7

STATE OF THE BIRDS IN EXURBIA

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ABSTRACT

Low density rural sprawl, or exurban development, results in significant negative impacts on wildlife including birds. We describe the results of a decade of field studies to document the response of birds and other taxa to exurban development in the Park. We have investigated: the size of the ecological impact zone associated with exurban houses and roads in the Adirondacks, the characteristics of avian communities before and after residential construction, whether exurban development alters the health of individual birds, whether the ecological context of the development regulates the intensity of its impacts, and how individual land ethics and land use decisions, operating with a regional land use context, shape human impacts on biological communities. We briefly describe these studies and draw conclusions across them to provide insight into the state of the birds in the exurban Adirondacks. Broadly, we find that: the size of the impact resulting from exurban development can exceed its physical footprint significantly, changes in avian communities associated with exurban development do not appear to be driven solely by the associated road network, these changes can be very rapid and are consistent across some taxa and ecosystems, predation pressure may be a key mechanism, the attraction effect of exurban development may be stronger than the deterrent effect, and the most prevalent pattern of change is one of simplification of avian communities. Neotropical migrants may be a particularly sensitive group in the Adirondacks.

KEYWORDS:

Adirondacks, bird community, biotic homogenization, exurban development

INTRODUCTION

Exurban development, or low-density rural sprawl, has significant consequences for wildlife habitat and populations (Reed et al. 2012). It is, at the same time, increasingly prevalent in the Adirondacks and beyond. Driven in part by proximity to natural amenities, exurban development consumes land and converts it to residential use at a rate 10 times that of urban and suburban development combined (Heimlich and Anderson 2001). Exurban development generally refers to development that occurs outside of the boundaries of incorporated cities and towns and is characterized by lot sizes in the range of 5-40 acres or more (Knight 1999, Theobald 2004). It is commonly believed that, because the matrix in which these dispersed homes are built remains in its original ecosystem type, the effects to wildlife from such a development pattern are minimal (Maestas et al. 2001). Recent work in the Adirondacks and elsewhere, however, suggests that significant changes to community structure, species behavior, and human-wildlife conflict patterns may occur as a result (Baron 2004, Casey et al. 2009, Glennon and Kretser 2013, Glennon et al. 2014, Hansen et al. 2005, Kretser et al. 2008, Odell and Knight 2001, Suarez-Rubio et al. 2011, Suarez-Rubio et al. 2013).

We have been investigating the impacts of exurban development on birds and other wildlife in the Adirondacks since 2004. Using a variety of research approaches and techniques, we have executed a number of field projects in the Park to bring to bear evidence from our own local ecosystem into discussions about the future of the park and the important land-use management decisions that govern that future. We have asked a variety of questions in an attempt to address some of what we consider to be the most critical issues facing this landscape with respect to private land development and its consequences for wildlife communities. These questions include: (1) what is the size of the ecological impact zone associated with exurban development in the Adirondacks, (2) what is the size of the ecological impact zone associated with rural roads in the Adirondacks, (3) what are the characteristics of wildlife communities before and after residential construction, (4) does exurban development alter the health of individual animals in the Adirondacks, (5) does the ecological context of the development regulate the intensity of its impacts, and (6) how do individual land ethics and land use decisions, operating with a regional land use context, shape human impacts on biological communities? This paper constitutes an effort to provide an overview and basic description of each these studies and to draw conclusions that have resulted from this long-term research effort.

In all of this work we have taken advantage of the wealth of species diversity provided by the Adirondack avifauna. Birds serve as ecological indicators more often than most taxa, both for their ease of sampling and the high numbers of species—and thus ecological functions—often represented. This is the case in the Adirondacks as much as anywhere. Species richness of birds in the Park is an order of magnitude higher than that of other

terrestrial vertebrates. The breeding birds of the Adirondacks span nearly 200 species distributed among 17 orders and 46 families. They make use of a wide variety of habitat types and, among them, represent a great diversity of breeding, feeding, and habitat guilds. As such, we can use birds as a powerful tool to investigate mechanisms of change within their communities. At the same time, the birds of the Adirondacks also constitute a range of commonness and rarity. Among them, more than 50 are considered species of greatest conservation need in New York by the Department of Environmental Conservation, and more than 50 have state rankings that indicate that they are limited to fewer than 100 occurrences statewide. While overlaps exist across these lists, they are not mutually exclusive. The work described here encompasses our efforts both to understand the impacts to Adirondack birds from this particular threat—that is, to describe the state of the birds in exurbia—and to provide suggestions for how that impact might be mitigated, particularly for those species that may be sensitive or rare.

STUDY AREA

All of our work has taken place in the Adirondack Park, and some of it has also occurred beyond the park. Within the Park, our studies have focused primarily in Essex County. The reason for this has been twofold: (1) we are located in Saranac Lake and the costs of working in more distant areas of the park have been prohibitive, (2) at the time we began our field studies, Essex County was the only one for which we had parcel data and boundaries for use in GIS. Being able to identify the owner is critical for any study making use of private lands. Essex County is 4,652 km^2 (1,794 mi^2) and has 39,000 residents. Most of Essex County is a heavily forested region in which natural openings are created primarily by wetlands and water bodies and is not heavily fragmented (Glennon et al. 2014). It is, however, the most highly populated county in the Park and the one in which numbers of building permits issued for new residential structures have been shown to exceed all other counties (Bauer 2001).

METHODS

House Distance Effect

This study was aimed at determining the ecological impact zone, or house distance effect associated with exurban development in the Adirondack Park. We borrowed methodology from a study that had asked the same question in Pitkin County, CO (Odell and Knight 2001), sampling birds at increasing distances from individual exurban homes. From among an initial selection of 136 parcels, we identified 30 willing landowners in Essex County within the towns of North Elba, Harrietstown, St. Armand, and Wilmington and visited each home twice during summer 2008. We used a standard point count methodology (Ralph et al. 1995) to sample the bird community at the forest/lawn edge, at 200 m into surrounding forest, and again at 400 m. We considered the 400 m (0.25 mi) distance to represent interior forest conditions. Point counts, the same method that has been used in all of our bird studies in the

Adirondacks, constitute a 10 minute period of time in which all individuals of songbirds (*Passeriformes*) or woodpeckers (*Piciformes*) seen or heard are noted (this method is not appropriate for other types of birds). The sample period is divided into three time segments for the purpose of comparing with bird data from other programs, and, in addition to species, activity (i.e., singing, calling, or individual seen) and distance to observer (i.e., within or beyond 50 m) are noted. Data are also recorded for factors which may impact both bird activity and our ability to successfully detect birds including date, temperature, time of day, wind and sky conditions, and observer identity. All counts are conducted during the peak of breeding activity (approximately late May to early/mid-July for the Adirondacks), between 5:00 and 9:00 a.m., and are not conducted during rain or high wind. We repeated counts twice at each house and used occupancy modeling (MacKenzie et al. 2006) to examine differences in occurrence of human-sensitive, human-adapted, and neutral species at increasing distances from residential structures. This study is fully described in Glennon and Kretser (2013).

Road Distance Effect

Because exurban development does not occur in the absence of roads, and because we wanted to determine whether observed impacts to bird species arose as a result of houses or the associated road network, we repeated the house distance effect methodology in the context of roads to determine the extent to which impacts from residential roads permeated into nearby intact forest. We chose a set of roads that represented a gradient of intensity of use and traffic levels and classified them into three broad categories of increasing impact based on a variety of characteristics including elevation, surface (paved/unpaved), canopy (open/closed), width, average speed, average annual daily traffic, and surroundings (nearby density of houses and roads, distance to water/wetland). We used the same point count method to sample birds at the road/forest edge, 200 m, and 400 m into interior woods to determine the potential impacts of both distance to road and road type on avian communities. We used occupancy modeling to examine changes in representation of birds within family groups among road types and at increasing distances from individual roads. This study is described more fully in Glennon and Kretser (2012a).

Before and After Effect

The majority of studies that have looked at the impacts of residential development on wildlife have focused on existing development; opportunities to examine the impacts of development as it occurs are relatively rare and almost no studies have been conducted comparing pre- and post-development fauna in any ecosystem type (Hostetler et al. 2005). Albeit with a small sample size, we followed wildlife communities pre- and post-development for two new homes constructed in the Adirondacks in 2009 with the goals of measuring the community of songbirds, small mammals, carnivores, amphibians, and plants before and after residential development and characterizing changes to these taxa brought

about by development. In addition to point counts of songbird and woodpecker communities as described above, we also sampled small mammal communities with live trapping and track tube detections (Glennon et al. 2002), large mammals with infrared camera traps (O'Connell et al. 2011), amphibians via timed searches, and plant communities via standard habitat sampling methods (Simon et al. 2001). We conducted surveys of the terrestrial vertebrate communities in 2008, prior to home construction, and again in 2010, one year post-construction, for both locations. At one of the sites we were also able to conduct sampling during the construction process in 2009. We also sampled at nearby control sites without development for both locations, but this design did not serve as a perfect before-after-control-impact (BACI) experiment because controls were not added until 2009. We used an occupancy modeling approach to investigate changes to these ecological communities after construction, using a multi-season model to explore changes in the members of the species pool present at each site after construction (MacKenzie et al. 2006). We modeled changes to relative species richness after construction for bird, small mammal, and amphibian communities and investigated the likelihood of local colonization and extinction at each of these sites based on body size and family as well as population, reproductive, activity/movement, habitat use/preference, and feeding/foraging characteristics. This study is described more fully in Glennon and Kretser (2012b).

Individual Health Effect

The majority of our work has focused on changes to the structure of bird communities as a result of exurban development, but we are also interested in the potential effects of development on wildlife health at the individual level. Capitalizing on an existing concurrent study for which landowner permissions had been previously secured, we examined the impacts of exurban development on a forest songbird, the ovenbird (*Seiurus aurocapilla*) breeding in areas with and without exurban housing development. We captured 62 male ovenbirds in areas of exurban housing and nearby control sites using a playback recording and mist nests deployed in the vicinity of a singing male. All birds were captured between 6:00 a.m. and 12:30 p.m. EST in early June 2012 and 2013 during the peak of the breeding season for this species. We collected up to 150 µL of blood via brachial venipuncture with a 26-gauge needle into heparinized capillary tubes immediately following capture. We also measured wing length and body mass and aged birds as second year or after second year based on plumage (Pyle 1997). We compared physiological condition of these birds using a variety of blood parameters including hematocrit volume and plasma triglyceride levels to compare energetic condition, plasma uric acid and total plasma protein levels to compare diet quality, and heterophil:lymphocyte ratios to compare chronic stress. Blood plasma samples were shipped to the Rochester Institute of Technology for analysis. Full details of this study are provided in Seewagen et al. (2015).

Ecosystem Effect

Hansen et al. (2005) stress that the effects of exurban development on biodiversity likely differ among ecosystem types and highlighted the need for research to derive generalities on the types of ecosystems that may be particularly vulnerable. We set out to address this question, in part, by comparing two contrasting ecosystems—that of the northeast temperate forest of the Adirondack Park and the shrub-steppe system of the Greater Yellowstone Ecosystem in Montana. We hypothesized that impacts to bird communities would be greater in the relatively homogeneous, closed canopy Adirondack forest of northern New York State than they would be in the more naturally heterogeneous grasslands interspersed with trees and shrubs of Madison County, MT. We sampled bird communities via point counts distributed in three exurban subdivisions and paired control sites here in the Adirondacks and in Madison County, MT. All sampling was conducted by a single observer in each landscape, and all counts were conducted in June and early July 2007, with each site counted twice during the season. We examined birds within five functional groups expected to be responsive to exurban development including area-sensitive, low-nesting, Neotropical migrant, microhabitat specialist, and edge specialist guilds, comparing relative abundance within subdivisions and control sites across these two regions. Full details of this study are provided in Glennon et al. (2015).

Bigger and Better Ecosystem Effect

The study described above was executed as a single-season pilot study in 2007. Results of this small-scale study were intriguing enough that we have pursued the work on a much larger scale and have continued to investigate the broad question of the relative sensitivity of these two different ecosystem types to the same development pattern. In summers of 2012-2014, we again sampled bird communities in exurban subdivision and control sites in the Adirondack Park and Greater Yellowstone Ecosystem, in this instance working in seven subdivisions and matched control areas in Essex County, NY and Madison County, MT and working directly on the lands of 80-100 private landowners in each landscape.

We sampled birds via point counts as previously described and also examined potential effects of exurban development on reproductive success of birds by locating and monitoring bird nests to document successful or unsuccessful nesting attempts. In addition to birds, we sampled mammal and plant communities, nighttime light disturbance, and acoustic characteristics in subdivisions and control sites. Plants were sampled via standard habitat sampling methods at all point count locations and around all nests after nesting was completed (Fletcher and Hutto 2008, Martin et al. 1997). Mammal communities were sampled via remotely-triggered trail cameras (O'Connell et al. 2011) deployed along trails and other likely pathways of mammalian carnivore movement. Nighttime light disturbance was sampled via protocols developed in collaboration with the National Park

Service Natural Sounds and Night Skies Division. Ambient sound characteristics in exurban subdivisions and control sites were sampled via autonomous recording units developed by Brown et al. (2013) and deployed for ≥10 days. Social research methods were used in concert with ecological survey methodologies to document and describe values, attitudes, behaviors, and practices of exurban homeowners in both landscapes. This was accomplished via standard 4-wave mail surveys and semi-structured interviews (Dillman 2000, Babbie 2010).

Our aim with this recently-completed project is to delve much more deeply into the cross-site comparison of Adirondacks—Greater Yellowstone and to test, specifically, how individual land ethics and land use decisions, operating within a regional land-use context, shape human impacts on biological communities and how understanding this relationship can yield better management opportunities and potentially ecologically healthier landscapes. Our objectives are to (1) relate avian community structure and reproductive success at a local scale to landowners' land ethics and practices, (2) compare the relative roles of human disturbance versus alteration of habitat structure in controlling avian community structure and reproductive success in exurban subdivisions, (3) determine the effects of local versus landscape level habitat attributes on avian community structure and reproductive success in exurban environments, and (4) determine the extent to which the magnitude of the effects of exurban development on avian communities across diverse landscapes can be explained by the large scale connectivity and resilience of the encompassing regions.

RESULTS

House Distance Effect

In our examination of the ecological impact zone associated with exurban development in the Adirondacks, we found that bird communities were altered up to 200 m from exurban homes (Glennon and Kretser 2013). Occupancy rates for human-adapted and human-sensitive species were different (36% higher and 26% lower, respectively) at points near homes versus those in surrounding forest (Figure 1). A 200 m distance effect translates to an area of 13 ha (31 acres) and suggests that the ecological impacts of development may far exceed its physical footprint. Our findings were very similar to those of a similar study in Pitkin County, CO (Odell and Knight 2001).

Road Distance Effect

We found that the ecological impact zone associated with rural roads in the Adirondacks was similar in magnitude to that of the house distance effect (~200 m) but that different mechanisms are probably operating in these two circumstances (Glennon and Kretser 2012a). In this instance, we did not have a priori expectations of particular bird groups that would respond positively or negatively to roads and therefore analyzed birds within

family groups. Also, because our selection of roads included a variety of characteristics and relative use levels, we investigated the impact of road type on avian communities. We found that, at the species level, the road type (hypothesized intensity of impact) more strongly influenced response of birds than did distance to road, with larger, paved, high-traffic roads having stronger impacts on adjacent bird community composition than smaller, unpaved, closed-canopy roads. When grouped into families, however, birds responded more strongly to the distance from the edge of the road than to the road type, suggesting that responses to roads are highly species specific. Similar to the house distance study, we identified a variety of responses of birds to roads, with sparrows attracted to road edges, and cardinal allies deterred by them. Most interestingly, however, a third group of birds (crows and jays) had high occupancy at road edges and in interior forest (400 m), but low occupancy at 200 m from the road (Figure 2). We do not have a simple biological explanation for this pattern.

Before and After Effect

Our examination of pre- and post-development impacts on bird and other wildlife communities revealed patterns in the types of species that appeared most and least sensitive to residential development. For the most part, relative species richness increased after homes were constructed, but underlying community structure changed (Glennon and Kretser 2012b). For birds, probability of colonization after construction was most closely tied to migratory strategy, where local extinction probability was most closely related to clutch size, feeding guild, and migratory strategy (Figure 3). Longer distance migrants, Neotropical birds, were less likely to colonize and more likely to be lost from the sites, whereas year-round residents more likely to be found around the construction site. These patterns were mirrored in small mammal community changes as well, with bird and mammal species most likely to colonize and/or persist after residential construction being those who (1) nested in protected spaces (i.e., cavity, underground), (2) made use of numerous food sources (i.e., omnivores), and—within the context of these species groups—those that (3) had larger body size and longer lifespan. Conversely, bird and small mammal species most likely to decrease in abundance and/or decline post-construction were those who (1) nested on the ground, (2) specialized in just one or two food sources, and (3) were of smaller body size and shorter lifespan. These findings suggest that significant changes to wildlife communities result from residential construction, even within very short time spans.

Individual Health Effect

Among the physiological condition indices measured in our examination of individual health effects of exurban development on ovenbirds, we found that only hematocrit volume (HCT) differed for birds captured in exurban subdivisions and nearby control areas, with birds near houses exhibiting lower values (Seewagen et al. 2015). HCT is a widely reported

hematological indicator of overall health in field studies of birds but is, at the same time, difficult to interpret and often discounted as a reliable index and not recommended as a sole indicator. The comparable values for all other blood parameters measured between subdivisions and control sites suggests that ovenbird food quality and availability were unaffected by exurban development in our study area and that exurban development does not significantly change chronic stressors faced by breeding male ovenbirds in these environments. We also found no difference in body mass, body size, or age ratio to indicate that habitats in either treatment type were in higher demand or more difficult to acquire. Effects of exurban development on this species may instead be mediated through attraction of synanthropic predators to these areas (Seewagen et al. 2015).

Ecosystem Effect

In our study of the relative impacts of exurban development in two contrasting ecosystems, we hypothesized that birds in the Greater Yellowstone Ecosystem—with its greater degree of structural diversity and natural patchiness—would be less sensitive and demonstrate fewer community changes as a result of development, with a higher degree of change expected in the relatively continuous forest of the Adirondacks. We found no support for our hypothesis and instead found that, despite the strong differences between the two ecosystems, changes to bird communities were strikingly similar. For birds in the area-sensitive, low nesting, and Neotropical migrant functional groups, relative abundance was lower in subdivisions in both landscapes while edge species were more numerous in subdivisions (Glennon et al. 2014, Figure 4). The direction and magnitude of change in avian communities was similar in both regions for four of five guilds examined, suggesting that humans and their specific behaviors and activities in exurban regions may be more important than habitat structural change in shaping avian responses to development.

Bigger and Better Ecosystem Effect

Findings from the prior pilot study to examine effects of exurban development in contrasting ecosystems (Glennon et al. 2015) were striking. Though they may simply be the result of small sample size, we were intrigued enough to pursue this work on a larger scale. The recent study, involving a total of ~180 landowners in both landscapes, and distributed over 33 study areas, has resulted in the collection of ~29,000 bird occurrence records, ~250 nest fate records, ~200,000 trail camera photos, ~19,800 hours of acoustic data, ~250 landowner surveys, and ~30 in-depth interviews with landowners and individuals in land management agencies. It is our hope that these data will enable us to investigate more fully the mechanisms of change in bird communities in exurban areas and to address how individual land ethics and land use decisions shape human impacts upon them.

DISCUSSION AND CONCLUSIONS

Though a growing literature has now begun to develop around the impacts to wildlife from exurban development (Reed et al. 2014), research addressing this form of land transformation still represents a small fraction of that which has been devoted to urbanization. When we began our research in the Adirondacks our aim was, in part, to provide information from field research executed in our own ecosystem. Most of what was known previously had come from studies conducted in the western United States and we were unsure of the degree to which such conclusions could apply in our eastern temperate forest system. Some of this work has since been published, and some has not, but we remain dedicated to our efforts to make use of the information to inform important land management decisions in the Adirondacks. We have regularly used these findings in discussions and comment letters to the Adirondack Park Agency, in working with local and regional planning authorities, in providing expert testimony, and in education and outreach efforts (Glennon 2012, Karasin et al. 2009, Karasin et al. 2013). We hope that they have been of use. We offer the following lessons learned from across the work we have conducted here on the impacts of exurban development and on the state of the birds in exurbia:

1. The size of the impact resulting from exurban development can exceed its physical footprint significantly

Our work in the Adirondacks to examine the house distance effect for songbirds, together with findings from a similar study in Pitkin County, CO, and similar research focused on small mammals in the Adirondacks (Danks 2008) suggests that—although the surrounding ecosystem remains in its original type and house and/or lawn size may be small, bird communities can be altered up to 200 m from exurban homes, translating to an impact area of 13 ha (31 acres).

2. The change in avian communities associated with exurban development does not appear to be driven solely by associated road network

We examined the ecological impact zone resulting from rural roads in the Adirondacks as a means of disentangling the effects of home development itself from the fragmentation effect that comes along with the associated road network. Though we found that the size of the impact zone was similar in magnitude, patterns of change to bird communities were not, suggesting that changes to bird communities from exurban development arise from both houses and roads.

3. Changes to native bird communities can occur on very short timescales

Our examination of characteristics of wildlife communities one year prior to and one year subsequent to construction of two exurban homes in the Adirondacks found measurable changes in avian (and mammalian) communities in this short time, suggesting that responses of bird communities can be very rapid.

4. Predation pressure may be a key driver

Our findings with respect to bird and mammal community changes in the context of residential home construction suggest that those species particularly vulnerable may be species that nest in less well-protected locations (e.g., ground-nesting vs cavity-nesting species). This pattern suggests that predation pressure may contribute to making particular types of species especially vulnerable. Dogs (Reed and Merenlender 2011, Silva-Rodriguez and Sieving 2012) and cats (Balogh et al. 2011, Gillies and Clout 2003) impact native wildlife, with cats increasingly found to be responsible for very large numbers of bird deaths annually (Lepczyk et al. 2003, Willson 2015). Zanette et al. (2011) found that, even in the absence of actual predators, the perception of predation risk alone can reduce the number of annual offspring produced by songbirds.

5. Attraction effect may be stronger than deterrent effect

In several of our studies, we found the numerical response of species attracted to the features arising from exurban development is of greater magnitude than the decline observed for those species that appear to be sensitive. Omnivorous species such as corvids, for example, have consistently shown a greater numerical response (positive) to development than insectivores like warblers, which most commonly decline. This may be related to the provision of resources around exurban homes that are otherwise rare in the Adirondack landscape (e.g., openings, edges, novel food resources). This potential "oasis effect" (Bock et al. 2008) offers both opportunity and challenge. Providing resources for these species can bring us into contact with birds we may not otherwise get to experience firsthand, but may also result in increased competition for rarer species who do not exploit exurban habitats as successfully.

6. Changes show some consistency across taxa and ecosystems

In several of our studies, we have either observed changes in bird communities similar to those observed for other wildlife communities (Danks 2008, Odell and Knight 2001) or have ourselves noted similarities in patterns between bird community changes and those of other taxa. Similarly, we have noted similarities in patterns of change to avian communities in the Adirondacks and the very different ecosystem of Greater Yellowstone (Glennon et al. 2015). These findings provide us with increased confidence that we can reasonably predict the likely impacts to wildlife from development in the context of low density residential development.

7. The most prevalent pattern of change is one of simplification

Across not only our work, but also that of researchers working with numerous taxa in many systems, we find that the same pattern appears again and again. In the context of exurban development here and elsewhere, species richness often increases, but is associated with a concomitant decrease in ecological specialization in the remaining community (Hansen

et al. 2005). Humans tend to provide opportunities for certain types of species, often at the expense of other types of species. Among avian communities, in response to exurban development in the Adirondacks, the birds in exurbia tend to exhibit the following patterns: (1) sensitive species, e.g., black-throated blue warbler are often replaced by commensals or those that coexist with humans, e.g. blue jay, (2) insectivores decline with increasing omnivores, (3) migrants decline with increasing prevalence of resident birds, (4) forest obligates are replaced by habitat generalists, and, in general (5) rare species are replaced by those more common. Several of these more sensitive characteristics are often found among Neotropical migrant birds, a group which may be particularly sensitive to the negative impacts of exurban development. This phenomenon of a few winners and many losers in response to urbanization has been termed biotic homogenization (McKinney and Lockwood 1999). Its consequences for bird and other wildlife communities are not fully known but include simplification of food web structure and increased susceptibility of communities to species invasions (Olden et al. 2004).

If we wish to maintain all of the bird diversity we enjoy in the Adirondacks, our challenge will be to maintain the opportunities that we can provide in the context of housing development for species that would not otherwise occur in the Adirondacks in high numbers, e.g. eastern blue birds, and that people can see and enjoy. However, at the same time we need to work to minimize the negative impacts that this development pattern creates for those more sensitive species experiencing population declines in New York State and those in the Northeast who breed more successfully in the contiguous forested lands characteristic of the Adirondacks, e.g. scarlet tanager. We hope that our work can help to inform land use management in the Adirondacks, so that the state of the birds in exurbia can be a net positive one.

ACKNOWLEDGEMENTS

We are indebted to individual private landowners numbering in the hundreds who have graciously tolerated our presence on their lands, on multiple occasions, at impolite hours of the day and night, and with a variety of sampling techniques of relative degrees of invasiveness. We are eternally grateful to them. We also deeply appreciate the support of the former New York State Biodiversity Research Institute, Northeastern States Research Cooperative, National Science Foundation, Nuttall Ornithological Association, and Northern New York Audubon.

Figure 1. *Probability of occupancy at increasing distances from exurban homes for (a) human-adapted, and (b) human-sensitive species in the Adirondack Park, NY (Glennon and Kretser 2013).*

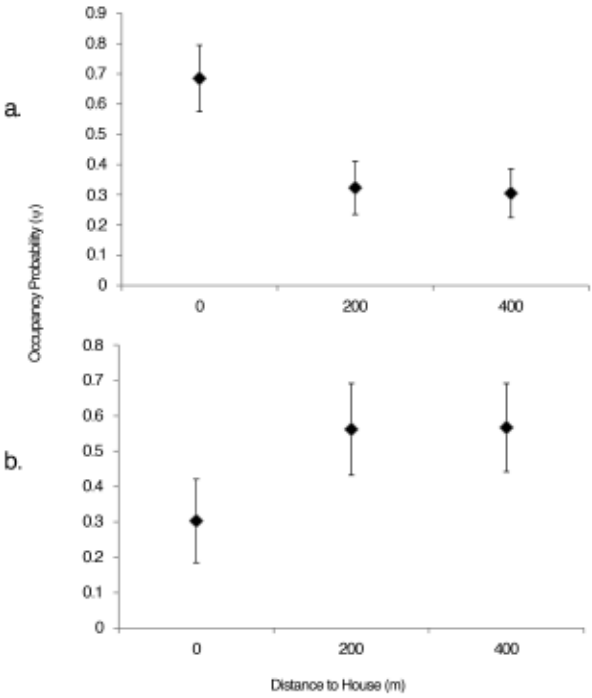


Figure 2. *Example of observed functional responses of occupancy probability for 3 bird families demonstrating positive (Emberizidae—sparrows), negative (Cardinalidae—cardinals, grosbeaks, and allies), and intermediate (Corvidae—crows and jays) response to increasing distance from rural exurban roads in the Adirondack Park, NY.*

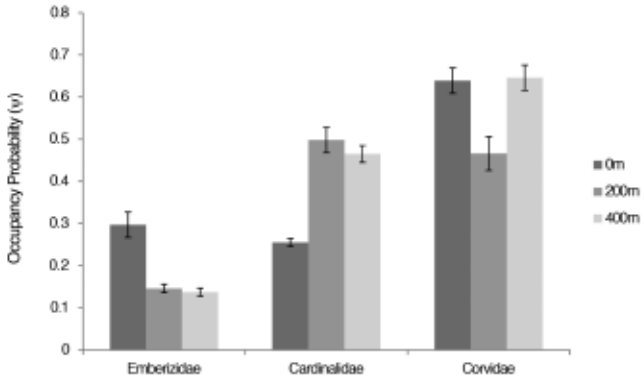


Figure 3. *Modeled effect of average clutch size on probability of local extinction (ε) of bird species following construction of 2 exurban homes in the Adirondack Park, NY (trend line added).*

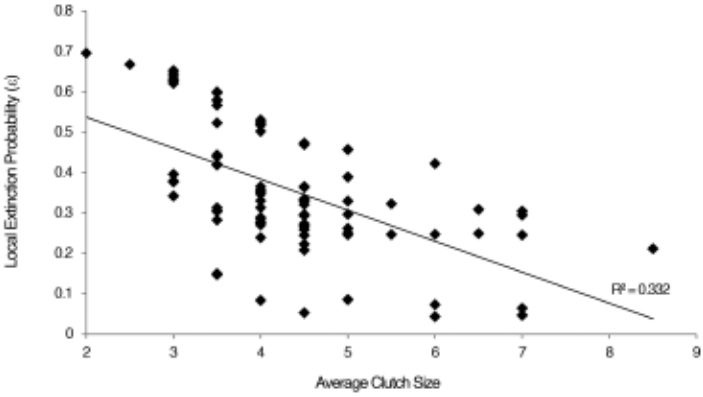
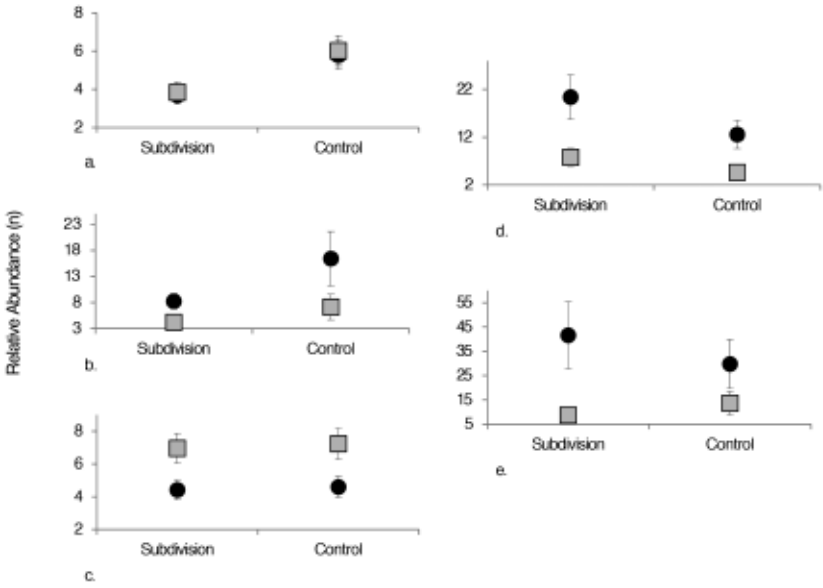


Figure 4. *Model-averaged abundance (birds/point) of (a) area-sensitive, (b) low nesting, (c) Neotropical migrant, (d) edge-adapted, and (e) microhabitat specialist bird guilds in exurban subdivisions in Essex County, NY (grey squares) and Madison County, MT (black circles; Glennon et al. 2015).*



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