CHAPTER 8

# Multicity Ecological Networks for Addressing Urban Biodiversity Conservation

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## Introduction

Different cities have different wildlife species. We find pumas (*Puma concolor*) in Los Angeles, long-tailed macaques (*Macaca fascicularis*) in Singapore, and grey herons (*Ardea cinerea*) in Amsterdam, partly because cities are embedded in different ecoregions of the world with their own unique biodiversity (Figure 8.1). But the structure of the built environment within a city also creates "winners" and "losers" and thus shapes which animals persist or are extirpated from the city. In the US, for example, Chicago, IL and Madison, WI are a little over 200 km apart and located in similar ecoregions. However, Madison has a much greater proportion of green space and a much lower human population density than Chicago. As a result, red fox (*Vulpes vulpes*) are widely distributed and highly abundant in Madison but are quite rare in Chicago (1).

To most people, however, biological differences pale in comparison to the cultural, economic, architectural, and other anthropocentric factors that characterize each urban region. When one compares New York City to Tokyo, a biologist might imagine the surrounding landforms, the differing bird and plant communities, and so on. But the average city resident is more likely to envision the buildings, the people, the highways, and the downtown nightlife. Each city also has its own local laws and ordinances, some of which relate to the management and maintenance of green spaces like parks or street trees. If cities are so different from one another, what value can conservation gain from comparing cities? Can policy makers, city planners, park managers, and backyard conservationists conserve biodiversity using research from another city? In fact, multicity comparisons allow the practice of conservation to better use science to inform actions. Multicity comparisons teach us which patterns and processes are generalizable across cities and which are specific to particular cities or city attributes.

Of course, the perceptive biologist knows that all of these factors impact urban biodiversity as well and can have as strong an influence as the underlying habitat (2–4). Roads, buildings, people, and their pets act as both threats and opportunities that shape the urban communities of plants and animals worldwide (5).

As both ecological and human factors influence urban biodiversity, a full understanding of the distribution, natural history, and ecology of these species requires data collection across multiple cities, regions, and continents (6). The history of urban wildlife research is, however, largely restricted to single-city examples (7). This has created an amalgamation of case studies but has limited general urban conservation insight and an

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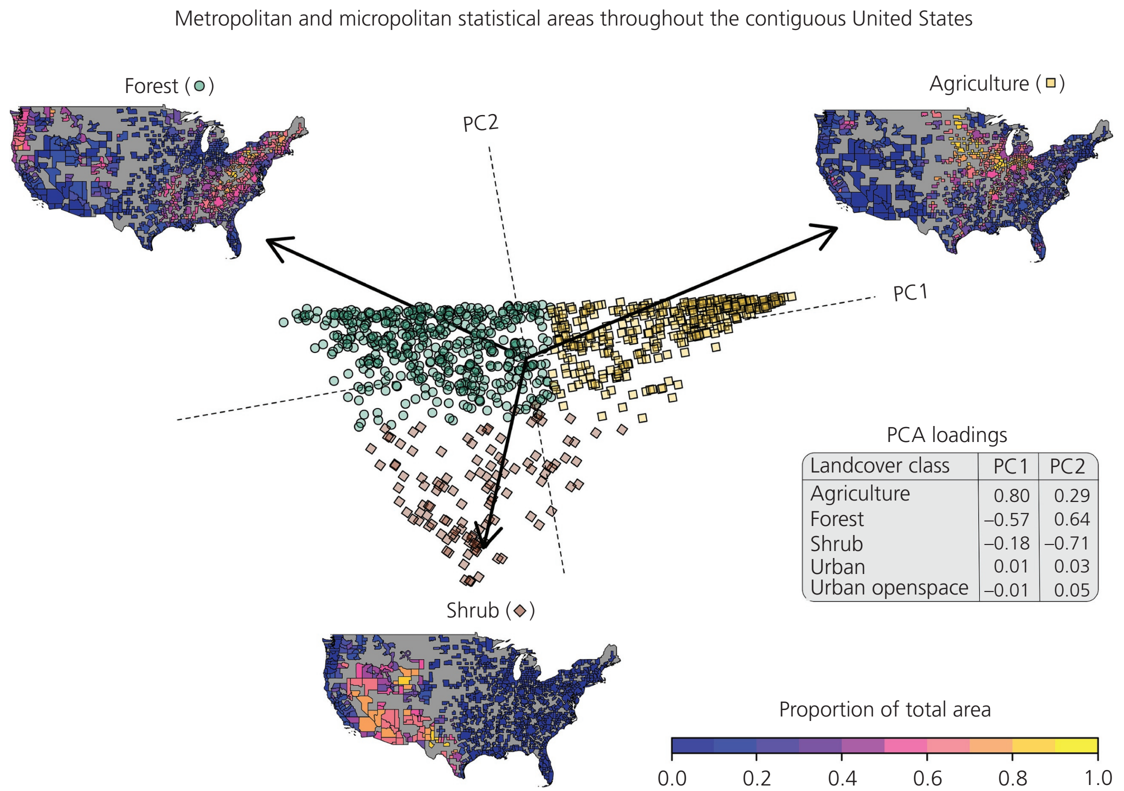


**Figure 8.1** Metropolitan and micropolitan statistical areas throughout the contiguous US are dominated by either forest cover, agriculture, or shrub cover. However, there is substantial variation among these 925 areas. Land-use land cover data were compiled from the 2019 National Landcover Dataset and class values were simplified to create five landcover classes (Agriculture: 81, 82; Forest: 41, 42, 43; Shrub: 51, 52; Urban: 22, 23, 24; Urban openspace: 21). Following dimension reduction by principal component analysis (PCA), a k-means clustering algorithm was used in conjunction with a silhouette analysis which classified three dominant land cover classes among statistical areas. The principal components plot in the center of this figure demonstrates the clustering of land cover classes among cities, where dots represent individual statistical areas and arrows represent the dominant PCA loadings. The three maps illustrate the proportion of these dominant land cover classes across the contiguous US.

understanding of what lessons can be translated among cities versus which are largely relevant to the city a study occurred in. While these single-city studies have certainly advanced the field, they fundamentally do not allow us to address how ecological and human factors in diverse and varied cities shape ecological communities at the scale of a region, a country, a continent, or our planet. Fortunately, numerous multicity networks and projects that employ a variety of methods to identify patterns of urban biodiversity have emerged to close this gap.

**Case study The diversity of multicity urban wildlife research networks**

Multicity research networks span local, regional, continental, and global scales and sample a variety of taxa. This section is not intended as a census of all existing multicity research networks, but we hope that by outlining some illustrative examples we can give a sense of their current scope and scale.

**Urban Wildlife Information Network (UWIN)**

UWIN was founded in 2015 and is currently composed of 47 partnering cities, 44 of which are in the US and Canada (6). UWIN uses systematic sampling protocols across cities (1,3), and started as a camera trapping project for terrestrial mammals. Since its creation, UWIN has added protocols to sample birds, bats, small mammals, and more. UWIN also connects researchers with architects and planners to incorporate their research into city planning and management (8; https://www.urbanwildlifeinfo.org). As one example, UWIN members in Chicago worked with the city to create a new Wildlife Management and Coexistence Plan, based partially on data collected in their study.

**Urban Biodiversity Research Coordination Network (UrBioNet)**

UrBioNet was founded in 2015 and is a US National Science Foundation (NSF)-funded global network for urban biodiversity research and practice. UrBioNet provides a forum for discussion and data sharing on topics relevant to urban biodiversity research as well as the management, design, and planning for urban biodiversity. With over 400 members from 40 countries, UrBioNet engages a global audience of researchers, landscape architects, urban planners, and students.

**Urban Long-Term Ecological Research Program (LTER)**

The LTER program is an NSF-funded network of 28 research sites (https://lternet.edu) that was intended to be a catalyst for ecological research in general and for documenting generalizable patterns. Recognizing the importance of long-term data to capture stochastic ecological events, the program began in 1980 with an emphasis on transdisciplinary ecological research across extended timescales. Within the broader LTER program, three sites focus on the urban biome: Baltimore (BES; 1997–2020), Central Arizona—Phoenix (CAP; 1997), and Minneapolis-Saint Paul (MSP; 2021). The urban LTERs examine land use and land cover change, human–environment interactions, and often leverage social science and community engagement in their research.

**The "Ecological Homogenization of Urban America" project (EHUA)**

This NSF-funded project is a multi-scale, multidisciplinary research network that studies residential yards across six cities in the contiguous US (9). All three urban LTER cities are part of EHUA, as well as Miami, FL; Boston, MA; and Los Angeles, CA. Research topics in EHUA were initially focused on the ecological homogenization of soil and plants across residential yards but have expanded as this network continues to grow (10).

**Global Urban Evolution Project (GLUE)**

GLUE is a consortium of researchers examining how urbanization drives evolution (11). Following standardized protocols, researchers from over 160 cities are sampling and assaying the same genetic loci from white clover (*Trifolium repens*) populations to understand if urbanization leads to similar parallel evolutionary changes in the antipredator defense chemical produced by the plant and what factors influence this relationship (https://www.globalurbanevolution.com/).

## Global perspectives

Single-city studies—while important and useful—only provide information about patterns of biodiversity within the city they are conducted, and moreover are biased to certain parts of the world (12). As a result, disagreements about patterns of urban biodiversity abound in the literature. For example, the distribution of Virginia opossum (*Didelphis virginiana*) throughout Amherst, MA is not strongly associated with open water sources (13) but opossum throughout Chicago, IL are (14). Urban bird species richness throughout various cities has been observed to either increase (15), decrease (16), or not change over time (17) depending on study location. Plant species richness throughout cities can positively or negatively covary with socioeconomics (18). If the goal of science is to seek generality, then such disagreements in the literature may seem troubling, as they collectively suggest that generality may not be possible. Yet, we contend that this is not the case.

In fact, the amount of potentially conflicting information among urban ecological studies is welcome. Why? Because, as in other fields of ecology, these differences indicate that hypotheses are likely supported or rejected depending on the system—in our case the city—where they are studied (19). The fact that context matters should not be surprising. Spatial or temporal variation in the relative fitness of species, and therefore patterns of biodiversity, is nearly ubiquitous in nature (19). As such, the extent to which ecological patterns generalize from one location to the next depends on how similar two locations are. When we recognize that cities are not carbon copies of one another it becomes clear that multicity research is imperative to add a regional, continental, or global perspective (depending on the scale of the cities involved) to urban ecology (20).

Urban ecologists, ourselves included, have recognized that future research should broaden to include cross-city comparisons across multiple scales, such as from local parks, to neighborhoods, to entire regions (6,20–25). In the last decade, significant progress has been made on this front, mostly through meta-analyses (analyses of other published studies (26–30)), though most are not the product of research networks (but see (31)). Meta-analyses are often used because they make it possible to synthesize past research to assess general patterns in the literature which could—in turn—help identify ways to conserve or increase biodiversity within cities. For example, through an analysis of 87 different publications across 75 cities worldwide, Beninde et al. (27) found that large (>50 ha) habitat patches with corridors have greater biodiversity, and therefore biodiversity-friendly management in cities should focus on increasing the area and connectivity of green space (Figure 8.2). After all, as cities typically contain only roughly 8% of nearby native regional birds and 25% of their regional plants (31), there are substantial opportunities to make cities more welcome to native flora and fauna through biodiversity-friendly management.

While meta-analyses do provide a way to synthesize past literature, they also come with caveats. For example, meta-analyses may have some bias because there is always uncertainty in how comparable published studies are given differences in methodology. Likewise, publication bias may mean some findings are overrepresented in the literature, which could distort results (32). These issues do not mean that these analyses are not valid, but additional tools are needed. Coordinated distributed experiments (33) and observational research networks (6,34) institute standardized methodologies across studies to address these shortcomings. Any one city is unlikely to be able to do all the research necessary to fully understand urban wildlife, and so it is essential to know what patterns can be applied to other cities and what information is likely to be context or city dependent. By using a common

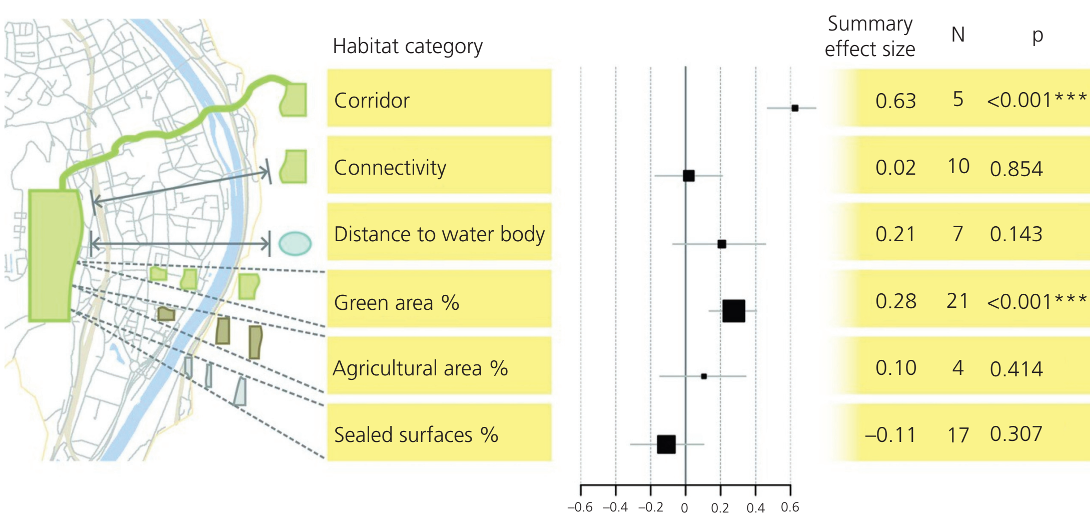


**Figure 8.2** Illustrating the importance of area and connectivity for urban biodiversity via a meta-analysis.
Reprinted with permissions from Beninde et al. (27).

study design, differences observed across a research network are far more likely to be ecological than methodological, which makes it possible to investigate how factors at various scales shape urban biodiversity (Figure 8.3).

While we have much to discover about regional and global urban ecological patterns, multicity research networks have started to provide the data necessary to understand how among-city variability relates to differences in urban biodiversity. A study from UWIN (see the Case study) showed that the distribution and relative scarcity of mammals across the US and Canada vary as a function of a city's average housing density and green space availability (1). As mammals can generate conflict with humans, findings like these can help target efforts toward outreach, coexistence, and management at scales previously impossible. Perhaps the largest example comes from the Global Urban Evolution Project (GLUE, see the Case study). By sampling over 6000 white clover populations (*Trifolium repens*) across urban gradients in 169 cities, Santangelo et al. (11) found that among-city variability in vegetation, impervious cover, and aridity was strongly associated with the production of hydrogen cyanide (HCN) in white clover, which is used as an anti-herbivore defense. These findings demonstrate not only that the magnitude of evolutionary or ecological phenomena can vary among cities, but also the direction of the relationship. Had these datasets been analyzed as single-city studies, generality would be hard to grasp given the dissimilar responses among cities. But through these collaborations, we see that such inconsistencies are the result of large-scale differences among cities. As such, multicity research networks can provide

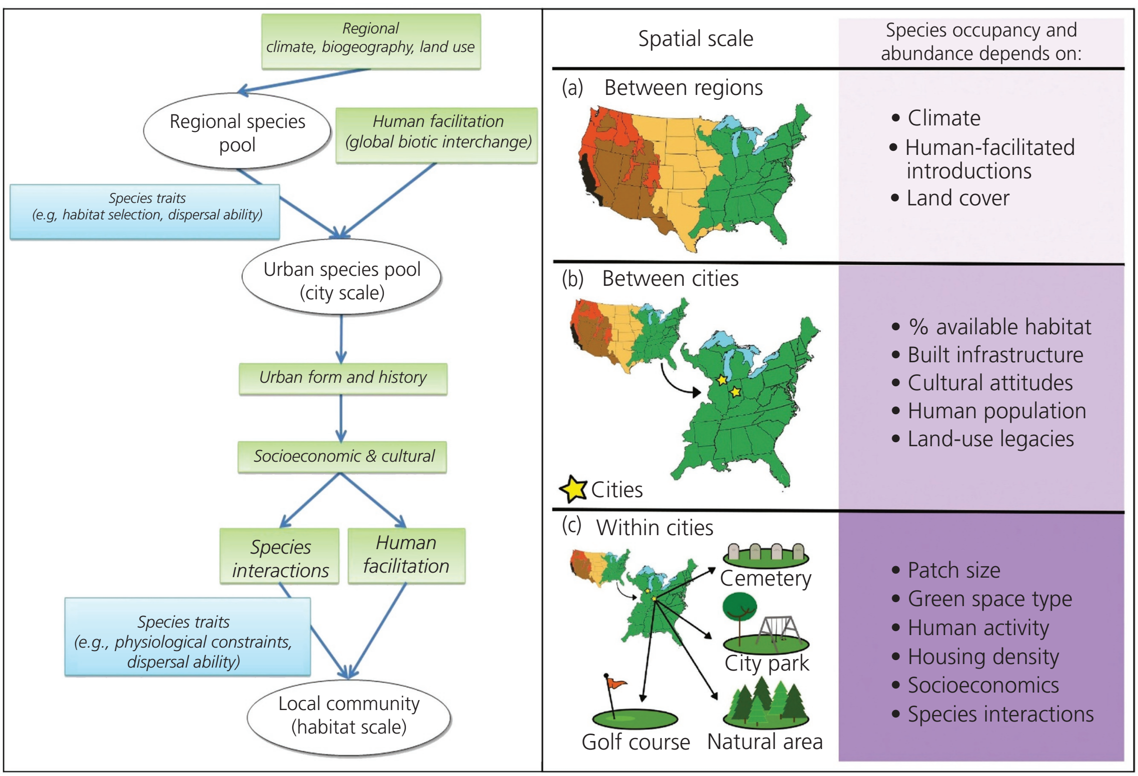


**Figure 8.3** Hierarchical filters shape patterns of urban biodiversity. The left figure, reprinted with permissions from Aronson et al. (20), illustrates how community assembly of urban species pools is determined by a series of hierarchical filters. Green boxes represent filters hypothesized to be important determinants of species distributions at different scales. White circles represent species pools. Species life history and functional trait filters are represented in blue boxes. The right figure, reprinted with permissions from Magle et al. (6), provides examples of factors at different spatial scales that may determine patterns of species occupancy or abundance.

mechanistic understanding of global patterns of urban biodiversity and how to manage it (35).

## Social-ecological applications

In urban areas, wildlife and people are inextricably linked, a phenomenon observed across disciplines such as human dimensions of wildlife, human–wildlife conflict mitigation, and environmental justice. Just as multicity networks are well-positioned to explore ecological questions, they have enormous power to explore linked social-ecological systems. Cities undoubtedly have as much variance in sociological factors as in ecological ones. As such, sampling an array of cities provides greater power and insight to understand how human communities influence other species. As an example, one study evaluated how mammalian wildlife were distributed with respect to wealth in a set of 20 North American cities (3). While species richness positively covaried with socioeconomic gradients in roughly half of the cities, it negatively covaried with gradients of urban intensity in nearly every city (Figure 8.4).

Urban wildlife are not distributed equally, or equitably, across neighborhoods, a fact that went unnoticed by the scientific community for far too long (36).[1] Systemic racism drives the structure and layout of cities, including where green space is situated. These decisions influence what habitats are colonized and inhabited by wildlife. As such, both positive and negative effects of living with wildlife are unequally distributed, with conflicts more often borne by communities of color and the rewards of living near nature, including health benefits and ecosystem services, more often coming to White neighborhoods. Schell et al. (36) outline several key research questions that integrate systemic racism, ecology, and evolution. These include "How does biodiversity vary with the degree of residential segregation within a city?" and "Is functional or structural connectivity reduced in cities with more pronounced economic or racial segregation?" The answers to these questions will be much more satisfying if they are asked across multiple cities. Quite often, wealth and racism are used synonymously in ecological studies (e.g., (3)) but they are not the same (36). With data from multiple cities, the effects of these separate (but potentially correlated) factors can be teased apart. Multicity networks also have the potential to evaluate the effects of systemic racism on wildlife across cities with varying levels and configurations of segregation and inequity.

Cities have enormous potential to support biodiversity, especially if properly managed (37). Decisions regarding urban planning and land use across multiple scales of governance, from residents up to municipal governments, can influence both the biodiversity present and the benefits to residents gained by exposure to such biodiversity (38–41). Multicity networks are ideal for studying such questions, identifying patterns, and informing management of urban areas to maximize biodiversity. For example, by examining the role of land management practices on bird species richness in six US metropolitan cities, Lerman et al. (10) identified key strategies for land management to support bird species diversity that were consistent across regions, with natural areas and residential yards playing an especially important role. Through UrBioNet (see the Case study), a meta-analysis examining the convergence of socioeconomic status and biodiversity and the role of human decision-making in 84 case studies across 34 cities identified a strong relationship between socioeconomic status and biodiversity in most cases. However, in cases where there was a negative relationship, social policy and human decision-making were able to mitigate this inequality, demonstrating the important role of governance and associated institutions in shaping urban biodiversity (40).[2]

## Education and outreach

Urban-based biodiversity research has tremendous opportunity for outreach and education given the close proximity of city residents to their wild neighbors. Many urban residents may be unaware of the diversity of species that are present in their cities, or the wealth of nature that surrounds them, even in the most densely populated cities. Residents

[1] Hoover's and Scarlett's chapter discusses biodiversity and environmental inequities in cities.

[2] Larson's and Brown's chapter outlines the role of human motivations and governance in urban wildlife conservation.

may also be surprised to learn of the enormous benefits that connecting to nature can provide (42), including mental and physical health, recreation, and relaxation. Public outreach and education is a key component to reducing negative interactions between humans and wildlife (43). As with other advantages of multicity research networks, the impact of public outreach and education is amplified because programs can be deployed across multiple cities and reach more and more people. Between shared lesson plans, knowledge of existing programs, and repositories of materials, researchers have access to a wealth of resources that have been developed and deployed by others successfully. For researchers or managers who have little experience with public outreach and little time to develop a program from scratch, plugging in to successful programs saves a lot of time and effort, and has a much stronger potential for success. For example, UWIN has an education committee that shares resources among partners in the network. As part of this committee, UWIN partners in St. Louis replicated a program originally developed in Chicago by Lincoln Park Zoo called Partners in Fieldwork, an award-winning and free year-long program implemented in local grade-schools. The program provides the opportunity for middle and high school students to become "student field researchers." Students collect data from a field station they set up on their school campus. Teachers are provided with ongoing professional training to implement the curriculum in their classroom and support students in designing their research projects.

## Fundraising opportunities

Another advantage of a multicity network is that they can open doors to more opportunities for funding, which can enhance the capacity of organizations to engage in conservation actions. Although

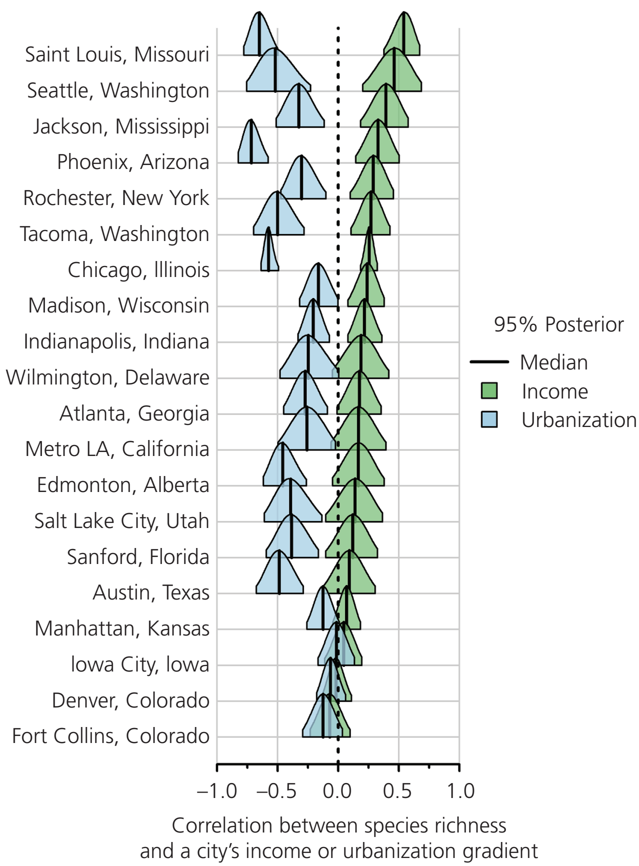


**Figure 8.4** The correlation between species richness of medium to large mammals and a city's income or urbanization gradient across 20 North American cities. There was strong evidence of a positive correlation between income gradients and species richness in 9 of the 20 cities, as evidenced by 95% credible intervals not overlapping zero. There was strong evidence of a negative correlation between species richness and urbanization in 16 of the 20 cities. Modified from Magle et al. (3).

some funding agencies may be focused on local research, many prioritize multidisciplinary, collaborative research with large impacts (e.g., NSF; (8)). As we have described earlier, the impact of research conducted by a multicity network is immense and amplified by its numerous members and vast geographic scope. Even if a funding agency is limited to supporting research that is conducted in a specific geographic area, that locally conducted research can contribute to a much broader dataset as a member of a multicity network. Furthermore, as part of a network, researchers can learn about foundations or grants that they may not be aware of, and apply as a group rather than independently, while emphasizing the multidisciplinary, collaborative, and broad-scale impact of the research.

## Increased temporal scale

Multicity research networks can also increase temporal scale, if data are collected multiple times per year—for example, during separate seasons—or across years. Speaking from experience, starting and maintaining multicity research networks is a tremendous amount of work, but adding a temporal component to such research has many advantages. Ongoing sampling means new interested partners have the opportunity to collaborate. Furthermore, increasing temporal scale makes it possible to study local or global change over time if data are collected before, during, and after relevant events. For example, the Covid-19 global pandemic led to dramatic changes in human activity patterns, which urban wildlife no doubt responded to (44,45). At a more local scale, urban development patterns no doubt change over time, and long-term datasets are an ideal way to determine how biodiversity may respond to changing patterns of urban development.

## Increased taxonomic breadth

Urban wildlife research is highly biased by taxa, with most work being conducted on birds and mammals (7,12). Arthropods, insects, fish, reptiles, amphibians, and other taxa remain relatively unexplored. This is a tremendous missed opportunity for urban ecology. Multicity networks have the potential to expand the number of species sampled, most obviously for the simple reason that sampling across wider regions expands the pool of available species based on their geographic ranges. Access to broader species pools increases our ability to model interactions and energy flows between individuals, populations, and differing trophic levels.

We have also observed a less obvious benefit to multicity networks with respect to diversity of sampling. Researchers who only have experience in sampling one taxon (e.g., mammals or birds) are often reluctant to launch research into a new one, largely because the methodologies are different, and learning new techniques takes a great deal of time and effort. Multicity networks bring together teams of researchers with different experiences, who can share expertise and draft flexible, straightforward data collection protocols, thus making the process of designing new studies less daunting. UWIN (see the Case study) began as a consortium dedicated solely to monitoring midsize terrestrial mammals using camera traps, but now is developing protocols for birds, bats, ticks, reptiles, and small mammals. Likely none of the members would have launched a large-scale study on these taxa on their own, but the resources of the network enabled them to reach beyond their normal comfort zone and capture data on understudied species.

## Providing community

Arguably the greatest benefit of a coordinated research network is the extensive professional community that they can provide. Inherent in that community is a diversity of viewpoints, knowledge, skills, and experience of researchers from around the world with a variety of backgrounds that can act as a resource for its members. For example, a challenge faced by practitioners and researchers in one city may have been faced and solved by those in another, one network member may have developed software that would be useful for answering a question posed by another city, or another member may have a compelling idea for a dimension to add to a collaborative paper which others had not considered. Combining efforts across many cities nationally and even globally enriches and elevates the quality of the research by bringing together people from diverse backgrounds with a variety of skills and ideas.

## Current challenges for multicity research

While the advantages of multicity research are extensive, there are reasons why single-city studies are more common—it is difficult to manage large research alliances. Coordinating researchers and their associated projects is challenging. Partners can have different goals and objectives, as well as their own unique resources and limitations. Academics, for example, are most often motivated by publications and grants, whereas researchers with nonprofit institutions may be more invested in outreach or educational gains. Managing a network means managing all of the associated personalities and motivations of collaborators, a task that is as much social as intellectual.

Some of these coordination tasks are straightforward, if not actually simple. When multicity research projects are proposed within the network, someone needs to lead them. Assigning research projects to individual principal investigators (PIs) can be challenging if multiple people are interested in similar questions. These issues, and those of determining authorship on collaborative projects, can often be best handled by a representative body composed of members from across the network. For example, UWIN handles these issues with a research committee with one vote from each participating city.

Research prioritization at a network scale is its own challenge, of course. Some networks have central leadership, a PI in charge of the project as a whole. These roles are challenging, requiring not only specific topic knowledge of the methods for the urban wildlife study in question, but also the ability to step back from the day-to-day field collection and analysis to focus on administration and logistics—not why most scientists went to graduate school. Others use a more democratic approach, with an advisory board or group of coequal PIs. This can be effective in sharing the work and ensuring effective outcomes, but it can also add time to the process of decision making. Whatever the approach to project management, it is critical to be upfront about the structure of the organization so that all parties are aware of their rights and responsibilities as members.

If a feature of the network is shared research protocols, a careful approach to the design of those protocols is absolutely essential. It is bad enough to design a local study poorly and find one cannot answer the intended research questions, but catastrophic to make the same mistake across multiple studies at once. Consultation with field ecologists and statisticians is critical to ensure the study design can address a given research question and can reasonably be executed. There is, however, also a risk of making the design too rigid. Each city is designed differently, and a spatial design that might work in an expansive, open metropolitan area, for example, Houston, TX, may not fit whatsoever for an island like Manhattan. Finding the proper compromise between scientific rigor and flexibility will be a task for a team that includes statisticians as well as people with deep experience in on-the-ground data collection.

As networks grow, logistical issues of scale follow. A network with three or four collaborators could be managed informally, with e-mails and spreadsheets perhaps the only needed tools. When that same network reaches 40 collaborators, disaster will ensue if new tools are not adopted. For example, with a small number of collaborators, distributed databases that individual partners manage, such as duplicate copies of the same local database, may be the best and cheapest option. As the number of partners increases, however, maintaining data integrity becomes difficult due to small differences in how data are entered among partners, such as the name or spelling of a species. These differences can snowball into a significant amount of data cleaning when the time comes to compile data across a network.

From the logistical side of coordinating networks, the larger and more complex the project, the more effort will be required to keep the partners moving in the same direction. If possible, a full-time coordinator is an invaluable asset, and perhaps essential for large networks. Funding these types of positions can be a challenge as they may not seem as flashy or productive to a granting agency, but large-scale research is all but impossible without them. The same types of productivity tools that work for non-research applications—cloud-based spreadsheets, calendar coordination, social productivity tools such as Slack—are also beneficial, though researchers are often hesitant to adopt them.

## Future needs for multicity research

While tremendous progress has been made, multicity urban wildlife research networks in any form are still in their infancy, and huge gaps remain, both in our knowledge, and in projects designed to acquire that knowledge. Our review of existing broad-scale research has revealed several promising areas for future work.

Many existing networks (e.g., Urban LTER) are restricted to a certain region or country, and even those that have a global scope (e.g., UrBioNet, UWIN) have patchy distributions of partners that leave significant gaps. In particular, existing urban wildlife research is heavily focused in North America, Europe, and Oceania, with poor representation in South America, Africa, and Asia (7,12). Given the huge variation in cities, a universal understanding of urban wildlife research will be impossible without networks that sample cities all around the world. In addition to spatial gaps, there are other limitations in existing research networks. Mammals and birds are fairly well studied, with arthropods, fish, reptiles, amphibians, and other taxa still mostly unknown (7,12).

It is a tired refrain, but true: to address these limitations and expand on the power of existing urban wildlife networks, additional funding will be needed. These large-scale projects are expensive, and while funding sources exist to initiate this type of work through the NSF's grants (LTER, infrastructure) and other sources, sustaining and growing them is another matter. Data managers, research software engineers, coordinators, graduate students, and postdoctoral researchers are all needed to make these multicity projects a reality. Funding is desperately needed to take these fledgling networks to the next level.

We have described several existing urban wildlife research networks, and others that include urban wildlife as part of a larger portfolio. Each has its own focus, strengths, and limitations. Most are focused on collecting ecological data, and an added focus on collecting and interfacing with social, economic, and cultural data is likely to be useful given the interdisciplinary nature of cities themselves. An interesting next step could be for urban data networks, whether focused on wildlife ecology or not, to start communicating and sharing data with one another, in essence creating metanetworks.

Within these proposed metanetworks, the process of conceptualizing and formatting data such that they can interface in a useful way will be a challenge, and in the case of transdisciplinary metanetworks, even differing language and terminology will need to be navigated. Although difficult, this process will be deeply rewarding. Real progress toward understanding, managing, and conserving wildlife in cities will require deep collaboration between ecologists, urban planners, architects, and urban residents at large (8). Multicity networks represent a critical first step toward this end goal, and a tantalizing glimpse at what we can achieve as the scope of our efforts keeps expanding.

## Conclusion

Urban wildlife research has become more prominent over the past few decades (12) and is now beginning to fill in knowledge gaps that have existed since the birth of modern wildlife ecology. The field has grown to encompass new spaces (e.g., suburban, exurban), new topics (e.g., justice, human dimensions), and new taxa beyond birds and mammals. All of these advances are important and useful, but to move the discipline beyond examination of local patterns, and toward an analysis of urban wildlife as global phenomena, multicity networks are essential.

If we are to conserve biodiversity and manage wildlife on an urban planet, we cannot do it alone. Not only must we work together within our discipline, but researchers must also work with urban planners, landscape architects, sociologists, economists, community organizers, residents, and everyone else who is a part of designing, creating, and maintaining our urban environments. These conversations will not get far if our ecological understanding is restricted to each researcher's own field sites. The only way to move beyond a patchwork of local studies and toward these global principles is multicity networks.

We have outlined many of the advantages of these networks, given examples of several growing networks, and described some of the difficulties of creating and maintaining them. We urge in the strongest possible terms that if you are starting up an urban wildlife study, or even if you have one ongoing, take a little time to research available networks that might be relevant to your project. Joining them may not require much additional work from you and could open up your research questions to all-new scales and in entirely new directions.

## References


1. Fidino M, Gallo T, Lehrer EW, Murray MH, Kay CA, Sander HA, et al. Landscape-scale differences among cities alter common species' responses to urbanization. Ecological Applications. 2021;31(2):e02253.
2. Magle SB, Lehrer EW, Fidino M. Urban mesopredator distribution: examining the relative effects of landscape and socioeconomic factors. Animal Conservation. 2016;19(2):163–75.
3. Magle SB, Fidino M, Sander HA, Rohnke AT, Larson KL, Gallo T, et al. Wealth and urbanization shape medium and large terrestrial mammal communities. Global Change Biology. 2021;27(21):5446–59.
4. Hassell JM, Ward MJ, Muloi D, Bettridge JM, Phan H, Robinson TP, et al. Deterministic processes structure bacterial genetic communities across an urban landscape. Nature Communications. 2019;10(1):2643.
5. Beninde J, Feldmeier S, Werner M, Peroverde D, Schulte U, Hochkirch A, et al. Cityscape genetics: structural vs. functional connectivity of an urban lizard population. Molecular Ecology. 2016;25(20):4984–5000.
6. Magle SB, Fidino M, Lehrer EW, Gallo T, Mulligan MP, Ríos MJ, et al. Advancing urban wildlife research through a multi-city collaboration. Frontiers in Ecology and the Environment. 2019;17(4):232–9.
7. Magle SB, Hunt VM, Vernon M, Crooks KR. Urban wildlife research: past, present, and future. Biological Conservation. 2012;155(Oct):23–32.
8. Kay CAM, Rohnke AT, Sander HA, Stankowich T, Fidino M, Murray MH, et al. Barriers to building wildlife-inclusive cities: insights from the deliberations of urban ecologists, urban planners and landscape designers. People and Nature. 2021;4(1):62–70. Available from: https://doi.org/10.1002/pan3.10283
9. Groffman PM, Cavender-Bares J, Bettez ND, Grove JM, Hall SJ, Heffernan JB, et al. Ecological homogenization of urban USA. Frontiers in Ecology and the Environment. 2014;12(1):74–81.
10. Lerman SB, Narango DL, Avolio ML, Bratt AR, Engebretson JM, Groffman PM, et al. Residential yard management and landscape cover affect urban bird community diversity across the continental USA. Ecological Applications. 2021;31(8):e02455.
11. Santangelo JS, Ness RW, Cohan B, Fitzpatrick CR, Innes SG, Koch S, et al. Global urban environmental change drives adaptation in white clover. Science. 2022;375(6586):1275–81.
12. Collins MK, Magle SB, Gallo T. Global trends in urban wildlife ecology and conservation. Biological Conservation. 2021;261(Sep):109236.
13. Kanda LL, Fuller TK, Sievert PR. Landscape associations of road-killed Virginia opossums (Didelphis virginiana) in central Massachusetts. The American Midland Naturalist. 2006;156(1):128–34.
14. Fidino MA, Lehrer EW, Magle SB. Habitat dynamics of the Virginia opossum in a highly urban landscape. The American Midland Naturalist. 2016;175(2):155–67. Available from: https://doi.org/10.1674/0003-0031-175.2.155
15. Fidino M, Limbrick K, Bender J, Gallo T, Magle SB. Strolling through a century: replicating historical bird surveys to explore 100 years of change in an urban bird community. The American Naturalist. 2022;199(1):159–67.
16. Strohbach MW, Hrycyna A, Warren PS. 150 years of changes in bird life in Cambridge, Massachusetts from 1860 to 2012. The Wilson Journal of Ornithology. 2014;126(2):192–206.
17. Shultz AJ, Tingley MW, Bowie RC. A century of avian community turnover in an urban green space in northern California. Condor. 2012;114(2):258–67.
18. Leong M, Dunn RR, Trautwein MD. Biodiversity and socioeconomics in the city: a review of the luxury effect. Biology Letters. 2018;14(5):20180082. Available from: https://doi.org/10.1098/rsbl.2018.0082
19. Vellend M. The Theory of Ecological Communities (MPB-57). Princeton, NJ: Princeton University Press; 2016.
20. Aronson MF, Nilon CH, Lepczyk CA, Parker TS, Warren PS, Cilliers SS, et al. Hierarchical filters determine community assembly of urban species pools. Ecology. 2016;97(11):2952–63.
21. Childers DL, Cadenasso ML, Grove JM, Marshall V, McGrath B, Pickett ST. An ecology for cities: a transformational nexus of design and ecology to advance climate change resilience and urban sustainability. Sustainability. 2015;7(4):3774–91.

22. Johnson MT, Munshi-South J. Evolution of life in urban environments. Science. 2017;358(6363):eaam8327.
23. McDonnell MJ, Hahs AK. The future of urban biodiversity research: moving beyond the "low-hanging fruit". Urban Ecosystems. 2013;16(3):397–409.
24. McPhearson T, Pickett ST, Grimm NB, Niemelä J, Alberti M, Elmqvist T, et al. Advancing urban ecology toward a science of cities. BioScience. 2016;66(3):198–212.
25. Niemelä J. Ecology of urban green spaces: the way forward in answering major research questions. Landscape and Urban Planning. 2014;125(May):298–303.
26. Batáry P, Kurucz K, Suarez-Rubio M, Chamberlain DE. Non-linearities in bird responses across urbanization gradients: a meta-analysis. Global Change Biology. 2018;24(3):1046–54.
27. Beninde J, Veith M, Hochkirch A. Biodiversity in cities needs space: a meta-analysis of factors determining intra-urban biodiversity variation. Ecology Letters. 2015;18(6):581–92.
28. Gámez S, Potts A, Mills KL, Allen AA, Holman A, Randon PM, et al. Downtown diet: a global meta-analysis of increased urbanization on the diets of vertebrate predators. Proceedings of the Royal Society B. 2022;289(1970):20212487.
29. Jung K, Threlfall CG. Trait-dependent tolerance of bats to urbanization: a global meta-analysis. Proceedings of the Royal Society B. 2018;285(1885):20181222.
30. Murray MH, Sánchez CA, Becker DJ, Byers KA, Worsley-Tonks KE, Craft ME. City sicker? A meta-analysis of wildlife health and urbanization. Frontiers in Ecology and the Environment. 2019;17(10):575–83.
31. Aronson MF, La Sorte FA, Nilon CH, Katti M, Goddard MA, Lepczyk CA, et al. A global analysis of the impacts of urbanization on bird and plant diversity reveals key anthropogenic drivers. Proceedings of the Royal Society B: Biological Sciences. 2014;281(1780):20133330.
32. Nakagawa S, Lagisz M, Jennions MD, Koricheva J, Noble DW, Parker TH, et al. Methods for testing publication bias in ecological and evolutionary meta-analyses. Methods in Ecology and Evolution. 2022;13(1):4–21.
33. Fraser LH, Henry HA, Carlyle CN, White SR, Beierkuhnlein C, Cahill Jr JF, et al. Coordinated distributed experiments: an emerging tool for testing global hypotheses in ecology and environmental science. Frontiers in Ecology and the Environment. 2013;11(3):147–55.
34. Cove MV, Kays R, Bontrager H, Bresnan C, Lasky M, Frerichs T, et al. SNAPSHOT USA 2019: a coordinated national camera trap survey of the United States. Ecology. 2021;102(6):e03353.
35. Knapp S, Aronson MF, Carpenter E, Herrera-Montes A, Jung K, Kotze DJ, et al. A research agenda for urban biodiversity in the global extinction crisis. BioScience. 2021;71(3):268–79.
36. Schell CJ, Dyson K, Fuentes TL, Des Roches S, Harris NC, Miller DS, et al. The ecological and evolutionary consequences of systemic racism in urban environments. Science. 2020;369(6510):eaay4497.
37. Lehrer EW, Gallo T, Fidino M, Kilgour RJ, Wolff PJ, Magle SB. Urban bat occupancy is highly influenced by noise and the location of water: considerations for nature-based urban planning. Landscape and Urban Planning. 2021;210(Jun):104063.
38. Belaire JA, Whelan CJ, Minor ES. Having our yards and sharing them too: the collective effects of yards on native bird species in an urban landscape. Ecological Applications. 2014;24(8):2132–43.
39. Kinzig A, Warren P, Martin C, Hope D, Katti M. The effects of human socioeconomic status and cultural characteristics on urban patterns of biodiversity. Ecology and Society. 2004;10(1):10.5751/ES-01264-100123.
40. Kuras ER, Warren PS, Zinda JA, Aronson MFJ, Cilliers S, Goddard MA, et al. Urban socioeconomic inequality and biodiversity often converge, but not always: a global meta-analysis. Landscape and Urban Planning. 2020;198(Jun):103799.
41. Pickett STA, Cadenasso ML, Rosi-Marshall EJ, Belt KT, Groffman PM, Grove JM, et al. Dynamic heterogeneity: a framework to promote ecological integration and hypothesis generation in urban systems. Urban Ecosystems. 2017;20(1):1–14.
42. Sandifer PA, Sutton-Grier AE, Ward BP. Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: opportunities to enhance health and biodiversity conservation. Ecosystem Services. 2015;12(Apr):1–15.
43. Espinosa S, Jacobson SK. Human-wildlife conflict and environmental education: evaluating a community program to protect the Andean bear in Ecuador. The Journal of Environmental Education. 2012;43(1):55–65. Available from: https://doi.org/10.1080/00958964.2011.579642
44. Kays R, Cove MV, Diaz J, Todd K, Bresnan C, Snider M, et al. SNAPSHOT USA 2020: A second coordinated national camera trap survey of the United States during the COVID-19 pandemic. Ecology. 2022;103(10):e3775.
45. Zellmer AJ, Wood EM, Surasinghe T, Putman BJ, Pauly GB, Magle SB, et al. What can we learn from wildlife sightings during the COVID-19 global shutdown? Ecosphere. 2020;11(8):e03215.