

10

Comparative studies of terrestrial vertebrates in urban areas

CHARLES NILON

Introduction

Comparative studies of terrestrial vertebrates are one approach that can be used by researchers to build on the extensive work done by animal ecologists and applied ecologists in cities (Luniak, 1990; VanDruff *et al.*, 1994; Nilon and Pais, 1997). Much of this work pre-dates the renewed interest in cities by mainstream ecologists. The new emphasis on the ecology of cities provides new tools and approaches to conducting comparative studies that will be useful in answering questions about vertebrates in cities. In this chapter I will discuss why comparative studies of vertebrates are important to ecologists, managers and people who live in cities by reviewing the comparative studies that have been done on the vertebrate fauna of cities. I will describe some of the research on vertebrates that occur within the framework of urban ecosystems research, and I will propose a comparative study that illustrates how contemporary approaches to urban ecology can be applied to a conservation issue.

Comparative studies ask and answer questions about the ecology of cities

The need for comparative studies comes from a need to answer questions about animals in cities. The questions are shaped by different groups (i.e. scientists, the public, resource managers, policy makers and conservationists)

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that care about animals in cities. Traditional ecologists studying cities ask questions about ecosystem structure and function. Ecologists working on the Baltimore Ecosystem Study, funded by the US National Science Foundation, consider terrestrial vertebrates as part of the question, 'How does the spatial structure of ecological, physical, and socioeconomic factors in the metropolis affect ecosystem function?' (Pickett *et al.*, Chapter 3.) This question is framed by the goals of understanding how urban ecosystems work and testing models about human ecosystems.

Residents of cities have their own understanding of important questions about vertebrates that is shaped by individual experience and by socially constructed views of nature and animals. Their questions might include, 'I've seen some dead birds on my street: does this mean we are at risk for West Nile virus?', 'Will cleaning up the vacant lots in our neighbourhood get rid of rats?', or, 'I really enjoy the birds in the patch of woods near my house. Will the new housing estate hurt them?'

Conservation and management questions are at the interface between questions raised by ecologists studying cities and urban residents. Management questions are shaped by the two sometimes conflicting goals for wildlife conservation in cities: to maintain regional biodiversity, and to provide opportunities for urban residents to have day-to-day contact with wildlife (Tylka *et al.*, 1987). These goals lead to multiple questions: 'Are these small forest patches sources or sinks for small mammals?', 'How is bird species richness influenced by garden management decisions and practices?', or 'How do government policies on brownfield development impact biodiversity at a local scale?' The rest of this chapter will consider how comparative studies can address management questions about vertebrates in cities.

Approaches used in comparative studies: developing a framework for comparisons among cities

Earlier comparative studies of vertebrates have focused on the distribution of species among cities. These studies have considered not only the distribution of cities but questions about kinds of cities where species occur and places within cities where species occur, an approach to comparison that requires an objective way of describing and grouping cities and areas within cities. Ecological, social and economic factors influence both the location of cities and how those cities grow and change over time. The same factors shape the physical structure and layout of cities and shape their physical environment and ecological characteristics (Bridgman *et al.*, 1995). Applied ecologists have used classifications based on ecological characteristics and on urban form to group cities for comparison.

Luniak *et al.* (1990) classified cities in central and eastern Europe based on their ecological setting: vegetation zone and presence/absence of sea coast or big rivers. Harris and Raynor (1986) classified British cities using a scheme developed by urban geographers to group cities with similar development histories (Moser and Scott, 1961). Sanders (1984) classified metropolitan areas in the United States using a system that combined potential natural vegetation (Kuchler, 1964) and period of maximum urban growth (Borchert, 1967).

Although most studies of vertebrates in cities have focused on remnant habitats, there is a growing recognition that a wide range of habitats exists in cities, and the need to identify these habitat types is an important step in comparative studies (McDonnell and Hahs, Chapter 5). Ecologists and managers need a way to define types of habitats or patch types within cities. In the United States this classification has often been based on land-use cover (Anderson *et al.*, 1976). Recent studies on the distribution of urban bird species illustrate how land use and land cover have been used as a surrogate for habitat or patch type (Hadidian *et al.*, 1997; Turner, 2003).

The recognition that land-use classifications may not accurately account for the heterogeneity of habitats in cities has led to efforts to classify cover types found in cities. Brady *et al.* (1979) developed a 'typology of the urban ecosystem' that defined different biotic zones in cities and linked land use and land cover. Matthews *et al.* (1988) used a protocol based on the US National Wetlands Inventory that combined 26 land-use categories and 31 land-cover categories to classify and compare seven cities in New York State.

Since the 1980s, biotope mapping approaches have been developed that use a hierarchical approach to habitat classification (Werner, 1999). These approaches have been developed to link habitat classification both to planning decisions (Freeman and Buck, 2003; Shaw *et al.*, 1998) and to broader ecological land-cover classifications (Löfvenhaft *et al.*, 2002a; Löfvenhaft, Chapter 24). Habitat classification using biotope mapping has been a key part of comparative studies of vertebrates in European cities.

Comparative studies: species composition

Three studies from Europe and North America serve as examples of comparative studies designed to answer questions about the distribution and abundance of species in cities. They are useful examples because they illustrate how the classification of cities, and of habitats within cities, has been used as a framework for comparison.

Ornithologists in Poland developed a survey of the avifauna of cities in central and eastern Europe (Luniak, 1990; Konstantinov *et al.*, 1996). Both studies used a

standardised questionnaire sent to ornithologists in several cities. The ornithologists were asked to provide information on the breeding status, abundance and population trend for each city. They were also asked to provide a list of new species occurring in their city. The goal of the original study (Luniak, 1990) was to provide a standardised list of species for cities, and to determine new species occurring in cities since the 1950s. The study by Konstantinov *et al.* (1996) was designed to provide information on changes occurring in the avifauna of eastern European cities since 1984. An important part of the comparison was to understand bird species composition in the context of regional features: vegetation zone, presence of sea coast, and presence of big rivers, that might be influenced by urbanisation (Luniak, 1990).

Cringan (1987) compared Christmas bird count data from four cities in the Rocky Mountain region of the United States that was collected over a 30-year period to determine whether the similarity in species composition was increasing as a result of urbanisation. His study focused on cities within a geographic region where cities had different types of pre-development vegetation but were showing similar patterns of growth and development.

Since 1990, ornithologists have developed the Urban Ornithological Atlas project to compare bird species composition in 14 Italian cities (Dinetti, 1996). The project developed standard methods for habitat classification and for conducting bird counts. Participants in a project working group developed a standard classification for habitats in cities that helped to standardise counting methods. Dinetti (1996) noted that the Atlas Project seeks to answer scientific questions about birds in cities as well as questions dealing with urban planning and conservation.

Comparative studies: populations

Comparative studies been used to answer questions about patterns of distribution and abundance that are relevant to managing populations. Conover (1995) surveyed state conservation agencies in the United States to determine cities with urban deer (*Odocoileus* spp.) populations. The survey asked biologists to identify when deer were first observed in a city and when complaints about deer abundance were first recorded. Conover (1995) received responses for 195 cities and attempted to develop general ideas about the occurrence of deer in cities that could be used to guide management-oriented research.

Luniak *et al.* (1990) studied the distribution of the blackbird (*Turdus merula*) in central and eastern Europe and used the results of the study to develop hypotheses about the kinds of species that become abundant in cities. Jerzak (2001) compared the distribution of the black-billed magpie (*Pica pica*) in 12 Polish cities

to understand how species respond to urbanisation. Tree planting associated with urban redevelopment, ameliorated climate and anthropogenic food were factors that contributed to increased abundance of crows over a 12-year period.

A long-term study of red foxes (*Vulpes vulpes*) in British cities has focused on understanding the factors controlling fox occurrence and population size. The core of the study is the development of a fox population model using data from several cities (Harris and Raynor, 1986). Part of this study included developing a model to predict fox occurrence that relied on socio-economic data on 158 British cities (Harris and Smith, 1987). The model predicted both the cities in which foxes occurred and the areas within cities that are likely to contain foxes. The development of the model was also used to understand the socio-economic factors and planning conditions that were associated with foxes becoming established in British cities.

The previously described studies are relevant to the questions asked by ecologists, urban residents and managers because they developed ways of classifying types of cities and methods for classifying habitats within cities. They have documented patterns of species occurrence and abundance among cities and linked these patterns to ecological and social factors. This information has been useful in understanding similarities and differences among cities in patterns of vertebrate species composition and abundance. However, as descriptive studies they have not focused on mechanisms that provide answers to questions raised by ecologists, residents and managers.

How can the current focus on urban ecosystems contribute to comparative studies of urban fauna?

The recent focus on the ecology of cities promises an approach that seeks to identify the mechanisms that underlie patterns and processes (Pickett *et al.*, 2001, Chapter 3; Niemelä *et al.*, Chapter 2). One method used by ecologists in their new focus on cities is the patch dynamics approach used by researchers working on the Baltimore Ecosystem Study, a project funding by the US National Science Foundation (Pickett *et al.*, 2001, Chapter 3). This approach considers the ecological properties of a patch, in this case habitat features and species composition, as being determined by: the history of the patch (patch origin), the spatial setting in which the patch occurs, and current influences on the patch. I will describe how patch dynamics and patch setting have been used as a framework to identify and understand potential mechanisms that determine vertebrate species composition and abundance in cities. It is important to understand that patch dynamics is proposed as an approach to studying vertebrates in cities rather than the only way to study vertebrates in cities. Of equal importance

is the recognition that the patch approach, as it is used in Baltimore, recognises that patches should be defined by the species that are being studied rather than an a priori assumption of what is a patch and what is a matrix.

Patch origin

Zipperer *et al.* (1997) described three types of patches that occur in urban areas: remnant patches of natural or semi-natural vegetation, emergent patches resulting from changing land uses within the patch, and planted patches. Although remnant patches are important in conserving biodiversity, planted patches offer unique opportunity for comparative studies among cities because they reflect international approaches to design, species selection and approaches to management (Forbes *et al.*, 1997).

Neighbourhood parks in US cities are an example of planted patches with similar design and management. Because most cities in the United States follow a standard set of park planning guidelines, neighbourhood parks are similar in size (5 to 10 ha) and typically are designed to serve residents living within 1 km of the park (Ignatava and Stewart, Chapter 23). Researchers in Baltimore and Phoenix have collaborated on a study of birds using small neighbourhood parks in the two cities (Paige Warren, personal communication). The studies use identical census techniques and compare small parks in very different cities to determine if there are similar species or groups of species in small parks, and to determine if small parks support different species from the neighbourhoods surrounding them. A key part of the study is the hypothesis that neighbourhood parks are similar in habitat structure and design and that these similarities would result in similar bird communities between the two cities. By focusing on planted patches they intend to focus on the role that park design, maintenance and management activities, and people's activities play in influencing the composition and abundance of bird species.

Patch setting

Ecologists use a number of metrics to describe the spatial setting of a patch (McDonnell and Hahs, Chapter 5; Yang and Zhou, Chapter 16). Landscape ecologists often consider the matrix of land uses surrounding the patch. Animal ecologists often look at metrics such as patch isolation or patch connectivity to describe the degree of isolation of the patch from similar habitats. Studies considering patch setting have been useful in studying factors that influence population growth and survival (Catterall, Chapter 8; Natuhara and Hashimoto, Chapter 12).

Williamson and DeGraaf's (1980) and Johnsen and VanDruff's (1987) studies of birds in urban neighbourhoods were some of the first to consider how socio-economic factors influence the landscape in which species occur. The recent

research focus on humans as a component of urban ecosystems has resulted in more research on the ecology of vertebrates in patches in different social landscapes (McDonnell and Pickett, 1993b). Cities and subdivisions of cities can be classified using a number of indicators of human social, economic, and demographic characteristics (McDonnell and Hahs, Chapter 5; Yang and Jinxing, Chapter 16). These characteristics can be used to develop scales and indices that allow comparison of cities and their subdivisions. Because socio-economic and census data are available for a number of cities it is possible to make comparisons of the social landscape surrounding patches in a number of cities and to compare how this landscape defines mechanisms shaping species composition and abundance.

Nilon and Huckstep (1998) used census data to define the social landscape surrounding small woodlands in Chicago neighbourhoods. Small woodlands are an important component of natural and semi-natural greenspaces in cities in the Northern Hemisphere. The patches they studied were similar in plant species and in vegetation structure. Patches surrounded by low-income neighbourhoods with rental housing and black American residents had more rubbish and human-related disturbance and had fewer numbers of native small mammal species and more exotic species.

The previously described study comparing bird communities in small neighbourhood parks in Baltimore and Phoenix considered the socio-economic setting of urban parks. Each park was classified by the socio-economic status of the adjacent neighbourhood. This initial comparison led to a number of additional questions that could form the core of other comparative studies. Researchers in Phoenix found that socio-economic status is correlated with several metrics for bird communities. Additional research might focus on how ownership and management of pets, bird feeding, and yard or garden management practices vary with socio-economic status and might be predictors of bird survival or other population characteristics.

A proposed comparative study using a patch dynamics approach

Comparative studies exist because there is a need to answer questions about the ecology of cities. I have described how comparative studies have been used to answer questions about the distribution of species among cities. I have also described how a focus on patch setting and patch type can be useful in understanding the ecology of vertebrates in cities. In this final section, I will describe how the approaches can be combined to answer questions about the mechanisms that shape species distribution and abundance, key factors in wildlife conservation programs.

Central cities of metropolitan areas in Europe, North America, and Australia contain large parks and cemeteries built during the last half of the nineteenth century. These greenspaces, including large cemeteries in several US cities, were built following design principles based on European romantic landscapes and can be viewed as planted patches of similar origin (Darnall, 1983; Forbes *et al.*, 1997). These sites are valued as important cultural resources but their conservation value for vertebrate species is largely unknown. Large greenspaces also occur in specific spatial settings, often older residential neighbourhoods that were developed to provide housing for wealthy residents. This combination of patch origin and spatial setting allows comparison among a group of cities selected based on location, ecological characteristics and pattern of development.

A comparative study focused on large greenspaces could take advantage of patches of similar origin and management history but occurring in very different settings to answer questions about the conservation value of the sites:

- (1) Do large greenspaces built with similar designs support similar species or guilds?
- (2) Are there differences in the presence, abundance, and population characteristics of native and exotic species among large greenspaces?
- (3) Do species using habitats in large urban greenspaces within the selected cities differ in reproductive success and survival?

Engaging ecologists from cities in different settings to develop projects that address the mechanisms that form the basis of questions about species occurrence and survival is the key to a successful study. Comparisons offer a framework for study and a way for bringing together researchers and managers to address important questions. An excellent example of the benefits of comparative ecological studies in different cities is the GLOBENET initiative which examined carabid beetle assemblages in several cities around the world (Niemelä *et al.*, 2002, Chapter 2).