

Chapter 27

Integrating avian ecology into emerging paradigms in urban ecology

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Abstract: We discuss emerging paradigms in the conceptual and methodological approaches to the study of urban ecosystems. We review methods used in urban studies of avian ecology, both historically and in this book, and discuss how the results of these studies can be incorporated into these paradigms. We explore the mechanistic links between the urban environment and between different levels of biological organization, from physiology to individuals to populations to communities and we suggest future approaches to increase the applicability of urban avian ecology to understanding the functioning of cities as ecosystems. These approaches require and will benefit from interdisciplinary research and education.

1. INTRODUCTION

Few could doubt the pervasive influence of humans on virtually every ecosystem on this planet. Some ecosystems have been wholly transformed while in others the effects of humans have been more subtly expressed. The cumulative effects have been enormous and these effects are on-going and accelerating (Vitousek et al. 1997). A complete understanding of ecosystem dynamics in any of these impacted systems depends on incorporating these effects; yet the response of ecologists has been relatively slow (Collins et al. 2000). As young graduate students, we were steered away from ecological

studies in human environments with admonishments of the difficulty of interpreting our results biased by the artifacts of humans on the environment. However, these artifacts are the very effects that influence ecological pattern and process in urban environments that subsequently influence the structure and composition of bird communities. The challenge to urban avian ecologists and to urban ecologists in general is to describe the urban ecosystem and then measure the appropriate attributes that influence the patterns and processes of interest (Collins et al. 2000).

A new paradigm of urban ecology is emerging that seeks to disentangle the patterns and processes of ecosystems driven by biogeophysical phenomena from patterns of human activity driven by socioeconomic phenomena (Grimm et al. 2000). This paradigm includes a dichotomy in research approaches, described by Nancy Grimm and her colleagues (2000) as “ecology in the city”, an effort to understand how ecological patterns and processes differ in the city from less urbanized habitats or wildlands and, “ecology of the city”, an effort to understand the dynamics of these processes within the city, especially as they are influenced by human activity in its many forms. Virtually all urban avian ecological studies have taken the form of “ecology in the city” in that they contrast urban bird communities or populations with areas at different stages of development during the process of urbanization (e.g. suburban, exurban, etc., see Marzluff et al. 2001) either using temporal comparisons or simultaneous spatial comparisons along an urban-rural gradient (McDonnell et al. 1993). Obviously these two approaches to understanding urban ecosystems are complementary and studies of ecology in the city can be interpreted in the larger conceptual framework of the city as an ecosystem.

A rigorous approach to urban ecology demands rigorous methodology, including observational studies to define patterns and experimental studies to understand how and which processes regulate those patterns. Development of realistic urban models that incorporate the socio-cultural human axis will be necessary to determine how these patterns and process are driven by human values. Our perceived societal gains and losses are shaped by these values, and these gains and losses shape public policy, thus forming a feedback loop by which human-driven change can influence the biotic and abiotic environment (McDonnell and Pickett 1990). If one of the goals of urban ecology is to inform management of cities to mitigate the deleterious effects of human progress (Niemelä 1999), then the integration of these two methodological approaches is critical. Here we review the methodological framework of the more traditional “ecology in cities” approach, with specific examples from the studies in this book, but emphasize how these studies may fit into an “ecology of cities” paradigm.

2. METHODOLOGY IN URBAN AVIAN ECOLOGY AND THE INTEGRATION OF TWO URBAN PARADIGMS

Because cities are enormously complex, including a built environment and anthropogenic alterations to the biotic and abiotic environments, the first challenge is to develop metrics that reflect variation likely to influence the ecological patterns and processes under study. In part, this requires identifying specific ecological processes affected by specific urban patterns, and then selecting the appropriate metric (Niemelä 1999, Grimm et al. 2000). The studies in this book have used a wide variety of metrics, often to define an urban gradient. These have included human housing density (Bowman and Woolfenden 2001; Haskell et al. 2001; McGowan 2001), the type of built environment (i.e. single-story houses versus multi-family dwellings and the percent of green space) (Savard and Falls 2001; Jerzak 2001), and percent area vegetated (Mennechez and Clergeau 2001). Although distance from urban centers has been used as a metric in the past, because urban areas are spatially heterogeneous, this metric is not particularly useful (Alberti et al. 2001). Other metrics that might be useful include percent impervious surface area, ratios of commercial to residential development, ratios of native to non-native species, and even socioeconomic metrics such as property values. Alberti et al. (2001) proposes a series of pattern metrics designed to link urban development to ecological conditions and expands the utility of urban ecological gradient analysis. Miller et al. (2001) suggest that these metrics can be nested at a variety of spatial scales. Spatial patterns of heterogeneity require their inclusion in defining the urban landscape, but they also provide the link to the “ecology of cities” paradigm. These spatial patterns may be influenced by both the natural and the human ecosystem, such as the environment, both biotic and abiotic, in which the city occurs, the age of the city, the growth of the city, the demography of its occupants, etc. (Grimm et al. 2000). Understanding these relationships may help us predict how and why these spatial patterns exist, how they change over time and space, and how these patterns influence ecological processes, which then enter into the feedback loop of public policy through society’s perceived gains or losses.

This spatial heterogeneity of the urban ecosystem also may require its own set of metrics. Landscape ecology provides a series of metrics such as patch size and shape, patch isolation and dispersion, corridors, matrices and networks and the configuration of these elements in the landscape (Forman and Godron 1986) that may be a useful starting point for defining the urban landscape (Alberti et al. 2001). Bolger (2001) defined patches in an urban environment by size and context; the interiors of large unfragmented habitat

blocks, the edge areas of blocks adjacent to the urban matrix, and fragments embedded in the urban matrix, but relatively few other studies are explicit about landscape patterns. Coppedge et al. (2001) used a large spatial scale to examine patterns of urbanization, juniper encroachment, and changes in bird communities, but limited their analysis to a single physiographic province. Several studies attempt to address spatial heterogeneity by including multiple study sites with different urban attributes (Azzerad and Nilon 2001; Blair 2001; Clergeau et al. 2001; Mennechez and Clergeau 2001; Savard and Falls 2001). Undoubtedly, human social and economic factors play a role in the distribution of neighborhood types within cities.

Incorporating spatial heterogeneity requires large-scale and multi-scale studies (Hostetler 2001) which often have enormous logistical and economical constraints. Rarely can these studies be designed with effective replicates and controls. Without this rigorous experimental framework, the validity of inferential statistics may be questioned (Oksanen in press). Miller et al. (2001) suggest a method of nested spatial sampling that lends itself to traditional statistical tools and geostatistical methods. Methods such as canonical correspondence analysis and principal components analysis, such as used by Azzerad and Nilon (2001) and others (Jokimäki and Suhonen 1998), might be used to reduce many related variables into composites that explain variation in the dependent variables. Sometimes large-scale patterns might be reproduced at smaller-scales where confounding variables might be controlled in a more rigorous experimental design. Such microcosm experiments (Okasanen in press) may allow complex interactions in the urban environment to be simplified to test the effect of just a single variable. Incorporating spatial heterogeneity at large-scales and developing experimental designs from which causality can be induced may be one of the biggest challenges to urban avian ecology. Deductive studies that lead to experimental inductive designs may be the best approach.

To assess urban effects on birds, the impacts of urbanization on the biotic and abiotic components of the ecosystem that are likely to affect birds also must be measured. Abiotic impacts might include changes in local climate, nutrient cycling, hydrology, air and water pollution, and disturbance regimes. For example, the urban infrastructure may have profound effects on fire regimes; habitat fragmentation caused by road construction is likely to reduce the frequency and extent of fire. Simultaneously, protection of private property results in fire suppression, further altering fire regimes. Coppedge et al. (2001) examine the interactions between alterations in fire regime, vegetation community composition, and bird communities. Recovery from disturbance also is likely to be modified in the urban environment. Impacts to the biotic community are likely to influence post-disturbance recovery. The structure and composition of the native vegetation is likely to vary in

relation to human land use (Kent et al. 1999, Reichard et al. 2001) and anthropogenic alterations to this structure are likely to result in novel responses to disturbance. Interactive effects such as phenological changes resulting from local climatic shifts, may influence post-disturbance recovery, but also may affect other resources such as food. Urban effects on climate and even global climate change may alter the phenological patterns of resource abundance; birds that cannot shift their timing of breeding to coincide with peak food abundance may suffer demographic impacts (Thomas et al. 2001). Urbanization is likely to directly affect arthropods, the primary foods for many birds, especially during reproduction, yet studies of the effects of urbanization on arthropods are few and often poorly designed to elucidate the mechanism by which the distribution and abundance patterns may be affected (McIntyre 2000). Introduction of novel predators such as domestic cats may have profound affects on birds (Churcher and Lawton 1987), but the distribution of native predators also may be influenced by the urban environment. Haskell et al. (2001) examined how terrestrial predator abundance varied with human housing density and the impact that variation had on predation rates on bird nests. However, they also extended their questions to the interaction of laws designed to slow human development, property tax rates, and human attitudes about both conservation and taxation. Ineffective planning may not achieve conservation goals and reduce overall tax revenues that inevitable increase the tax burden on others. Bowman and Woolfenden (2001) examined variation in nest success across an urban gradient and concluded that patterns were a result of a complex interaction between predators and the timing of breeding, both of which were influenced by the urban environment. However, providing food for birds and letting domestic cats roam freely are both human social traits, illustrating that some demographic variation in urban bird populations may be driven as much by the human social and cultural parameters as local ecological variables.

Goldstein et al. (1980/1981) described conflicts between the desire of humans for particular structural patterns of vegetation around their homes and the needs of wildlife for a more complex structural pattern. Clearly, human values can influence the biotic and abiotic environment. These human preferences might have a historical or cultural origin (Orians 1998), but if different structural patterns favor wildlife, then understanding the human perceptual basis is necessary if the goal is to shift public behavior towards one favoring wildlife rather than people.

3. MECHANISTIC LINKS IN ECOLOGICAL ORGANIZATION

Although the changes in bird community structure and composition in response to urbanization seem to be consistent enough to make broad generalizations (Blair 2001, Marzluff 2001), relatively few studies have examined the response of birds at underlying levels of biological organization, such as populations and individuals. These levels are often hierarchical; effects on individuals may often be manifested through changes in survival and/or fecundity, which in turn effect demographic patterns and population trajectories. Species-specific responses then alter community structure through additional complex interactions such as changes in competitive interactions. Yet growing evidence exists that urbanization does have impacts at all levels of organization. Lead from car exhaust may lower hemoglobin concentration in urban populations of Tree Sparrows (*Passer montanus*) (Kostelecka-Myrcha et al. 1997). Access to protein and lipid-rich anthropogenic foods results in higher levels of plasma cholesterol and blood urea nitrogen in urban House Sparrows (*P. domesticus*) (Gavett and Wakely 1986). Schoech and Bowman (2001) attempted to relate phenological differences in the timing of breeding between suburban and wildland populations of Florida Scrub-Jays (*Aphelocoma coerulescens*) by examining blood constituents. A vast suite of physiological indices, such as blood characteristics, nutritional condition, and growth rates could be influenced by the urban environment that might affect demographic patterns. In addition, the behavior of birds might be directly and indirectly affected. Human disturbance can influence time and activity patterns of birds and this may vary depending on the urban context, as shown by Fernández-Juricic et al. (2001) Time and energy budgets, dominance hierarchies, and interspecific interactions are all likely to be influenced in an urban environment.

Developing mechanistic links between individual and population level patterns requires detailed studies of demography, ideally longitudinal comparisons of marked populations across an urban gradient. Bowman and Woolfenden (2001), Marzluff et al. (2001), and McGowan (2001) use such studies to examine how urbanization influences demography and how these demographic patterns may affect community structure. In contrast, Bolger (2001) compares top-down and bottom-up regulation of population processes and how these may vary depending on urban context. Changes in both regulatory processes and demographic patterns themselves can alter population structure and life history parameters such as age at first breeding. Urban populations of Florida Scrub-Jays have higher adult mortality rates, but lower age of first reproduction (Breininger 1999) and fewer young

remain as helpers on their natal territory. In part, this may reduce the resilience of the population to stochastic demographic variation.

Changes in the urban landscape also are likely to have large-scale effects on dispersal and immigration and emigration rates. These alterations are likely to have effects beyond the scale of individual populations, impacting metapopulation dynamics and regional patterns of genetic diversity. Relatively few studies have addresses such issues. Urban populations of Florida Scrub-Jays disperse farther than those in wildlands and the movement patterns are unidirectional; jays move from suburbs to wildlands, but not vice versa (Thaxton and Hingtgen 1996), but is difficult to determine if this is an effect of the urban environment or habitat fragmentation or an interaction between both. Alterations in dispersal patterns and changes in population size and structure could lead to changes in genetic diversity and the loss of local adaptations. However, the urban environment may have more direct effects on genetic patterns. Exposure to anthropogenic toxins may increase rates of heritable mutation (Yauk and Quinn 1996). Indeed, rapid changes in avian population and community structure with urbanization and the concomitant changes in niche space may result in rapid evolution of urban avifaunas (Diamond 1986, Johnston 2001).

Developing mechanistic links between population and community level patterns requires understanding the demographic trends and underlying mechanisms for a large variety of species. The links between the environment, demography, and community structure may be expressed in community measures seldom examined in urban avian ecological studies. Although community measures such as density, species richness and evenness are relatively common, measures such as resource partitioning, guild representation and trophic relations are relatively rare. Blair (2001) demonstrates a process where urban avifaunas in different regions may converge through processes of local extinction and local invasion, providing the best example of how population-level processes can influence community structure.

4. CONCLUSIONS

The research approach outlined here and evident in the body of urban bird literature is clearly that of the ecology of birds in cities. A rigorous ecological and experimental approach to understanding avian ecology in an urban context, such as that outlined by Bolger (2001), is necessary to understand how process influences patterns, but we have largely ignored how human values influence these processes. If humans are part of their environment rather than separate and distinct from it, then our social and

cultural values must be shaped and, in turn, shape the environment. Understanding that feedback loop and how human values influence variation in urban patterns and processes is necessary to ultimately manage the urban environment to improve the quality of life for birds and for humans. Only by understanding the ecology of cities and integrating the vast patterns of human activities into the conceptual framework can we hope to develop urban environments that lessen their ecological footprint (Wackernagel and Rees 1996; Collins et al. 2000) and reduce their impact on avian biodiversity. Studies of the ecology in cities are fine, but we also need to be able to integrate our finding into the larger conceptual framework of the ecology of cities.

Understanding the ecology of cities will require broad interdisciplinary partnerships. Avian ecologists will increase the applicability and relevance of their research by working with urban planners, landscape architects, geographers, and policy scientists. Productive teams also will need a diversity of social scientists, economists, and demographers to better understand the socio-economic and psychological drivers of human decisions that shape urban patterns. Integrated, interdisciplinary research on urban ecosystems is challenging, but possible and productive as evidenced by recent NSF LTER sites in the urban settings of Phoenix, Arizona and Baltimore, Maryland.

Sustaining interdisciplinary research teams requires novel graduate education programs. Students from the natural and social sciences need to be immersed in interdisciplinary teamwork, including team-authored graduate theses. Programs at the University of Washington and Arizona State University are training urban ecologists using these methods with success. The result will be a new generation of graduate students that seek the challenges of teamwork in urban ecosystems, rather than steer away from ecological studies in urbanizing settings.

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