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Having our yards and sharing them too: the collective effects of yards on native bird species in an urban landscape

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Abstract. Residential yards comprise a substantial portion of urban landscapes, and the collective effects of the management of many individual yards may "scale up" to affect urban biodiversity. We conducted bird surveys and social surveys in Chicago-area (Illinois, USA) residential neighborhoods to identify the relative importance of yard design and management activities for native birds. We found that groups of neighboring yards, in the aggregate, were more important for native bird species richness than environmental characteristics at the neighborhood or landscape scale. The ratio of evergreen to deciduous trees in yards and the percentage of yards with trees and plants with fruits or berries were positively associated with native bird species richness, whereas the number of outdoor cats had a negative association. The number of birdfeeders was not an important predictor for native species richness. We also found that migratory birds were observed on transects with more wildlife-friendly features in yards, and nonnative birds were observed on transects with greater numbers of outdoor cats and dogs. Our results highlight the potential importance of residential matrix management as a conservation strategy in urban areas.

Key words: birdfeeders; Chicago; domestic cats; residential landscapes; urban bird; urban ecology; wildlife-friendly gardening; yard management.

Introduction

Cities represent a substantial but often-overlooked opportunity for conserving biodiversity and reconnecting people with nature (Miller and Hobbs 2002, Turner et al. 2004, Dearborn and Kark 2009). Urban areas across the world harbor species of conservation concern and retain a substantial number of endemic native species (Aronson et al. 2014). In Illinois (USA), the Chicago metropolitan area contains a large number of threatened and endangered species thanks to the extensive forest preserve districts of Cook, Lake, McHenry, DuPage, and Will Counties (Herkert 1991, 1992). Urban parks and preserves are important to both people and wildlife, and the "matrix," or mosaic of land uses between habitat patches, can be equally important. Managing the matrix can lead to high conservation returns by providing additional habitat area and reducing effective isolation of patches (Prugh et al. 2009). Often, however, the habitat potential of the urban matrix is underestimated and even ignored in urban conservation efforts.

Residential yards, which can comprise over one-third of the land area in a city (Matthieu et al. 2007), have the potential to act collectively as patches of interconnected habitat within urban areas (Goddard et al. 2009). Residential neighborhoods also provide a major opportunity to reconnect people with wildlife (DeStefano and DeGraaf 2003), especially if these spaces are designed with both people and nature in mind (e.g., the concept of "reconciliation ecology" [Rosenzweig 2003] or "zoopolis" [Seymour and Wolch 2009]). But we know very little about how the characteristics of neighboring yards affect urban wildlife or the relative importance of groups of yards compared to environmental characteristics at broader spatial scales (e.g., coverage of tree canopy and undeveloped area in the surrounding landscape), although recent work has begun to shed light on these questions (Lerman and Warren 2011, McCaffrey and Mannan 2012, Goddard et al. 2013). Here, we investigate the collective effects of yards on urban bird communities and identify specific yard design and management practices that, when implemented across a neighborhood, can influence native bird conservation.

Ecologists have long known that species respond to the landscape at a range of spatial scales (Wiens 1989), and urban birds are no exception (Hostetler and Holling 2000). In urban areas, human decisions affect the landscape at various scales, ranging from the choices individuals make in their yards all the way up to municipal or regional efforts that shape environmental characteristics. Kinzig and others (2005) use the terms "bottom-up" and "top-down" to describe the ways in which humans can influence biodiversity patterns in

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urban areas. "Bottom-up" influences reflect the combined effects of local decisions made at the individual or household scale. In contrast, "top-down" effects reflect the influence of decisions made by government entities (Kinzig et al. 2005). For example, the amount of open space within the landscape can be thought of as a "top-down" influence, as this is determined primarily by city- or county-level agencies (e.g., the Cook County Forest Preserve District in our study area). On the other hand, the number of birdfeeders in a neighborhood represents a "bottom-up" influence, because it is the manifestation of many individual household decisions. A recent review of urban bird studies at various spatial scales suggests that habitat factors operating at a local scale are more important than the broader landscape in structuring urban bird assemblages (Evans et al. 2009).

In urban areas, residential yards can provide extensive resources for wildlife (Gaston et al. 2005). Of the relatively few urban bird studies that have examined fine-scale variation in residential yards, most were conducted at the individual yard or parcel scale (e.g., Daniels and Kirkpatrick 2006, Burghardt et al. 2009, van Heezik et al. 2013) or several adjacent yards (e.g., Lerman and Warren 2011, McCaffrey and Mannan 2012). Studies from across the world have demonstrated that the composition and management of residential yards contribute importantly to urban bird conservation. For example, yards with native plants have been shown to support greater species richness and abundance of native species (notably insectivorous birds and birds of conservation concern) than yards landscaped with exotic plants (Burghardt et al. 2009), and a study in Phoenix showed that even a small number of native plants in a series of residential yards can attract native birds (Lerman and Warren 2011). Researchers in Australia found that multiple vegetation layers in residential yards were important influences on birds (Daniels and Kirkpatrick 2006); in particular, that study highlighted increased shrub cover and greater canopy height as important factors for native bird species richness. In general, more vegetated area within yards and more wildlife-friendly resources are linked with greater bird diversity (Goddard et al. 2013, van Heezik et al. 2013), although yard features such as birdfeeders have been linked with increased richness of exotic bird species (Daniels and Kirkpatrick 2006). Together, these studies highlight the importance of yards for urban conservation. Groups of yards, in the aggregate, may provide even greater biodiversity benefits; a matrix of wildlife-friendly yards could improve habitat connectivity and even add to the total habitat area for some species, especially when yards are located near existing patches (Rudd et al. 2002, Colding 2007, Goddard et al. 2009, 2013, Vergnes et al. 2012, 2013).

Here we investigate the relative importance of "bottom-up" yard characteristics relative to "top-down" neighborhood characteristics on native bird communities in residential neighborhoods throughout the Chicago, Illinois metropolitan region. To our knowledge, this study is the first to investigate the aggregated effects of many yard-scale decisions, including both front and back yards, at key locations near urban forest preserves. We combined and integrated standard methods and approaches of field ecology, geographic information systems (GIS) analysis, and social surveys, to address the following questions: (1) What is the relative importance of groups of yards ("bottom-up" influences) in explaining variation in native bird species richness outside of forest preserves; (2) which specific yard decisions, when implemented by multiple households, affect native bird species richness; and (3) how do different bird species groups (migratory, year-round residents, nonnative species) respond to specific bottom-up influences? The findings from this study can help guide urban conservation strategies by highlighting elements of residential yards that, if extended across large swaths of urban areas like Chicago, could increase native bird species richness.

Methods

Study sites

Cook County, Illinois is home to Chicago, the third most populous city in the United States, and almost 70 000 acres of forest preserves. Many of the forest preserves in Cook County are riparian corridors adjacent to major rivers (Fig. 1). We selected 25 transect sites in residential areas adjacent to linear riparian forest preserves along the North Branch of the Chicago River and the DesPlaines River and their tributaries. Each transect began 100 m from the edge of a forest preserve and extended 1 km outward into the adjacent neighborhood. Previous research in the Chicago region reported observations of neotropical migrants up to 0.5 km from large natural areas (Loss et al. 2009), so we used 1-km transects to encompass (and extend beyond) the hypothesized zone of spillover effect. In selecting the transects, we looked for areas extending outward from riparian forests that were dominated by residential land use for 1 km. Median household income per transect ranged from US\$45 000 to US\$191 000 (mean = US\$106 000; based on American Community Survey data 2005–2009; *available online*).[5] The transects also varied substantially in terms of housing density (minimum = 16 homes adjacent to a 1-km transect, maximum = 77 homes) and canopy cover (minimum = 20%, maximum = 46%, mean = 33%). Transects were located along streets and were at least 500 m apart to minimize spatial dependencies.

Estimation of bird species richness

We conducted bird surveys during the peak breeding season in the Chicago area, from 4 June to 6 July 2012.

[5] https://www.census.gov/acs/www/data_documentation/2009_5yr_data

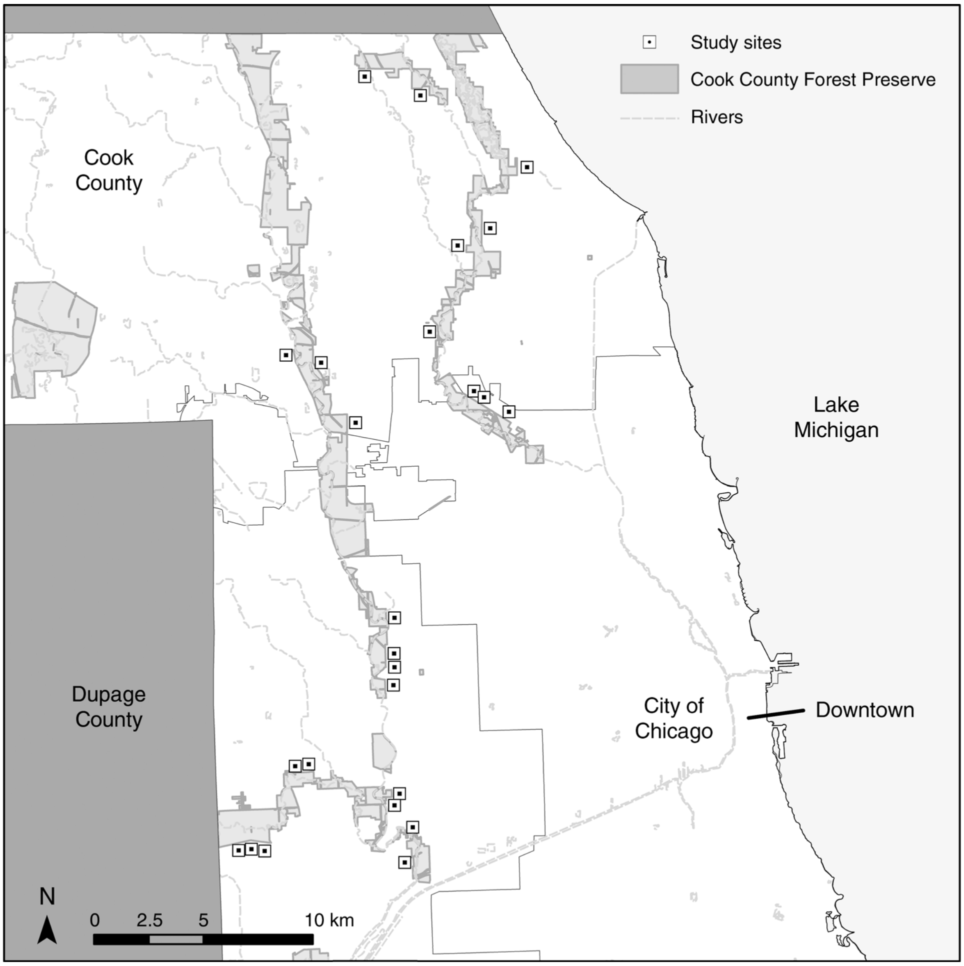

FIG. 1. Study area in Cook County, Illinois, USA. Site locations include 25 1-km transects adjacent to Cook County forest preserves.

A single observer (J. A. Belaire) conducted 5-min point counts at designated points every 100 m along each transect (on streets), and all birds seen and heard within 50 m of each point were recorded (Ralph et al. 1993). Bird surveys were conducted in one year, 2012, in order to coincide with the time when we gathered data about yard composition and management practices (with the social survey described in *Environmental variables in yards*). We summarized bird species presence/absence data at the transect level, such that presence of a particular species at a single point count location counted as a presence for that transect. Each transect was surveyed twice during the breeding season, and all point counts were conducted between sunrise and 10:00 on days with minimal wind and little to no precipitation. To ensure that birds were using the local habitat, we excluded from analyses all birds observed flying over the point, as well as species with broad-scale daily movement patterns (e.g., hawks) and species that were likely in-transit during migration. We calculated total species richness as the number of species present on a particular transect. We also classified species as native/nonnative and as migratory/year-round resident to evaluate responses of different groups (Appendix A).

Environmental variables in yards

We used a social survey instrument to gather information about yard design and management practices (Appendix B). We developed a questionnaire (following the guidelines of Dillman et al. [2009]) to ask residents whether their front and/or back yards contained any of the following wildlife resources: deciduous trees, evergreen trees, shrubs, plants with fruits and berries, flowers/herbs/vegetables, vegetation intended to attract birds, native vegetation, bird feeders, bird houses, water features, and brush piles or open compost areas (Box 1). We also asked about yard activities, such as insecticide application and whether the home has outdoor pets (Box 1).

We asked that the survey be completed by one adult with some responsibility for decisions about managing the yard. Surveys were distributed, along with a US$1

Box 1. Yard elements included in resident questionnaire

Wildlife resources
- Deciduous tree
- Evergreen tree
- Shrubs or bushes
- Plants with fruit or berries
- Flowers, vegetables, or herbs
- Vegetation planted with the goal of attracting birds
- Plants or trees native to the Midwest
- Birdfeeder
- Birdhouse or other nesting structure
- Water feature (excluding pools/hot tubs)
- Brush pile or open compost area

Yard activities
- Cat that spends time outdoors
- Dog that spends time outdoors
- Insecticide use

token financial incentive, to all single-family residences adjacent to each transect (Fig. 2) using the "drop-off/pick-up" method (Steele et al. 2001, Allred and Ross-Davis 2012) during July–September 2012. We distributed surveys to 1751 residences and received responses from 924 (overall 52.7% response rate). Response rates per transect ranged from 38.7% to 65.1%, with a mean transect response rate of 52.2% (per-transect minimum = 12 respondents, maximum = 57 respondents). After surveys were collected, we checked for non-response bias by comparing respondents to non-respondents in two ways: grass and canopy cover in yards (using 0.6-m QuickBird imagery; DigitalGlobe, Longmont, Colorado, USA) and socioeconomic characteristics (comparing survey responses to American Community Survey block group data). These checks indicated that residents who did not respond to the survey did not differ significantly from those who did respond with respect to either yard composition (grass cover and canopy cover) or socioeconomic characteristics.

Our goal was to summarize the characteristics of multiple yards, acting collectively as potential habitat, so we aggregated survey responses for each transect to determine the environmental characteristics of groups of yards. We estimated the total number of birdfeeders and outdoor cats and dogs by multiplying the proportion of survey respondents with each particular element by the number of residential parcels adjacent to the transect. We counted birdfeeders only if residents indicated that the feeder contained food at least several days per month. For yard vegetation variables, we used survey responses to calculate the proportion of all yards (including front and back yards) adjacent to a transect containing a particular vegetation type (e.g., percentage of yards with trees). We also used this method to find the proportion of yards on which insecticide is used, which can affect birds directly or indirectly (Pimentel et al. 1992, Mineau and Whiteside 2013). We expected that a greater ratio of evergreen to deciduous trees would be important for bird richness (Melles et al. 2003, Fontana et al. 2011). We therefore divided the proportion of yards with evergreen trees by the proportion of yards

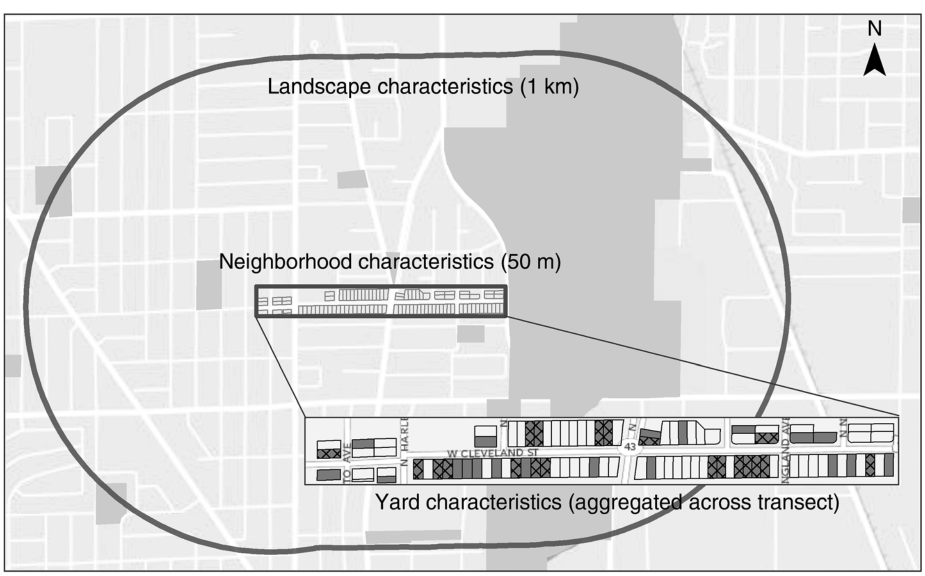

FIG. 2. Environmental characteristics were measured at yard-, neighborhood-, and landscape-level scales at each study site. Environmental characteristics were summarized with GIS layers at the neighborhood scale (50 m) and landscape scale (1 km) surrounding each 1-km transect. Yard characteristics were aggregated across a single transect (inset) based on survey responses. Parcels shaded in gray responded to the survey, while parcels in white did not; hatched parcels in this example indicate yards with plants that have fruit or berries.

Table 1. Environmental characteristics of 25 residential neighborhoods in Cook County, Illinois, USA.

Characteristics	Data source	Mean	SD	Min–max
Yard characteristics†				
Yards with trees (%)	resident surveys	88.9	9.0	67.9–100.0
Yards with plants that have fruit/berries (%)	resident surveys	34.2	9.9	18.3–58.3
Yards with trees (%) × yards with shrubs (%)‡	resident surveys	78.7	14.5	50.6–97.7
Ratio of evergreen to deciduous trees in yards	resident surveys	0.72	0.12	0.5–1.17
Yards with insecticide use (%)	resident surveys	35.5	13.3	16.7–66.7
No. outdoor cats	resident surveys	3.9	2.8	0–10.43
No. dogs	resident surveys	29.4	10.4	8.2–48.7
No. birdfeeders that contain food at least several days per month	resident surveys	21.2	7.0	7.9–37.53
Average no. wildlife resources per yard§	resident surveys	6.0	0.78	4.9–7.9
Neighborhood-wide characteristics				
Vegetation within 50 m (%)	2008 QuickBird imagery (0.6-m resolution)¶	72.4	7.8	57.7–88.1
Canopy cover within 50 m (%)	LiDAR	32.7	5.6	19.6–46.0
Landscape characteristics				
Canopy cover within 1 km (%)	LiDAR	28.1	5.1	17.1–38.1
Land classified as open space within 1 km (%)	CMAP 2005 Land-use Inventory (version 1.0)#	25.5	6.6	13.9–39.8
Distance to nearest river (m)‖	Esri rivers shapefile††	620.5	232.2	189.4–1264.7

Notes: All variables were summarized at the transect level. See *Methods* for descriptions of calculations for percentage and count variables. The range min–max shows the minimum and maximum values for each characteristic.

† Yard characteristics were aggregated for all front and back yards adjacent to each transect.

‡ Prior to analyses, each variable in the interaction term was centered prior to multiplying. However, for ease of interpretation, this table indicates values for the interaction term prior to variable centering.

§ Eleven possible wildlife resources were included in the questionnaire (see Box 1).

¶ DigitalGlobe, Longmont, Colorado, USA.

\# CMAP is the Chicago Metropolitan Agency for Planning; the Land-use Inventory is available online; see footnote 6.

‖ Distance to nearest river was measured from midpoint of transect.

†† Esri, Redlands, California, USA.

with deciduous trees and included this ratio as an environmental variable. Bird diversity has also been linked with structural diversity of vegetation (e.g., MacArthur and MacArthur 1961, Evans et al. 2009), so we multiplied the proportion of yards with trees by the proportion of yards with shrubs to represent the interaction of tree canopy with midstory plantings in yards. Finally, we calculated a summary variable for each transect to capture the average number of wildlife resources per yard, of the 11 possible options included in the questionnaire (Box 1).

Environmental variables in neighborhoods and landscapes

One of our goals was to determine the relative importance of decisions made about yards, as compared to the broader neighborhood or landscape, in terms of supporting native bird richness (Table 1). To describe characteristics of the immediate neighborhood that might also be important to birds (e.g., street trees, pocket parks, total green space [Strohbach et al. 2013]), we used ArcGIS 10.1 (Esri, Redlands, California, USA) to calculate percent canopy cover and percent vegetation within 50 m of each transect (Fig. 2). We also calculated two landscape-scale environmental characteristics within a 1-km buffer surrounding each transect (Fig. 2): amount of open space (includes forest preserves and all other publicly accessible land classified as open space) and percent canopy cover. We also calculated the distance to nearest river (Esri rivers shapefile; Table 1). We extracted canopy cover from LiDAR data, vegetation (all trees and grass) from 0.6-m resolution classified QuickBird satellite imagery, and area classified as open space from a Chicago-area land use map (CMAP [Chicago Metropolitan Agency for Planning] 2005 Land-use Inventory, version 1.0; *available online*).[6]

Model selection among yard, neighborhood, and landscape-scale characteristics

To address the relative importance of characteristics in yards, neighborhoods, and the broader landscape, we employed the information–theoretic model comparison approach to select among candidate linear regression models (Table 2). We defined seven candidate models to represent environmental characteristics at different spatial scales: (1) aggregated yard characteristics (i.e., summary variable for the average number of wildlife resources listed in Box 1 and the estimated number of outdoor cats), (2) neighborhood characteristics (i.e., percent canopy cover and percent vegetation within 50 m of each transect), (3) landscape characteristics (i.e., distance to nearest river, amount of open space within 1 km, and percent canopy cover within 1 km), (4) aggregated yards plus neighborhood characteristics, (5) aggregated yards plus landscape characteristics, (6) neighborhood plus landscape characteristics, and (7) combined yard, neighborhood, and landscape charac-

[6] http://www.cmap.illinois.gov/data/land-use/inventory

teristics (Table 2). We compared the seven competing models with Akaike's information criterion corrected for small sample sizes (AIC_c) (Burnham and Anderson 2002). This approach examines multiple working hypotheses simultaneously to identify the best-supported model or models and is useful for evaluating ecological hypotheses in complex systems when manipulative experiments are difficult or impossible (Johnson and Omland 2004).

Multi-model inference to identify important yard features

We examined all yard characteristics (Table 1) to identify specific elements within groups of yards with bottom-up influences on native bird species richness. We again used AIC_c to identify the best-supported model or models. When multiple models are well supported, multi-model inference can be used to make robust estimates of model parameters (Burnham and Anderson 2002). Our candidate models included all possible combinations of yard characteristics in linear models (i.e., the first eight variables in Table 1); none of these variables was strongly correlated with one another (Pearson's correlation coefficient <0.7 for all pairs). Environmental variables were standardized prior to modeling to convert all variables to a similar scale. The models were then ranked using the corrected AIC, and parameter estimates were averaged across all models with strong support ($\Delta AIC_c < 2$; Burnham and Anderson 2002). Relative importance of variables was also calculated by summing the Akaike weights over the best-supported models in which that variable was included. We used the MuMIn package as implemented in R for all model selection and model averaging procedures (Barton 2012).

Bird species groups' responses to yard features

To identify how different species groups responded to aggregated elements in yards, we developed an index for each yard-related variable for each bird species. The index was calculated by determining the average value of a variable across all transects where a species was present. For example, the Baltimore Oriole was found on eight transects; to calculate the outdoor cat index for this species, we found the average number of outdoor cats for those eight transects where it was observed. We then examined the indices for birds classified according to migratory status: migratory, year-round native resident, and nonnative species (Appendix A). We used Kruskal-Wallis tests (as recommended for small sample sizes) to identify whether species groups differed in their yard-related variable indices. When differences were detected, we then conducted post-hoc Wilcoxon-Mann-Whitney tests to identify the source of the difference. We did not use corrections for multiple comparisons because they can obscure important patterns in ecological studies (Moran 2003) and we were interested in exploring the relative effects of the full range of yard features.

Results

We observed a total of 36 bird species (excluding species observed flying over or likely in-transit species) across the study sites, with American Robin (*Turdus migratorius*), American Goldfinch (*Spinus tristis*), Northern Cardinal (*Cardinalis cardinalis*), and House Sparrow (*Passer domesticus*) being most widespread. Eight species were observed at only a single transect. Twenty of the observed bird species were migratory, 12 were year-round native residents, and four were nonnative species. Species richness ranged from 11 to 21 bird species across the 1-km transect (16 ± 0.43 bird species; mean $\pm$ SE).

Resources in front and back yards

Survey responses from over 900 residents allowed us to analyze the vegetation types, management techniques, and yard features incorporated into residential yards. We verified survey responses by assessing the presence of two vegetation categories (shrubs and deciduous trees) in the front yards of 50 respondents, and found 90% agreement between survey responses and our own assessment. Over one-half of all respondents (55.0%) reported vegetation in their yards that has fruit or berries (although the proportion of yards on a transect with fruit-bearing plants varied substantially across the study area; Table 1). Over one-third (34.4%) of all respondents had a birdfeeder in their yard, and 80.5% of those with birdfeeders reported that the feeder is filled with food for several days per month or more during the summer months. The average respondent indicated a presence of 5.9 wildlife resources on his/her parcel, of the possible 11 options included in the questionnaire (Box 1).

Native bird species richness and spatial scales

From the seven candidate models, the model representing the aggregation of yard characteristics alone was the best supported (lowest AIC_c value and high Akaike model weight) for native bird species richness (Table 2). This model explained 42.3% of the variance in the number of native bird species observed per transect. The average number of wildlife resources per yard had a positive influence on native bird species richness, while the influence of outdoor cats was negative. The second-best model, which included the combination of yard and neighborhood characteristics, had considerably less support ($\Delta AIC_c = 6.46$ and Akaike weight of 0.04).

Yard elements linked with native bird species richness

When we focused on the relationship between aggregated yard characteristics and native species richness, eight models were highly supported ($\Delta AIC_c < 2$). The following variables were included in those models: the ratio of evergreen to deciduous trees, the percentage of yards containing plants with fruit or berries, the number of outdoor cats, the percentage of front and back yards with trees, the percentage of yards

TABLE 2. Alternate models of native bird species richness, representing environmental characteristics at three spatial scales.

A priori models	Wildlife resources per yard	Outdoor cats	Vegetated area within 50 m	Canopy cover: Within 50 m	Canopy cover: Within 1 km	Open space within 1 km	Distance to nearest river	AIC_c	ΔAIC_c	K	w_i	R^2
Aggregated yard characteristics	x	x						104.3	0.00	3	0.93	0.42
Aggregated yards + neighborhood	x	x	x	x				110.7	6.46	5	0.04	0.43
Aggregated yards + landscape	x	x			x	x	x	112.7	8.38	6	0.01	0.47
Neighborhood characteristics			x	x				113.4	9.23	3	0.01	0.17
Landscape characteristics					x	x	x	115.0	10.70	4	0.00	0.22
Neighborhood + landscape			x	x	x	x	x	118.4	14.12	6	0.00	0.34
All scales	x	x	x	x	x	x	x	121.7	17.44	8	0.00	0.48

Notes: Cells with x indicate variables that are included in each model. Data were collected from 25 residential neighborhoods in Cook County, Illinois, USA. AIC_c is Akaike's information criterion (AIC) corrected for small sample sizes. ΔAIC is the difference in AIC_c between each model and the "best" model. Models were ranked by ΔAIC_c, which seeks to balance model fit with model complexity. K is the number of predictor variables plus intercept and w_i is the Akaike model weight. Weights are normalized across the set of models to sum to one.

with insecticide use, and the number of dogs. The ratio of evergreen to deciduous trees in groups of yards had the greatest relative importance (sum of Akaike weights for models in which the variable was included = 1.00) and standardized model-averaged regression coefficient (1.01, P = 0.02; Fig. 3). The percentage of yards containing plants with fruit or berries and the number of outdoor cats on a transect were also important variables for native bird species richness (relative importance of 0.43 and 0.55, respectively), although the effect of fruit/berries was positive (standardized model-averaged coefficient of 0.75, $P = 0.07$) while the effect of outdoor cats was negative (–0.51, P = 0.08). The percent of front and back yards with trees was also important (relative importance of 0.38), with a positive association with native bird richness (standardized model-averaged coefficient of 0.68, $P = 0.08$). The two variables that were not included in any of the best-supported models were the number of birdfeeders along a transect and the interaction of trees and shrubs within yards. The average R^2 for the set of best-supported models was 0.47.

Yard characteristics linked with species groups

Kruskal-Wallis tests indicated differences between species groups for six of the nine yard variables: percentage of yards with trees (P = 0.02), the ratio of evergreens to deciduous trees (P = 0.03), percentage of yards with fruit/berries (P = 0.07), average number of wildlife-friendly resources per yard ($P = 0.07$), number of outdoor dogs ($P = 0.07$), and number of outdoor cats (P = 0.06). Post hoc Wilcoxon-Mann-Whitney tests revealed significant differences between migratory birds and nonnative species for those six variables (Fig. 4). Migratory birds, as a group, were more frequently observed on transects with more trees in yards (mean = 91.6% of yards with trees, compared to 85.4% for exotic birds), more plants with fruit or berries (mean = 39.5% of yards with fruit/berries; 31.7% for exotic birds), a greater number of wildlife resources on average (mean = 6.3 resources per yard; 5.8 for exotic birds), and higher ratios of evergreens to deciduous trees (mean = 0.79 evergreens per deciduous tree; 0.68 for exotic birds; Fig. 4).

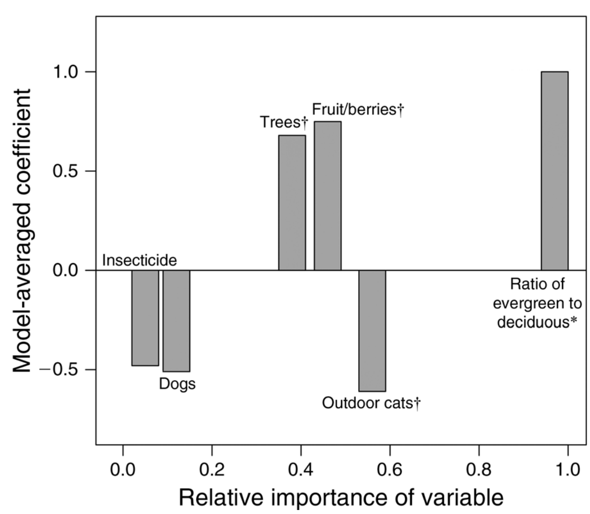

FIG. 3. Relative importance and effect size of aggregated yard elements in models for native species richness. Yard characteristics are ordered from left to right along the x-axis in order of relative importance, as calculated by summing Akaike weights for the best models (ΔAIC < 2) in which this variable is included. The y-axis is the standardized model-averaged coefficient for the variable (averaged across models in which this variable is included). Symbols after variable names indicate statistical significance.

† $P < 0.10$; * $P < 0.05$.

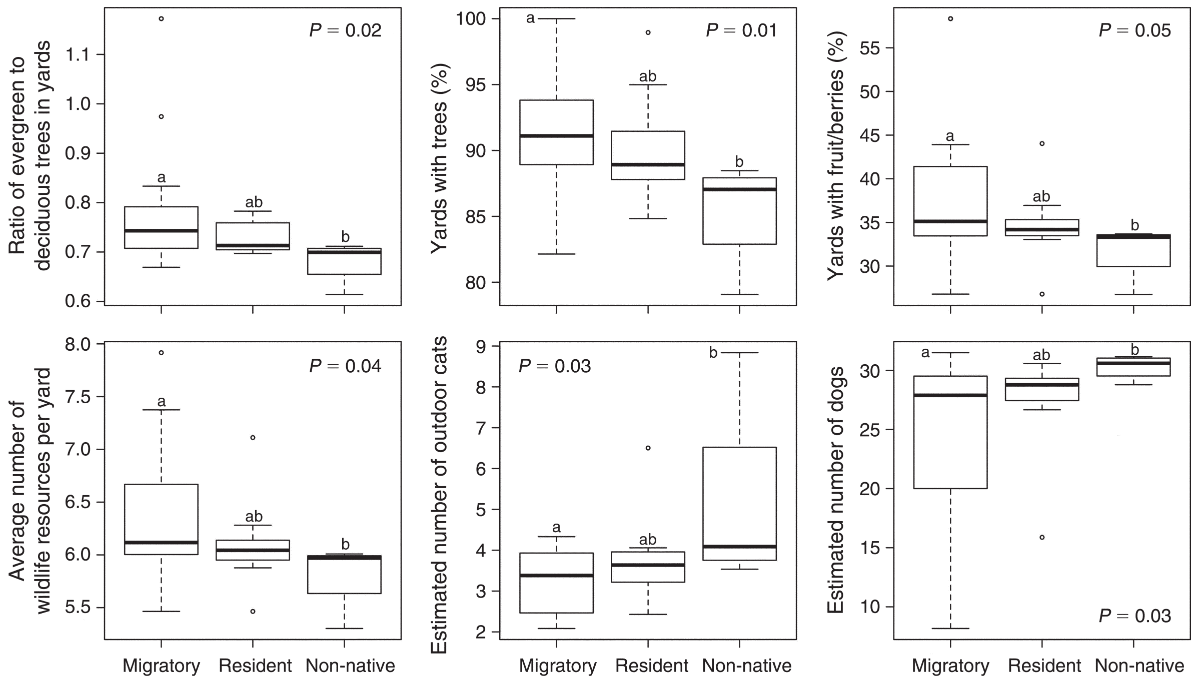

FIG. 4. Yard characteristics for migratory, year-round resident, and nonnative birds. Boxplots indicate quartiles, bold lines showing median values, whiskers extend to the most extreme value within 1.5 times the interquartile range, and open circles represent outliers beyond those values. Differences between native migratory group and nonnative group are significantly different (*P* values for Wilcoxon-Mann-Whitney test displayed in upper portion of each plot) for all variables displayed here.

Migratory birds were also found on transects with the fewest outdoor cats (mean = 3.2 cats per transect; 5.1 for exotic birds) and fewest dogs (mean = 24.4 dogs per transect; 30.3 for exotic birds). There were no significant differences between species groups for birdfeeders, tree–shrub interaction term, or insecticide use.

DISCUSSION

This study demonstrates the importance of yard design and management decisions for native birds in Chicago-area residential neighborhoods. We compared environmental variables within yards, neighborhoods, and the broader landscape, and found very strong support for the yards-only model in describing native bird species richness. The collective effects of yard design and management activities were strongly linked with the native bird diversity along a transect; in particular, the percent of yards on a transect with fruit/berries and ratio of evergreens to deciduous trees were positively associated with native bird richness, while the number of outdoor cats on a transect had a negative association. We also found significant differences in the yard characteristics associated with migratory birds and nonnative birds: migratory birds were observed on transects with more wildlife-friendly features, on average, and nonnative birds were observed on transects with greater numbers of outdoor cats.

Role of residential yards in the urban conservation puzzle

Our study joins a growing body of research indicating that yards play an important role for urban biodiversity (e.g., Daniels and Kirkpatrick 2006, Lerman and Warren 2011), making a strong case for residential matrix management as a conservation strategy (Cooper et al. 2007). Management efforts that address the quality of the matrix, in combination with that of parks, reserves, and open areas, will maximize the ecological value of cities (Marzluff and Rodewald 2008). Previous multi-scale studies for urban birds have demonstrated the importance of habitat variables at both local and landscape scales (e.g., Hostetler and Holling 2000, Melles et al. 2003, Pennington and Blair 2011, McCaffrey and Mannan 2012), although a recent review of 72 urban bird studies suggests that variables at the local scale are more important than those at broader scales for urban bird species richness (Evans et al. 2009).

Our results suggest that urban conservation agendas would benefit from "thinking outside the park" (Marzluff and Rodewald 2008) and highlighting to residents the positive collective effects of minor yard enhancements. Recent research indicates that people are more interested in taking actions when the positive aggregated effects of small behavioral changes are highlighted (Dickinson et al. 2013). Informal programs like Cornell Lab of Ornithology's YardMap and the National Wildlife Federation's Community Habitat program provide platforms for organizing neighbors and sup-

PLATE 1. Groups of Chicago-area yards provide important resources for urban birds. A mix of evergreen and deciduous trees in yards, as shown here, is linked to increased native species richness. Photo credit: E. S. Minor.

porting ecological goals across multiple yards. Grassroots efforts that focus on interactive dialogue with residents, rather than top-down education or incentives, have been demonstrated to be successful in catalyzing yard changes in several studies (van Heezik et al. 2012, Goddard et al. 2013). Formal institutions, like homeowners associations, may also provide a means for organizing the landscaping and management practices of many yards simultaneously, thereby increasing the bird and plant diversity of residential areas (Lerman et al. 2012). Moreover, municipal programs could provide incentives for residents to design and manage their yards in wildlife-friendly ways. For example, the City of Chicago's Sustainable Backyard Program currently offers rebates to city residents for elements such as native plants and trees purchased for yards. This program could also highlight elements shown to be important in Chicago-area neighborhoods (e.g., evergreen trees, plants that provide fruit/berries) to help promote wildlife-friendly elements as part of a Sustainable Backyard.

Residential neighborhoods play another important role in the conservation puzzle: they provide a major opportunity to reconnect people with wildlife (DeStefano and DeGraaf 2003). Our results indicate that Chicago-area residents share their neighborhoods with a surprising number of bird species (mean = 16 species), although bird diversity is not evenly distributed across all residential neighborhoods in our study area (minimum = 11 species, maximum = 21 species). Previous research in Chicago indicated that neighborhoods dominated by low- to mid-income Hispanic populations had significantly fewer bird species than other neighborhoods in the city (Davis et al. 2012), which aligns with results from Phoenix, Arizona, USA as well (Lerman and Warren 2011). We found a weak but positive relationship between native bird species richness and median household income (J. A. Belaire, *unpublished data*). Yards may be part of the solution to this potential environmental justice concern, because they are widespread and easily accessible for many residents. People who design or manage their yards to attract wildlife report positive impacts on their quality of life or emotional well-being (Goddard et al. 2013), and recent research suggests that when urban residents develop an awareness and understanding of the biodiversity around them, they may be more likely to engage in pro-conservation behavior (Cosquer et al. 2012, van Heezik et al. 2012).

Implications of specific yard design and management activities for bird diversity

Management efforts to improve the wildlife-friendliness of yards could reduce the effective isolation of patches (Ricketts 2001, Rudd et al. 2002) and even provide additional habitat for some bird species in cities by "expanding" the total area of habitats in parks and preserves (Chamberlain et al. 2007). We found that several key elements within groups of yards are linked with native bird diversity (Fig. 3) and could be used to enhance the matrix quality in residential neighborhoods.

First, we found that more yards with trees, especially a more balanced mix of evergreens and deciduous trees, support greater native bird diversity (Fig. 3) and numbers of migratory birds (Fig. 4). Studies in urban green spaces have also highlighted the importance of mixing evergreens with deciduous trees to support bird species richness (Fontana et al. 2011, Ferenc et al. 2014), and in residential areas, coniferous trees have been linked with increased likelihood of species presence for a variety of birds (Melles et al. 2003). Trees in yards, especially a combination of evergreens with deciduous species, may enhance bird richness by adding habitat complexity and vertical structural diversity to residential areas where the landscape is often more savannah-like with less vegetation at mid- and upper-canopy levels (see Plate 1).

Second, we found that the percent of yards with plants containing fruit or berries had a strong positive effect on native bird richness. In contrast, the number of birdfeeders along a transect was not an important variable in any of the best-supported models ($\Delta AIC_c < 2$) for native bird species richness. This could be because many of the birds in our study rarely or never visit birdfeeders (14 of the 32 native species are considered uncommon or extremely rare at birdfeeders), whereas almost 70% (22 of 32) of the native birds we observed eat fruits or berries at some time during the year (Ehrlich et al. 1988). Although much recent research has focused on the role of bird feeders in structuring urban bird assemblages (Fuller et al. 2008, Robb et al. 2008, Evans et al. 2009), our results suggest that yard vegetation is also an important food resource. Melles et al. (2003) reported a similar finding when evaluating habitat variables at small spatial scales (50 m): the presence of large berry-producing shrubs often explained the presence of multiple bird species, while the presence of a birdfeeder did not.

Third, we found that the number of outdoor cats on a transect was negatively linked with native species richness (Fig. 3). Furthermore, nonnative bird species, on average, were observed on transects with above-average numbers of outdoor cats (Fig. 4). A growing body of research suggests that cats have significant consequences for urban bird communities (van Heezik et al. 2010, Stracey 2011, Thomas et al. 2012). Native birds may be especially at risk; Loss et al. (2013) reported that cats preyed primarily on native bird species. Many of the native migratory bird species observed in our study were open-cup nesters (14 of 20), which may make them especially vulnerable to nest predation (Stracey and Robinson 2012). On the other hand, the nonnative species we observed are cavity nesters (e.g., House Sparrow, European Starling) or frequently use human-built structures for nesting (e.g., House Finch), which likely make them inaccessible to predators (Stracey and Robinson 2012). This may explain our finding that native birds (especially migratory species) seem to be more sensitive to the number of outdoor cats than nonnative birds (Fig. 4). Another possible explanation is that the mere presence of cats, which are top predators in urban systems, may induce fear in their prey and subsequently affect their habitat use and behavior (Brown et al. 1999, Becker et al. 2007, Ale and Whelan 2008, Bonnington et al. 2013). For example, birds have been shown to adjust nest placement in response to nest predation (Marzluff 1988) and appear to discern between safe and dangerous habitats and adjust their use of the landscape accordingly (Forstmeier and Weiss 2004, Eggers et al. 2006, Laundre et al. 2010). Two important limitations to our study are that we did not conduct on-the-ground cat surveys to verify the estimates of cat numbers based on survey responses, and we included only pet cats in our analysis, although stray or feral cats may cause the majority of bird mortality (Loss et al. 2013). Nonetheless, efforts to prevent outdoor access by cats, especially at night (Stracey 2011), could enhance native bird diversity in the residential matrix. Outdoor dogs were not as important as outdoor cats for native bird species richness, but we did find that nonnative birds, on average, were observed on transects with more dogs, whereas migratory bird species were observed on transects with fewer dogs. Previous studies have found that the presence of dogs had a neutral (Parsons et al. 2006, Meffert and Dziock 2012) or negative effect on urban birds (Banks and Bryant 2007), and our results suggest that limiting the number of outdoor dogs could be a boon to more-sensitive bird species.

Conclusions

This study adds to the growing body of evidence that bottom-up influences, that is, the characteristics of residential yards, impact urban biodiversity (Kinzig et al. 2005, Daniels and Kirkpatrick 2006, Burghardt et al. 2009, Lerman and Warren 2011, Goddard et al. 2013). Here, we demonstrated that the aggregated effects of individual yard design and management decisions are linked with native bird richness in residential areas. Yards, collectively, comprise a major component of the land area in urban areas and "could be places for the most creative urban nature interventions" (Beatley 2011). Our results suggest several complementary ways to do this, including planting fruiting shrubs or trees, increasing presence of evergreen trees, and restricting outdoor activities of both cats and dogs, all of which could be promoted by homeowners associations, municipal incentive programs, and conservation groups communicating with residents. Why not ask more from our residential landscapes?

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Supplemental Material

Ecological Archives

Appendices A and B are available online: http://dx.doi.org/10.1890/13-2259.1.sm