas would have contributed to this non difference.

Rural communities were more evenly distributed as compared to urban areas which had high dominance of omnivorous species like house crows and common myna. Chiari et al. (2009) proposed that more species rich communities have larger populations and hence have low local extinction rates. Our study however does not corroborate this finding as there was no significant difference in individual counts between the urban and rural communities.

The communities in the urban areas were a nested subset of the larger species pool in the rural areas. Nestedness is an important measurement that has conservation implications and has been observed across many taxa. Platt and Lill (2006) in an important study had shown nestedness of urban avian communities within a larger set recorded in urban parks. This signifies the sensitivity avian community to variation in resource base. Higher percentage of unique or rarer species in rural areas also corroborates such response of the bird community to variation in resource base. Fernandez-Juricic (2002) had shown how human disturbance can create nestedness in bird community structure.

Our hypothesis that extent of built up area will determine the bird species distribution was corroborated by the high correlation between the house lot density and bird species diversity. Dinicola (1990) had shown earlier that houselot density is a good measure of imperviousness



Fig. 7 Maximally packed species by site matrix for 48 bird species across 6 sampling sites

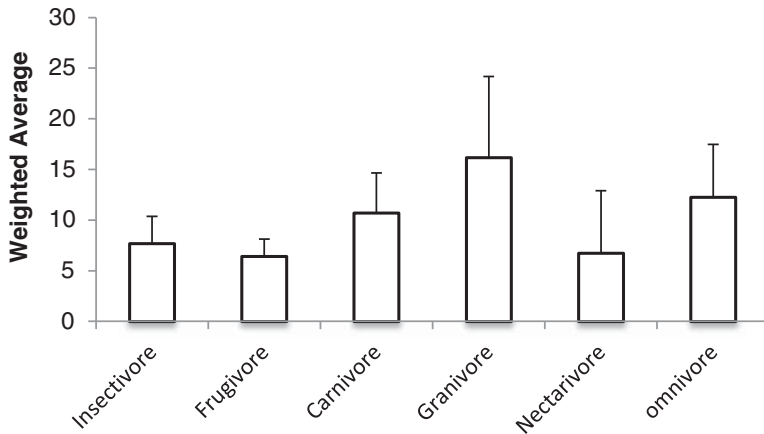


Fig. 8 Weighted averages for bird abundance

of ground substratum and can be considered as an important parameter for habitat characterization. Melles et al. (2003) had found a significant relationship between the house lot density and bird species richness.

A study along a larger scale with more habitat parameters will throw more light on the responses of bird communities to various levels of resource availability due to habitat disturbances. This study also shows the need for creating and preserving more wilderness areas around the urban nucleus. Restoration of city parks would definitely go a long way in conserving the avian community in and around the Kolkata metropolitan area.

Acknowledgements We acknowledge Arijit Chatterjee for his help during the field identifications. Ms. Rahi Soren Ritam Bhattacharya and Soumik Chatterjee helped in classifying the bird community into foraging groups. Soumik Chatterjee had also helped in data analysis and made useful comments on an earlier draft of the manuscript.

Appendix 1

Table 3 Checklist of bird species across different sites. # indicates presence of a species

COMMON NAME	SCIENTIFIC NAME	Rural 1	Rural 2	Rural 3	Urban 1	Urban 2	Urban 3
Asian palm Swift	<i>Cypsiurus balasiensis</i>	#	#	#	#	#	#
Asian Koel	<i>Eudynamis scolopacea</i>	#	#	#	#	#	#
Ashy drongo	<i>Dicrurus leucophaeus</i>		#				
Asian pied starling	<i>Sturnus contra</i>	#	#	#	#	#	#
Bank myna	<i>Acridotheres ginginianus</i>			#			
Black-crowned Night Heron	<i>Nycticorax nycticorax</i>	#	#		#		
Black drongo	<i>Dicrurus macrocercus</i>	#	#	#	#	#	#
Black Hooded Oriole	<i>Oriolus xanthornus</i>	#	#	#			
Black kite	<i>Milvus migrans</i>	#	#	#	#	#	#

Table 3 (continued)

COMMON NAME	SCIENTIFIC NAME	Rural 1	Rural 2	Rural 3	Urban 1	Urban 2	Urban 3
Black rumped flameback	<i>Dinopium benghalense</i>		#				
Blue throated barbet	<i>Megalaima asiatica</i>	#		#		#	
Cattle egret	<i>Bubulcus ibis</i>		#		#		#
Chestnut tailed Starling	<i>Sturnus malabaricus</i>	#					
Cinnamon Bittern	<i>Ixobrychus scinnamameus</i>		#				
Common Myna	<i>Acridotheres tristis</i>	#	#	#	#	#	#
Common tailorbird	<i>Orthotomus sutorius</i>	#		#	#	#	#
Coppersmith barbet	<i>Megalaima haemacephala</i>	#	#	#	#	#	#
Darter	<i>Anhinga melanogaster</i>					#	
Golden Oriole	<i>Oriolus oriolus</i>	#	#				
Greater Coucal	<i>Centropus sinensis</i>	#	#	#			
Green Bee-eater	<i>Merops orientalis</i>	#	#				
House crow	<i>Corvus splendens</i>	#	#	#	#	#	#
House sparrow	<i>Passer domesticus</i>	#	#	#	#	#	#
House swift	<i>Apus pacificus</i>			#	#	#	#
Jungle Babbler	<i>Turdoides striatus</i>	#	#		#		#
Large Billed Crow	<i>Corvus macrorhynchos</i>	#		#	#		
Little cormorant	<i>Phalacrocorax niger</i>	#	#	#	#	#	#
Little egret	<i>Egretta garzetta</i>	#	#	#	#		#
Open-billed Stork	<i>Anastomus oscitanas</i>	#			#		
Orange Headed Thrush	<i>Zoothera citrina</i>	#					
Oriental Magpie Robin	<i>Copsychus saularis</i>	#	#	#	#	#	#
Pond heron	<i>Ardeola grayii</i>	#	#	#	#	#	#
Purple sunbird	<i>Nectarinia asiatica</i>				#		#
Red-vented bulbul	<i>Pycnonotus cafer</i>	#	#	#	#	#	#
Rock pigeon	<i>Columba livia</i>	#	#	#	#	#	#
Roseringed parakeet	<i>Psittacula krameri</i>	#	#	#	#	#	#
Rufous Treepie	<i>Dendrocitta vagabunda</i>	#	#	#	#		#
Rufous woodpecker	<i>Celeus brachyurus</i>	#			#		
Shikra	<i>Accipiter badius</i>		#		#		
Spotted dove	<i>Streptopelia chinensis</i>	#	#	#	#	#	#
Spotted owl	<i>Atheni brama</i>		#		#		#
Stork Billed Kingfisher	<i>Halcyon capensis</i>	#	#		#		
Whiskered Bulbul	<i>Pycnonotus jocosus</i>		#				
White Breasted Waterhen	<i>Amaurornis phoenicurus</i>	#			#		
White Throated Kingfisher	<i>Halcyon smyrnensis</i>	#	#	#	#	#	#
White Wagtail	<i>Motacilla alba</i>	#					
Yellow footed Green pigeon	<i>Treron phoenicoptera</i>		#				

References

- Atmar W, Patterson BD (1993) The measure of order and disorder in the distribution of species in fragmented habitat. *Oecol* 96:373–382
- Austen MJW, Francis CM, Burke DM, Bradstreet MSW (2001) Landscape context and fragmentation effects on forest birds in southern Ontario. *Condor* 103:701–714
- Beissinger SR, Osborne DR (1982) Effects of urbanization on avian community organization. *Condor* 84:75–83
- Blair RB (1996) Land use and avian species diversity along an urban gradient. *Ecol Appl* 6:506–519
- Blair RB (2001a) Birds and butterflies along urban gradients in two ecoregions of the United States: is urbanization creating a homogeneous fauna? In: Lockwood JL, McKinney ML (eds) *Biotic homogenization*. Kluwer Academic/Plenum, New York, pp 33–56
- Blair RB (2001b) Creating a homogeneous avifauna. In: Marzluff JM, Bowman R, Donnelly R (eds) *Avian ecology and conservation in an urbanizing world*. Kluwer Academic, Norwell, pp 459–486
- Blair RB, Launer AE (1997) Butterfly diversity and human land use: species assemblages along an urban gradient. *Biol Conserv* 80:113–125
- Bolger DT, Scott TA, Rotenberry JT (1997) Breeding bird abundance in an urbanizing landscape in coastal southern California. *Conserv Biol* 11:406–421
- Boren JC, Engle DM, Palmer MW, Masters RE, Criner T (1999) Land use change effects on breeding bird community composition. *J Range Manag* 52:420–430
- Buckland ST, Anderson DR, Burnham KP, Laake JL, Borchers DL, Thomas L (2001) *Introduction to distance sampling*. Oxford University Press, Oxford
- Chace JF, Walsh JJ (2006) Urban effects on native avifauna: A review. *Landscape Urban Plan* 74:46–69
- Chiari C, Dinetti M, Licciardello C, Licitra G, Pautasso M (2009) Urbanization and the more individuals hypothesis. *J Anim Ecol* 79:361–371
- Crooks KR, Suarez AV, Bolger DT (2004) Avian assemblage of urbanization in a highly fragmented landscape. *Biol Conserv* 115:455–462
- Davidar P, Yoganand TRK, Ganesh T, Niraj J (1996) An assessment of common and rare forest bird species of the Andamans Islands. *Forktail* 12:135–142
- Diamond JM (1988) Urban extinction of birds. *Nature* 333:393–394
- Dinicola RS (1990) Characterization and simulation of rainfall-runoff relations for headwater basins in western King and Snohomish Counties, Washington. U.S. Geological Survey Water-Resources Investigations Report No. 89-4052 US Geological Survey Tacoma, Washington
- Emlen JT (1974) An urban bird community in Tucson, Arizona: Derivation, structure, regulation. *Condor* 76:184–197
- Er KBH (2002) *Effects of forest loss and fragmentation with urbanization on bird communities in Vancouver*. Thesis. University of British Columbia, Vancouver
- Fahrig L (2001) How much habitat is enough? *Biol Conserv* 100:65–74
- Fernandez-Juricic E (2002) Nested patterns of species distribution and winter flock occurrence of insectivorous birds in a fragmented landscape. *Ecoscience* 9:450–458
- Fraterrigo JF, Wiens JA (2005) Bird communities of the Colorado Rocky Mountains along a gradient of exurban development. *Landscape Urban Plan* 71:263–275
- Garaffa PI, Filloy J, Bellocq IM (2009) Bird community responses along urban-rural gradients: does the size of the urbanized area matter? *Landscape Urban Plan* 90:33–41
- Germaine SS, Rosenstock SS, Schweinsburg RE, Richardsson WS (1998) Relationships among breeding birds, habitat, and residential development in Greater Tucson, Arizona. *Ecol Appl* 8:680–691
- Hunter P (2007) The human impact on biological diversity. How species adapt to urban challenges sheds light on evolution and provides clues about conservation. *EMBO Rep* 8:216–218
- Jongman RH, Braak CJF, Van Tongeren OFR (1995) *Data Analysis in Community and Landscape Ecology*. Cambridge University Press, Cambridge
- Kluza DA, Griffin CR, DeGraaf RM (2000) Housing developments in rural New England: Effects on forest birds. *Anim Conserv* 3:15–26
- Kowarik I (1995) On the role of alien species in urban flora and vegetation. In: Pysek P, Prach K, Rejmanek M, Wade M (eds) *Plant invasions. General aspects and special problems*. SPB Academic Publ, Amsterdam, pp 85–103
- Lancaster RK, Rees WE (1979) Bird communities and the structure of urban habitats. *Can J Zool* 57:2358–2368
- Marzluff JM (2001) Worldwide urbanization and its effects on birds. In: Marzluff JM, Bowman R, Donnelly R (eds) *Avian ecology in an urbanizing world*. Kluwer, Norwell, pp 19–47

- Marzluff JM, Gehlbach FR, Manuwal DA (1998) Urban environments: influences on avifauna and challenges for the avian conservationist. In: Marzluff JM, Sallabanks R (eds) *Avian conservation: Research and management*. Island Press, Washington, pp 283–296
- McKinney ML (2002) Urbanization, biodiversity, and conservation. *Bioscience* 52:883–890
- Melles S, Glenn S, Martin K (2003) Urban bird diversity and landscape complexity: Species–environment associations along a multiscale habitat gradient. *Conserv Ecol* 7(1):5
- Mills GS, Dunning JB, Bates JM (1989) Effects of urbanization on breeding bird community structure in southwester desert habitats. *Condor* 91:416–428
- Mörtberg UM (2001) Resident bird species in urban forest remnants; Landscape and habitat perspectives. *Landsc Ecol* 16:193–203
- Pauchard A, Aguayo M, Pena E, Urrutia R (2006) Multiple effects of urbanization on the biodiversity of developing countries: the case of a fast-growing metropolitan area (Concepcio'n, Chile). *Biol Conserv* 127:272–281
- Platt A, Lill A (2006) Composition and conservation value of bird assemblages of urban 'habitat islands': do pedestrian traffic and landscape variables exert an influence? *Urban Ecosyst* 9:83–97
- Saab V (1999) Importance of spatial scale to habitat use by breeding birds in riparian forests: A hierarchical analysis. *Ecol Appl* 9:135–151
- Savitha S, Barve N, Davidar P (2008) Response of ants to disturbance gradients in and around Bangalore, India. *Trop Ecol* 49:235–243
- Schaefer V (1994) Urban biodiversity. In: Harding LE, McCullum E (eds) *Biodiversity in British Columbia*. Environment Canada, Canadian Wildlife Service, Vancouver, pp 307–318
- Sodhi NS, Briffett C, Kong L, Yuen B (1999) Bird use of linear areas of a tropical city: Implications for park connector design and management. *Landsc Urban Plan* 45:123–130
- Soulé DME, Bolger T, Alberts AC (1988) Reconstructed dynamics of urban habitat islands. *Conserv Biol* 2:75–91
- Tilghman NG (1987) Characteristics of urban woodlands affecting breeding bird diversity and abundance. *Landsc Urban Plan* 14:481–495
- Trzcinski MK, Lenore F, Merriam G (1999) Independent effects of forest cover and fragmentation on the distribution of forest breeding birds. *Ecol Appl* 9:586–593
- Wright DH, Reeves JH (1992) On the meaning and measurement of nestedness of species assemblages. *Oecol* 92:416–428