Chapter 1

A historical perspective on urban bird research: trends, terms, and approaches

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Abstract: As Earth's human population continues to increase and urbanize, it is likely to increasingly affect biodiversity. Avian ecologists have been studying these effects for over a century. Here, we review these studies to: 1) characterize the type of research approaches that have been used, 2) suggest strengths and weaknesses of these approaches, 3) offer a standardized nomenclature for the degree of settlement that will be used throughout this volume, and 4) suggest how our approach can be strengthened to better inform public policy. The majority of urban bird studies were conducted since 1980. The typical study is a one- or two-year correlational investigation of breeding bird relative abundance in the forests of the United States or northern Europe. Experimental studies are rare despite the frequent and replicated land transformations conducted by developers. Studies of birds in tropical, urban settings are especially rare. This is problematic because human populations are expected to rapidly grow and urbanize in such regions and biodiversity there is rich. Recognizing trade-offs among study duration, spatial extent, and mechanistic understanding, we suggest that researchers use short-term, correlational studies of the entire gradient of urbanization to inform long-term, mechanistic studies of bird populations. We define five points along the gradient of urbanization for consistent use throughout this volume (wildland, exurban or rural, suburban, and urban; Table 1.1). These are useful for categorizing study areas at the landscape scale (>1km^2). Briefly, wildlands are unsettled lands that may occasionally include dwellings. Rural and exurban

lands are sparsely settled by individual homesteads, recreational development, and small towns (they are distinguished by the surrounding matrix: rural = agricultural, exurban = native habitat). Suburban lands are characterized by moderate- to high-density, single-family housing with lot sizes of 0.1-1.0 ha. Urban lands are primarily covered by multi-family and/or multi-storied buildings. Urban bird studies would more effectively inform policy, planning, and management if they were more relevant, rigorous, compelling, and visible. We suggest that this can be accomplished by 1) understanding how development pattern affects birds, 2) increasing study of birds in tropical urban areas, 3) increasing the use of experimental, mechanistic investigations, 4) using landscape ecological metrics to quantify the urban settings we study, and 5) distilling clear graphs or photographs of important results.

1. INTRODUCTION

Human populations continue to grow and dominate ecosystems around the world (Horiuchi 1992; Vitousek et al. 1997). Wild portions of Earth are urbanizing and humans are increasingly on the move in many parts of the world, shifting from rural regions to burgeoning urban centers. As a result, the world's urban population multiplied tenfold last century. The United Nations estimates that by 2050, the global urban population will equal today's total population (~6.5 billion; United Nations 1996). Most urban growth is occurring in developing countries, where human populations are increasing at exponential rates (Fig. 1.1; WRI 1996). By 2025 the urban population in developing countries will reach 4 billion (3x the expected urban population of developed countries; United Nations 1996). In those countries urban growth will occur so rapidly that it will strain the ability of local governments to provide adequate housing, infrastructure, sanitation, public safety and other essential services. The result will be an increased human impact on ecosystems.

In the developed world, however, a greater proportion of the land is urbanized and populations are moving away from traditional city centers. Emigrants tend to redistribute themselves in a suburban or exurban pattern, causing cities to grow in area much faster than in population and resulting in strong gradients of human density. These gradients of urbanization become increasingly complex and multi-modal as suburbs take on increasingly urban characteristics (Alberti et al. 2001). These processes, collectively known as urbanization, had a staggering effect on native flora and fauna. Urbanization is likely to be the single most important driver of extinction during this century. Already, urbanization is the second most frequently cited cause of species endangerment in the United States (Czech and Krausman 1997).

This book aims to document and discuss the effects of human settlement on birds. To put this current discussion into perspective, we have reviewed

the published literature on the effects of urbanization on birds. In this chapter, we use this review to: 1) characterize the type of research approaches that have been used, 2) suggest strengths and weaknesses of these approaches, 3) offer a standardized nomenclature for different levels of human settlement along the urban gradient that will be used throughout this volume, and 4) suggest how ecological research on birds along this can be strengthened to better inform public policy.

2. METHODS

We reviewed the modern literature (1900-2000) using electronic databases and manual search. The databases *Biosis, Wildlife Worldwide, and Current Contents* were queried using *urban, birds, human effects on birds, fragmentation, settlement, suburbs, and development* as key words. The literature cited section of each article found by electronic search was reviewed for additional published works on birds in urbanized settings. In total, we found 101 articles that reported new empirical research on birds and urbanization. We excluded review and theoretical articles.

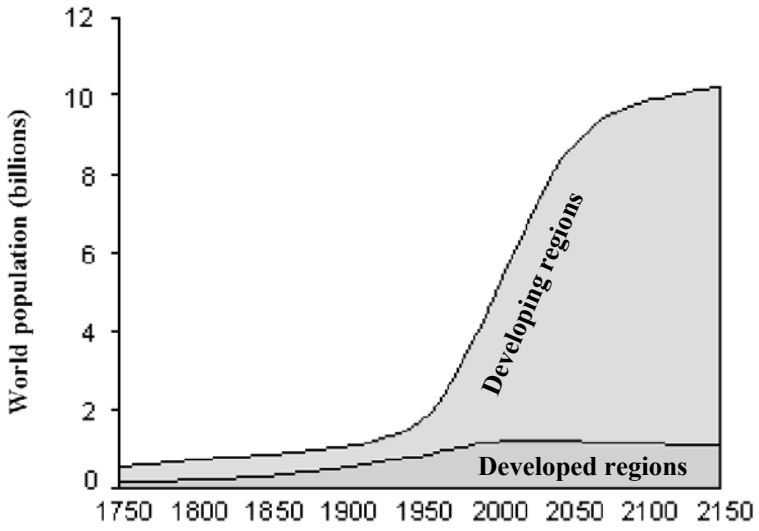

Figure 1.1. Past and projected growth of human populations in developed and developing regions of Earth compiled by the World Resources Institute (WRI 1996). Growth is expected to increase most dramatically in developing regions.

3. RESULTS AND DISCUSSION OF LITERATURE REVIEW

The study of urban effects on birds has increased steadily (Fig. 1.2) since Pitelka (1942) characterized how the coastal avifauna of California responded to suburbanization and recreational development. Nearly 75% of the studies we reviewed were conducted during the last 20 years.

The typical study of the impact of urbanization on birds is one- or two-year (Fig. 1.3) correlational investigation of the relative abundance of breeding birds in the forests of the United States or northern Europe (Fig. 1.4). Most studies of urbanization (63%) simultaneously compared avifaunas at two to four points along a portion of the gradient from urban areas to wildlands. Rarely (8%) the study areas spanned the entire gradient. Often (29%), only one point on the gradient was studied. Longer-term studies were not uncommon; 39% of studies lasted >5 years and four (Batten 1972, Walcott 1974, Bezzel 1985, and Luniak and Mulsow 1988) documented avifaunal change at a site that became increasingly urbanized over more than a century. These long-term studies often employed a time

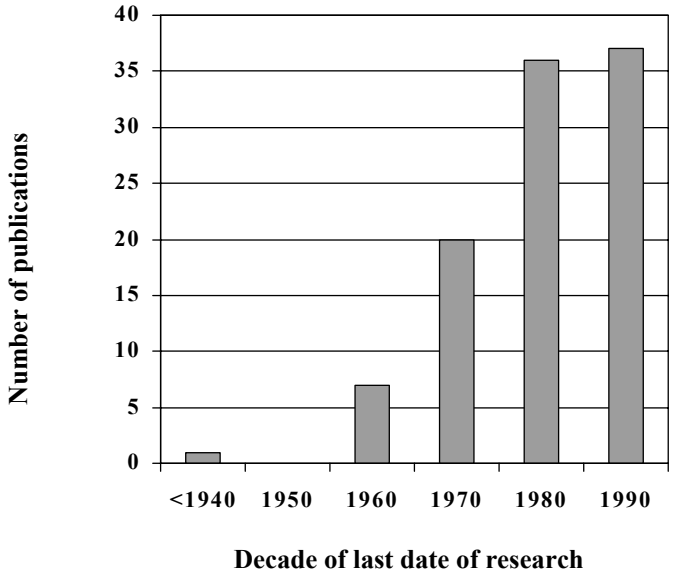

Figure 1.2. Occurrence of published studies (n = 101) on urban effects on birds during the past 60 years. Numbers of studies that conducted research in each decade is plotted.

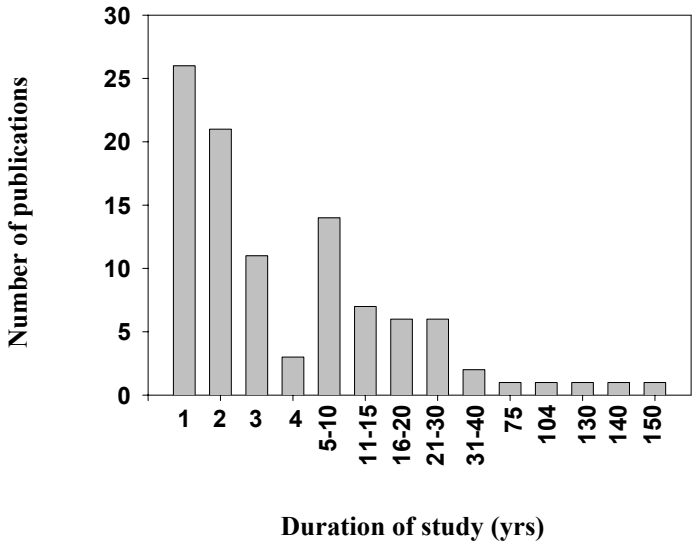

Figure 1.3. Duration (years) of 101 studies on the effects of urban development on birds.

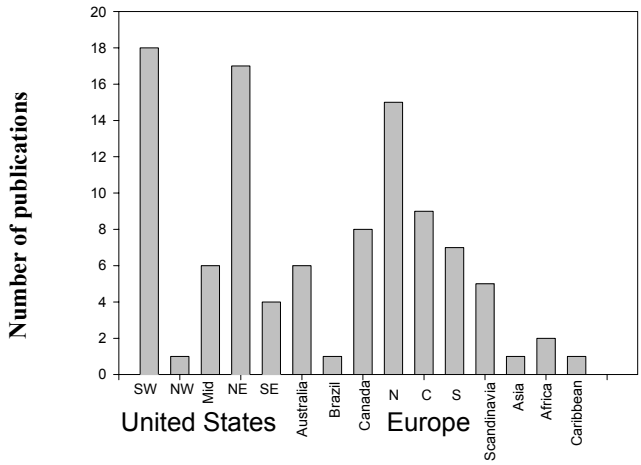

Figure 1.4. Locations where 101 studies of the effects of urbanization on birds were conducted. N Europe = Germany, Poland, Russia, and Switzerland. C Europe = Estonia and the United Kingdom. S Europe = Spain and Italy. The two African studies were conducted in South Africa. The Caribbean study was done on Trinidad.

series method of analysis and hence could be considered quasi-experimental. However, only five studies used a true experimental approach with replicates and controls. These five were all investigations of predation rates using experimental nests deployed at varying distances from human settlement. Despite the rapid pace of urbanization, its proximity to major research institutions, and its obvious effects on ecosystems, we found no studies that used actual human settlement patterns as replicated factors in a controlled, experimental study.

The preponderance of one- and two-year studies is not surprising given the usual tenure of funds and graduate students, but the occurrence of truly long-term studies is notable. Ecological studies in general (Kareiva and Anderson 1989), and studies of birds in particular (Marzluff and Sallabanks 1998) are of notoriously short duration. Yet long-term records of birds in areas settled by humans have allowed us to relate avian community composition to increasing human settlement over decades and even centuries. The study of Blackbirds (*Turdus merula*) over a period of 150 years by Luniak and Mulsow (1988) is especially notable, because they documented increasing density of Blackbirds in response to urbanization and identified increased fecundity and survival as the mechanisms for the density increase.

Our inferences about the response of birds to urbanization may be based on solid temporal studies, but this literature is woefully limited to breeding birds of temperate, upland forests. Over 60% of the studies (n = 65) were conducted only during the breeding season and over 70% were conducted in temperate forests (n = 71). Studies of other ecoregions do exist, but in small numbers. We found 10 studies of shrublands, that while modest in size, were distributed across a broad geographical area (America, Europe, Australia, and South Africa). Five or fewer studies were conducted in each of the following ecoregions: aquatic (n = 2), coastal or island (n = 4), desert (n = 3), grassland (n = 5), and riparian forest (n = 5).

Studies of birds in tropical urban settings are especially lacking. We found only six such studies. Two were from the neotropics (Caribbean: Fonaroff 1974; Brazil: Ruszczyk et al. 1987) and four were from the Australian tropics (Jones 1981, Green et al. 1989, Munyenyembe et al. 1989, Kentish et al. 1995). Given the expected increase in human populations and urbanization in the tropics (Fig. 1.1) and the rich biodiversity that characterizes this region, more studies are desperately needed to inform public policy so that the negative consequences of human development are mitigated.

Most studies of the effects of urbanization on bird community structure and composition have quantified the relative abundance of each species (Fig. 1.5). These studies are essential to understanding how community structure

and composition change with urbanization, but they provide limited, and potentially misleading, information about the mechanisms that drive community changes with increasing urbanization. Such studies cannot distinguish among source, stable, and sink populations (Pulliam 1988) which is essential to understand if we are to manage birds effectively (Van Horne 1983). They do not inform us about the relative movement patterns of individuals along the urban gradient or about the potential metapopulation structure that may exist among populations along that gradient. Nor do they inform us about the ecological changes along that gradient and how these changes influence demographic patterns. Therefore, to improve our understanding of how birds respond to urbanization we need community-level studies, but we also need studies examining demography, including fecundity and survivorship and studies examining population dynamics, including immigration and emigration, at a variety of spatial scales. This requires long-term studies that focus on populations and demography rather than entire communities. Such studies are not uncommon in urbanizing environments. Thirty-seven percent (n = 37) of studies focused on populations, 19 measured annual breeding success, and 12 measured

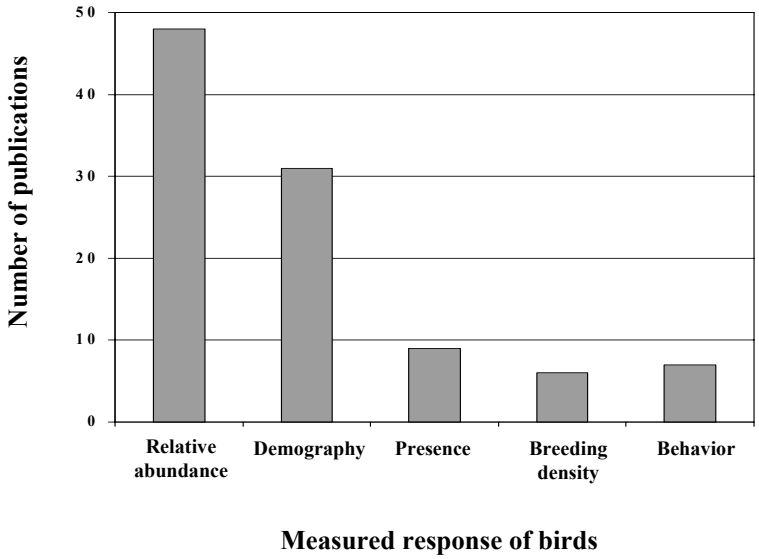

Figure 1.5. Measured responses of birds to urbanization in the published (n = 101 articles) literature. Demography includes 19 studies of annual breeding success and 12 studies of fecundity or survivorship. Presence documents studies that recorded presence or absence of a particular species. Behavior includes 4 studies of diet, 1 of time budget, and 2 of other behaviors.

fecundity and survivorship. Sixteen studies discussed the source-sink structure of populations in urbanizing environments. However, few of these studies examined emigration or immigration rates and none examined the large scale structuring of populations along an urban gradient.

Urban bird studies are distinctly population- (n = 37) OR community-level (n = 64) investigations. We found no studies that explicitly discussed the connection between population-level dynamics and community structuring. Yet, a full understanding of ecological communities requires understanding of individual, population, and higher order biotic effects, as well as abiotic effects (Wiens 1989, Marzluff and Ewing 2001, Bolger 2001).

In accord with the large spatial extent of urbanization, urban bird studies often (n = 42 studies) related landscape features to urban bird communities and populations. However, measures of urban landscape features are crude or nonexistent (Fig. 1.6). Forty percent (n = 41) of the studies we reviewed did not quantify the urban setting in which their study occurred! Those that did quantify the degree of urbanization used relatively simple measures such as the percentage of the landscape that was urban or the density of houses surrounding the study area (n = 38). Distance to human settlement was used to quantify urban landscapes in five studies. Sophisticated measurement of urban patterns using typical landscape ecology metrics, as proposed by Alberti et al. (2001), has not been utilized in past avian studies. Likewise, multi-scale analyses that recognize the varying spatial sensitivity of individuals and populations as recommended by Hostetler (2001) are lacking.

Our review suggests that studies of birds in urbanizing landscapes must often make tradeoffs among increasing duration, increasing spatial resolution, and increasing mechanistic understanding. Understanding the mechanisms of population responses to urbanization does not appear to reduce a study's duration. On average, population-level studies lasted 12.7 years (SE = 4.0; n = 37) and community-level studies lasted 12.0 years (SE = 3.5; n = 64). However, mechanistic understanding appears to carry a cost of reducing spatial extent of study (Fig. 1.7). Studies that included landscapes ranging from urban or suburban to wildlands were twice as likely to employ a community-level approach, than a population-level approach (Fig. 1.7). Some community-level studies also were done at only a single point along the gradient. Increasing spatial extent appears to reduce study duration. The average duration of studies conducted at one point on the gradient was 12.8 years (SE = 5.1, n = 29). In contrast, studies spanning the entire urban to wildland gradient lasted an average of 10.9 years (SE = 4.3, n = 8). Studies spanning intermediate portions of the gradient lasted 12.1 years (SE = 4.3, n = 64).

What are the advantages and disadvantages of trading spatial extent for mechanistic understanding and study longevity? Short duration, community-level studies at many points along a gradient of urbanization can reveal patterns of community assembly quickly and relatively cheaply. However, such patterns will remain unexplained until longer-term, population-level studies are done. Therefore, a prudent study of birds in urbanizing environments would first conduct a short-term (perhaps even only a single year) correlational study designed to document the presence or absence of species along the full extent of the gradient. This study would simply be used to inform future long-term, population-level studies with hypotheses suggesting what points along the gradient affect birds differently and what species are most responsive to urbanization. Populations of responsive species could then be studied at points along the gradient where they should differ in demography and/or density. These latter studies would be designed to reveal mechanisms responsible for bird changes and amenable to policy adjustment (Marzluff et al. 2000).

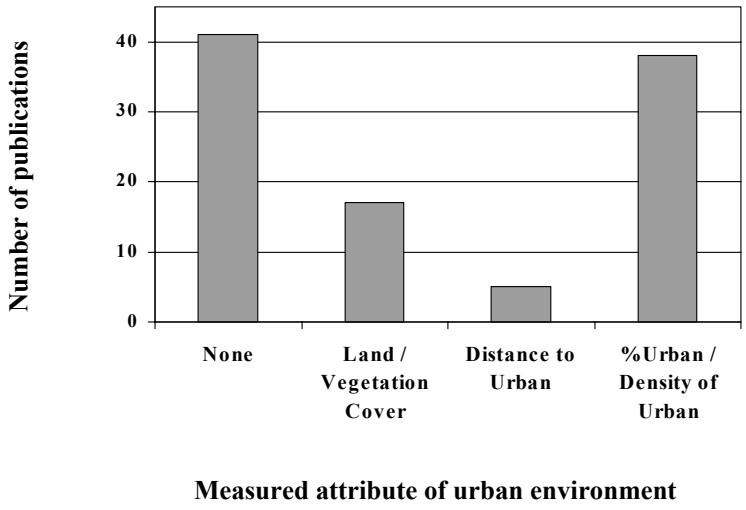

Figure 1.6. Measured attributes of the urban environments where birds studies (n = 101 articles) were conducted. Often no attributes of the environment are quantified (none).

4. STANDARDIZING TERMS

In our view, urbanization is the process of human settlement that gradually transforms uninhabited wildlands into lands including some degree of relatively permanent human presence. It is a continuous process that produces a range of settlement densities and patterns from widely spaced agricultural and recreational homesteads to the concrete and steel heart of a large metropolitan area. For a variety of social, economic, political, behavioral, and temporal reasons, much of this range in settlement patterns can often be found in proximity to large cities around the world (Alberti et al. 2001, Marzluff 2001). This range in settlement density and pattern is often referred to collectively as a gradient of urbanization (McDonnell et al. 1993) in recognition of its continuous, as opposed to discrete, nature. Certainly urbanization is continuous, even if complexly multinuclear with

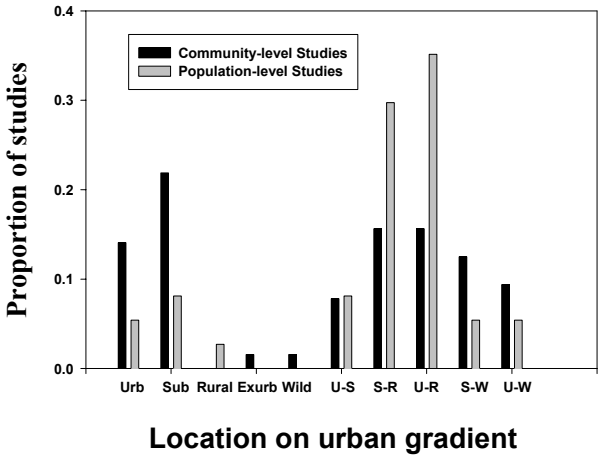

Figure 1.7. The proportion of studies reviewed (n = 101) that were conducted at single (Urb, Sub, Rural, Exurb, Wild) versus multiple (all other bars) points along the gradient of urbanization. Only the bar to the extreme right hand side of the graph (U-W) represents studies along the entire gradient of urban to wildland settings. Proportions are calculated separately for community- and population-level studies to emphasize tradeoffs in mechanistic understanding and spatial extent. Abbreviations are as follows (Urb=urban; Sub=suburban; Rural=rural; Exurb=exurban; Wild=wildland; U-S=sites in urban and suburban areas; S-R=sites in suburban and rural; U-R-sites in at least 2 locales spanning urban to rural areas; S-W=sites in at least 2 locales spanning suburban to wildland areas; U-W-sites in at least 2 locales spanning urban to wildland areas.

respect to distance from a city center (Alberti et al. 2001). However, researchers often characterize their study areas with discrete terms that describe their position along this continuum. To this end, a variety of terms have been used in the published urban ecology literature (e.g., *wildland, hinterland, greenbelt, rural, countryside, rurban, outskirts, exurban, extraurban, urban fringe, suburban, dwelling quarters, residential area, periurban, urban, city center*). The diverse terminology is especially confusing because terms often have different regional and cultural meanings. For example, to some "rural" means a relatively wild area far from humans (Yaukey 1996); to others this is the "extra-urban" (Plesník 1990), "rurban" (Hohtola 1978), "hinterland" (Fonaroff 1974), "outskirts" (Lo Valvo et al. 1985), or "greenbelt" (Erz 1966), because "rural" implies some degree of pastoralism (Nuorteva 1971).

To avoid confusion created by diverse, colloquial terminology we have defined a few, often studied points along the urban gradient (Table 1.1). Use of these terms is convenient for the author and reader, but even these terms are relatively broad and can still describe a range of human settlement patterns. Therefore, many of the studies included here report quantitative measures describing the urban characteristics most relevant to the particular study. Measures such as housing density, human density, and percentage of undeveloped land are useful. Additionally, because such measures are scale-dependent, the extent of the classified area must be defined. For most of these studies, we have included a large-scale aerial image of the study area and surrounding landscape.

We use five terms to describe the landscape of settlement (Table 1.1). In order of increasing settlement they are: wildland, rural or exurban, suburban, and urban. Building density and the proportion of built area increases monotonically in this terminology. However, resident human density is not necessarily greater in urban than suburban areas because urban areas often

Table 1.1. Standardized terms that describe major points along the gradient of urbanization. These terms are most meaningful at relatively large (>1km^2), landscape scales. Other attributes of each class and suggestions for subdividing classes are provided in the text. Residential human density refers to the density of humans occupying living quarters (dwellings) in the area.

Term	Percent built	Building density	Residential human density
Wildland	0-2	0	<1 / ha
Rural / exurban	5-20	<2.5 / ha	1-10 / ha
Suburban	30-50	2.5-10 / ha	>10 / ha
Urban	>50	> 10 / ha	>10 / ha

include large amounts of industrial or commercial development characterized by low resident human, but high building density. In general, ***wildlands*** are unsettled lands that may occasionally (especially at large scales) include dwellings. ***Rural and exurban lands*** are sparsely settled by individual homesteads, recreational developments, small towns, and villages. Unsettled land is much more abundant than settled land, but the actual pattern of settlement can vary widely (see below). Rural lands are distinguished from exurban lands by the matrix surrounding settlement. Settlements in Exurban areas are surrounded by a natural matrix; settlements in rural areas are surrounded by an agricultural matrix. ***Suburban lands*** are characterized by moderate- to high-density, single-family housing with lot sizes of 0.1 to 1.0 ha. Lawns and gardens are common. Basic services, light industry, and multi-family housing are interspersed with the typical single-family dwellings. Most buildings are single- or double-storied. ***Urban lands*** are areas where the majority of the land is covered by buildings. Building density is high and many buildings are for commerce, service, or industry. Single-family homes are rare and typically densely packed with little garden or lawn space. Multi-family housing and multi-storied buildings characterize urban areas.

The continuous nature of the urban gradient dictates that each of our discrete categories can be infinitely subdivided. Rural and exurban settlement could profitably be categorized based on a combination of landscape metrics such as contagion, interspersion, or patch size. As a starting point, Nilon et al. (1995) classified exurban lands as "dispersed" if lots were ≥1 ha or "clustered" if they were <1 ha. Suburban lands could be classified based on development age and retention of original vegetation. For example, Guthrie (1974) distinguished new, mature, and old suburbs based on their age (1, 25, and 75 years, respectively) and DeGraaf and Wentworth (1986) distinguished 15-year-old subdivisions in native forest from those initiated on denuded areas. Within suburban and urban landscapes, classifications might also include characterization of land use, such as single-family dwelling, multi-family dwelling, industrial, commercial, parkland, woodland, garden, etc. (Blair 2001, Mirabella et al. 1996, Lancaster and Rees 1979).

Descriptive classifications, such as the wildland to urban terminology described above, and quantitative measures of urban characteristics may differ in scale. The urban to wildland scale (Table 1.1), the complete urban gradient, is a landscape scale and is often broader than many urban ecological studies, which may be conducted in just a small portion of the overall gradient. Quantitative measures of urban characteristics within a study area describe a more local scale. Typically we consider areas of 1 to many km^2 when we characterize study areas into these categories. The finer

subdivision various authors use to describe their actual point of data collection is usually at a local plot scale that is <1 km^2. At this scale land use can be consistent and categorized as suggested above. It would reduce confusion and perhaps more accurately describe areas of study if these differing scales were considered before characterization. Throughout this volume, we have consistently used the coarse, landscape-scale classification scheme (Table 1.1). We urge others to do likewise and to provide quantitative measures of the urban characteristics in their study area so that we might improve our knowledge of animal ecology in urban landscapes.

5. POLICY AND MANAGEMENT IMPLICATIONS

Science is but one of many sources of information that urban planners, managers, and policy makers use in their decision making process. The decisions they make will determine in large part how much and what type of biological diversity survives in the face of a growing and increasingly urban human population. Much of the current urban planning and policy-making process concerns the impacts of urbanization on human society, rather than on biodiversity. For biodiversity to become a major consideration in the planning and implementation process, the available science must be relevant, rigorous, compelling, and visible. Our review of the literature suggests that we can improve in each of these areas.

Urban ecological research is relevant if it explicitly compares biodiversity and ecological and biotic patterns that contribute to biodiversity at a variety of spatial and temporal scales, including the range of human settlement patterns. Population growth, urbanization, and suburbanization are inevitable for the foreseeable future. Therefore, our research should serve to direct inevitable development so that threats to biodiversity are minimized.

To effectively direct development from a biological conservation perspective, we need to understand: 1) where development will have the least effect on organisms, 2) how biodiversity responds to settlement density, and 3) if certain patterns of settlement minimize expected effects of density. Our review suggests that, for birds, we have addressed (2); avian diversity is routinely compared at various points along a gradient of urbanization. However, we have not explicitly considered (1). Are there certain areas within urbanizing landscapes where development would be especially damaging to birds? We could make educated guesses based on general relationships between habitat features and bird species diversity, but this needs more explicit consideration. We have rarely addressed (3). Nilon et al. (1995) compared the relative abundance of bird species to dispersed and

clustered recreational development, but such study is sorely needed in rapidly urbanizing areas, especially at the urban/suburban and the suburban/exurban or suburban/rural interfaces. Developments with similar human densities, but different patterns of settlement may have different ecological impacts; thus policy might be crafted to favor urban development with ecologically benign settlement patterns. The relevance of urban avian ecology and of urban ecology in general to the urban planning process can be increased by identifying those processes or patterns that have important implications to both humans and to biodiversity. In addition, focusing research on those areas where relatively little is known, but predictably large impacts of future urbanization are likely to occur, will make data relevant to future planning decisions. Developing, tropical countries have the largest human growth rates, most of the Earth's biodiversity, and rapid expected rates of urbanization, yet studies of the impacts of urbanization in the tropics are exceedingly rare. Current investigations are just beginning address the complex effects of human settlement in the tropics (Brooks and Begazo 2001), but future research should address all three areas of investigation mentioned previously.

Only rigorous science is likely to produce well-informed, effective public policy. In addition to the surveys and correlational investigations that typify past studies of urban avian ecology, we need to incorporate the combination of observational and experimental studies common to more traditional ecological investigations (see Bolger 2001). These studies can identify mechanisms and causal relationships underlying patterns identified in the former studies (Marzluff and Sallabanks 1998, Marzluff et al. 2000, Bolger 2001). Past studies rarely connect population-level mechanisms (reproduction, survivorship, dispersal) to community-level patterns. Nor have most studies searched for ecological correlates to population patterns and experimental research will be needed to establish cause and effect. The lack of experimental studies in urbanizing areas is puzzling. Developers conduct large-scale, replicated land transformations on a regular basis in urbanizing areas. We could learn much about the causal link between urbanization and diversity by comparing population and community measures among, before, and after such disturbances. Increasing the rigor with which we quantify urban landscapes also will strengthen our science. Past studies often only subjectively categorize their study areas. Alberti et al. (2001) and Hostetler (2001) provide examples and advice for quantifying the urban environment.

A challenge facing scientists working on urban ecology issues is how to make their complex, and to some degree uncertain, science accessible to policy makers. Meeting with planners, managers, and policy makers is critical, as is joint development of research goals and publishing in non-

traditional outlets (Kochert and Collopy 1998; Young and Varland 1998). Tailoring the format of results to a more diverse audience is also important. For example, maps or photographs that communicate the association of land cover with avian population viability would be especially compelling to planners, managers, and policy makers. Such summaries are not to be overly simplified or gross extrapolations. Rather, they should be distillations based on our rigorous studies that have been peer reviewed and published.

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