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Landscape and Yard-scale Characteristics Drive House Sparrow (*Passer domesticus*) Nest Site Selection in the Northeastern USA

Susannah B. Lerman[1*] and William V. DeLuca[2]

Abstract - Urbanization alters wildlife habitat through the removal of native vegetation and replacement with more exotic plants, and installation of impervious surfaces. Thus, many urban areas have become unsuitable for some species, yet favorable for others, particularly generalist and invasive species. Understanding some of the habitat features enabling invasive species to exploit urban environments has important conservation implications. Here, we focus on the nest site characteristics of the introduced House Sparrow (*Passer domesticus* Linnaeus) in residential yards in Springfield, MA, US. First introduced to the US in the 1850s, the House Sparrow is one of North America's most widespread and abundant species. To improve our understanding of nest site characteristics, we investigated how different habitat features, both at local and landscape scales, influence the presence of House Sparrow nests in yards. We located active House Sparrow nests along an urban intensity gradient and measured habitat features at both local and landscape scales. Our analysis indicated that the percent shrub cover in yards and the amount of impervious surface within a 1 km radius of a yard had the highest support for explaining the presence of a House Sparrow nest (specifically, yards with low shrub cover and high local impervious surface were more likely to support a nest). We applied the regression model to determine how much shrub cover at the yard scale is required to decrease the probability of a House Sparrow nesting in a particular yard. When impervious cover was 30%, yards with at least 13% shrub cover reduced the probability of a sparrow nest occurrence in a yard to below 50%. Our results have potential implications for conservation efforts of House Sparrow competitors in their introduced range and for House Sparrows in their native range, where they are a species of conservation concern. Here in the US, increasing shrub cover and structural complexity has the potential to discourage House Sparrow nesting.

Introduction

Urbanization alters wildlife habitat through the removal of native vegetation and replacement with more exotic plants, and installation of impervious surfaces (McKinney 2008). This has rendered cities unsuitable for some species yet favorable for others (Aronson et al. 2014, Blair 1996, Czech et al. 2000, Grimm et al. 2008). The shift in community composition partially explains the proliferation and density of generalist and invasive species in urban environments (Møller et al. 2012, Shochat et al. 2010). In addition to creating optimal environmental conditions for invasive species, these species might have a competitive advantage over their native counterparts (Didham et al. 2005, Shochat et al. 2010). A meta-analysis on plant invasions demonstrated that invasive species had higher phenotypic plasticity but not necessarily a fitness advantage (Davidson et al. 2011) suggesting invasive species were better at adapting to and thriving in altered urban habitats. Invasive species represent one of the primary drivers of animal extinctions (Bellard et al. 2016, Clavero and García-Berthou 2005) and are largely responsible for the declines in biodiversity (Lebbin et al. 2010). Thus, gaining a better understanding of some of the factors enabling invasive species to exploit urban environments has important conservation implications.

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The House Sparrow (*Passer domesticus*) was introduced to the United States from Great Britain in the 1850s and has subsequently became one of North America's most widespread and abundant species (Lowther and Cink 2006). Life history traits that give House Sparrows an advantage to flourish in urban and novel environments include having aggressive behavior towards competitors and predators, a generalist diet, being a colonial nester and synanthropic, and a fast-lived strategy that prioritizes fecundity over survival (Lowther and Cink 2006, Møller et al. 2015, Sol and Maspons 2016). For example, in a comparison of two populations in similar environments of a western Mexican city, researchers found that areas with recent House Sparrow invasions had lower bird community evenness, and House Sparrows dominated the bird community when compared with sites without House Sparrows (MacGregor-Fors et al. 2010). This demonstrated how House Sparrows had a homogenizing force in the urban bird community (Morelli et al. 2016). Further, remodeled urban parks in southeastern Spain (i.e., those with increased impervious surfaces and artificial turf, and the removal of natural vegetation and covering of bare soils) significantly reduced House Sparrow abundance (Bernat-Ponce et al. 2020). When investigating how birds respond to the urban landscape, the presence of built structures and impervious surface explained much of the variation of House Sparrow distribution (Hostetler and Knowles-Yaniz 2003). Further, in Phoenix, AZ, USA, House Sparrow increased their abundance in neighborhoods landscaped predominantly with exotic turf grass and were largely absent in more native, desert-like landscapes, suggesting a possible limitation in their ability to exploit certain vegetation features in cities (Lerman and Warren 2011). These and other studies have begun to describe some of the local and landscape features that might be attractive to House Sparrow in North America (Chace and Walsh 2006).

Our understanding of House Sparrow breeding behaviors outside of Europe has largely focused in more rural settings, without integrating local and landscape habitat features into studies. Research from a long-term study of House Sparrow in Kentucky found that older males and males that were born in the area (i.e., natal philopatry) were more likely to occupy a particular nest box, whereas the extent of the black feathering on males did not predict occupancy (Morrison et al. 2008). When investigating causes of hatching failures of House Sparrow, small egg size and not environmental factors (e.g., seasonal, temperature) played a primary role (Stewart and Westneat 2013). When comparing three different nesting substrates (nest boxes, trees, crevices), nests located in trees experienced slightly lower success and it appeared that females preferred nest boxes (Cink 1976). However, local and landscape habitat features were not integrated into these studies, so it remains unclear how these factors might influence nest selection and ultimately nest success outside of the species' native range.

Detailed information on the environmental characteristics surrounding House Sparrow nests is important for developing conservation strategies that discourage these invasive birds. Because of its synanthropic nature (Blair 1996), yard management and yard features, in addition to urban intensity influence their persistence in urban areas. The primary goal of this study was to improve our understanding of nest site characteristics of House Sparrows within residential landscapes of varying development intensity in Springfield, MA, USA. We investigated how different habitat features, both at local (e.g., shrub, tree canopy and herbaceous cover, and maintained turf within the yard) and landscape scales (e.g., impervious surface within 1 km of the yard), influence the presence of House Sparrow nests in yards. Yards surrounded by more impervious surface at the landscape scale and with fewer shrubs at the local scale were expected to have more nests.

Materials and Methods

Study Area

We conducted our study in the Springfield, MA, metropolitan area. Springfield is the third largest city in Massachusetts and has a total population of 154,207 (US Census Bureau 2020). The study was part of the Smithsonian Institution's Neighborhood Nestwatch project, a mentored citizen science program that seeks to understand how urbanization impacts backyard bird populations while teaching households about biology in their private yards (Ryder et al. 2010). A major component of the project involves scientists visiting yards once per year to collect data and train household members to locate and monitor nests. In 2014, we visited 92 yards in the Springfield metropolitan area. Sites were equally distributed along an urban intensity gradient (Fig. 1).

Nest Searching

Both scientists and citizen scientists searched for and found nests at each site of any species during the breeding season (May–July) of 2014. Nest searching included examining nest boxes as well as observing bird behaviors for activities such as carrying nesting material, carrying food items and fecal sacs, actively defending a nest site, and territorial calls at nest boxes and other nesting locations (Ralph et al. 1993). Nest searching was limited to property boundaries due to access issues. While citizen scientists actively monitored nests as part of the broader Neighborhood Nestwatch program, this study focused on nest presence and habitat type.

Habitat Measurements

We measured habitat features at three different spatial scales: at the nest (when applicable), within the yard and at a broader landscape scale to determine how different habitat features and urban intensity influenced nest presence. For the nest and yard scale,

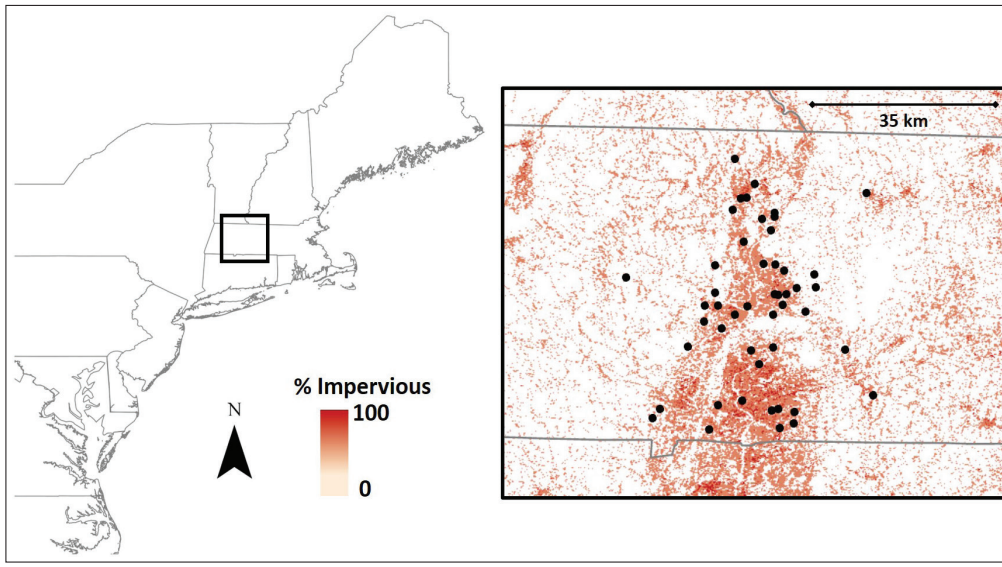

Figure 1. Study map of Springfield, MA, with location and distribution of yards used to evaluate the influence of habitat characteristics on the presence of House Sparrow (*Passer domesticus*) nests. The sites fell along an impervious surface gradient, with ~30% representing relatively high levels of impervious surface for our study system.

we followed the i-Tree Eco protocol (www.itreetools.org), an urban forest assessment tool developed by the US Forest Service to assess ecosystem services provided by urban forests, including carbon sequestration, stormwater mitigation, and bird habitat potential (Lerman et al. 2014). We incorporated five 11.4-m radial sampling plots, with one plot centered at the nest and the remaining plots randomly placed within a 50 m radius of the nest. For yards with no House Sparrow nests, one of the i-Tree plots was placed in the center of the yard and the remaining four plots were randomly placed within a 50 m radius of that centered plot. In the few instances when yards had multiple nests, we increased i-Tree sampling to 6 or 7 plots. The i-Tree variables we predicted to have the strongest association with House Sparrow nest selection, and were thus considered in statistical analyses, included the percentage of the following covers: shrub, canopy, impervious surface, building, cement, tar, rock, soil, duff, herbaceous, maintained grass, and unmaintained grass (Lerman et al. 2014). All vegetation surveys were conducted after birds had fledged. To account for landscape scale features (i.e., urban intensity), we calculated the percent impervious surface within a 1 km radius of each yard (Lerman and Warren 2011) using the impervious surface layer from Massachusetts Bureau of Geographic Information (MassGIS 2007). Although House Sparrows are known to respond at smaller scales (100–500 m; Hostetler and Knowles-Yanez 2003, Skórka et al. 2016), the1-km scale better reflects conservation efforts and the applicability of the research (Rodewald et al. 2013).

Data Analysis

To determine whether House Sparrow nest sites were simply driven by the presences of available nest boxes, we used a two-sided Fisher's exact test to test whether yards with nest boxes were more likely to have House Sparrow nests present. Then, we examined the correlation matrix of potential nest site explanatory variables and removed those that were excessively correlated with other variables such that the correlation coefficient between any two final covariates was <0.40. The final set of variables for further consideration included canopy cover, shrub cover, unmaintained grass (yard scale), and impervious surface within 1 km of the yard (landscape scale).

We used a generalized linear analysis of variance model with a binomial error distribution to compare yards with and without House Sparrow nests to identify important variables that influence the presence of House Sparrow nests. We compared residual deviance to degrees of freedom to determine that overdispersion was not an issue in any of the candidate models. All potential combinations of the reduced set of predictors were compared using Akaike information criterion (AIC) to identify model support (Burnham and Anderson 2002). Models with delta AIC values of <2.0 were strongly supported. Variables included in models with strong support and that were included in >1 multi-predictor candidate model were deemed most useful in describing House Sparrow nest occurrence and used for further interpretation. We then used the model with most support to illustrate the relationship between important nest site predictors and nest occurrence. All analyses were conducted in R (R Core Team 2019).

Results

While visiting 92 yards in 2014, we located 121 nests from 17 different bird species in 56 yards. These totals included 23 House Sparrow nests located in 19 yards. Some of these yards with House Sparrow nests (n = 9) also had nests of other species. We documented House Sparrows nesting in nest boxes (n = 12), on houses (e.g., eaves, siding, sheds; n = 8),

other anthropogenic structures (n = 2), and in a honeysuckle vine (n = 1). Due to access issues, we were only able to collect vegetation data at 48 of the yards (15 of these yards had House Sparrow nests), so the remaining analyses were limited to these 48 yards.

Yards with nest boxes were not more likely to have House Sparrow nests (Fisher's Exact Test; $P = 0.14$). Models with the strongest support included percent shrub cover, impervious surface within 1 km of the yard, percent unmaintained grass, and percent canopy cover (see Table 1 for descriptive statistics); however, only shrub cover and impervious surface within 1 km were included in all models with strong support with >1 predictor and were significant in each model (Table 2). The model with the most support also only included percent shrub cover and percent impervious surface within 1 km (Table 2). To examine how the percent of shrub cover in the yard could be used to deter House Sparrow nesting in urban landscapes, we applied the top model to the range of shrub cover values while holding impervious surface within 1 km to 30% (relatively high for our study area). We found that when yard shrub cover reached 13% it resulted in a 50% probability of a House Sparrow nest occurring in the yard (Fig. 2).

Discussion

In our study area, yards with few shrubs and located amidst higher amounts of impervious surface at the broader landscape had a greater probability of hosting House Sparrow nests. By including both local and landscape features, our study addresses some of the inherent factors driving landscape variation in sparrow nest occurrence. Further, illustrating the relationship between these influential variables provides managers with targeted information for discouraging this invasive species (Kroll and Haufler 2006). The extent of impervious surfaces has been indicative of House Sparrow presence in other studies in the US (e.g., Hostetler and Knowles-Yanez 2003, Rega et al. 2015). We recognize our small sample size and caution the broad generalization of our research. Nonetheless, our results concur with other studies that have demonstrated an inverse relationship between shrub density and House Sparrow presence (Lerman and Warren 2011). Further, increasing shrub coverage can benefit native species (Bernat-Ponce et al. 2020, Lerman et al. 2014). Taken together, management that reduces impervious surfaces while simultaneously increasing shrub layer and complexity has the potential to enhance habitat for native species, while also making urban landscapes less desirable for invasive species such as House Sparrows.

We chose to model the probability of nest occurrence as a function of shrub cover while holding the amount of impervious surface at 30% because this represented a high amount of imperviousness relative to our study area. We therefore wanted to identify whether an individual household could compensate for high impervious surface by increasing shrub cover. Increasing shrub cover from 0–15% decreases the probability of a House Sparrow nest in a particular yard by almost half. Further, we focused on alternative shrub density rather than reducing impervious surfaces because increasing plantings, particularly berry-producing shrubs, represents a feasible solution given that it can occur based on decisions at the homeowner scale as opposed to the more complicated process of reversing impervious or developed land uses (Belaire et al. 2014).

Our study also adds to the growing body of literature that local habitat features can have significant importance in structuring urban bird communities (Daniels and Kirkpatrick 2006, Lerman and Warren 2011, Narango et al. 2017). However, other factors (e.g., phenotypic stress markers) might respond to either the landscape or local scale (Strubbe et al. 2020). The majority of management recommendations aim to increase the suitability of urban areas for native biodiversity (Aronson et al. 2017). Including strategies that discourage

Table 1. The influence of habitat features on House Sparrow (*Passer domesticus*) nesting in yards was investigated in Springfield, MA. Presented are descriptive statistics (mean ± standard error, minimum and maximum, and n) for variables that were included in statistical models with strong support in predicting the presence of House Sparrows nests. Impervious surface (%) was calculated at the landscape scale (1 km) and all other variables were calculated at the yard scale.

Nest Status	Number	Impervious Surface (%)			Shrub Cover (%)			Unmanaged Grass (%)			Canopy Cover (%)		
		mean (se)	min	max	mean (se)	min	max	mean (se)	min	max	mean (se)	min	max
Absent	33	10.21 ± 1.50	2	36	12.51 ± 0.84	3.4	22	6.71 ± 2.08	0	39	36.62 ± 2.98	9	71
Present	15	17.93 ± 2.92	3	35	8.67 ± 1.38	2.29	23	6.32 ± 3.03	0	40	28.12 ± 4.87	5	65

Table 2. The influence of habitat features on House Sparrow (*Passer domesticus*) nesting in yards was investigated in Springfield, MA. Presented are beta coefficient values for logistic regression models that had the strongest support (ΔAIC <2) for predicting the presence of a House Sparrow nest. Habitat features included IMP1km = Impervious surface (%) within 1 km at the landscape scale and SHRUBcov = Shrub cover (%), CANcov = Canopy cover (%), and UNMgrs = unmanaged grass (%) at the individual yard scale.

Model	Shrub Cover (%)	Impervious surface1km (%)	Canopy Cover (%)	Unmanaged Grass (%)	d^2	Δ AIC
SHRUBcov+IMP1km	0.15**	0.07**	-	-	0.17	0
CANcov+SHRUB+IMP1km	-0.13*	0.06*	-0.02	-	0.18	1.72
SHRUBcov	-0.17**	-	-	-	0.1	1.74
SHRUBcov+UNMgrs+IMP1km	-0.14*	0.08**	-	0.02	0.18	1.93
IMP1km	-	0.08**	-	-	0.1	1.95

**Significance at the α = 0.05 level
*Significance at the α = 0.10 level

invasive species, especially when they have the potential to compete with native species, is also an important factor to consider. We recognize that broad scale factors also play a role in shaping urban bird communities, particularly the fragmentation and replacement of contiguous forest with impervious surfaces and (Grimm et al. 2008).

The majority of House Sparrow nests in this study were in nest boxes, but half of the study yards had nest boxes, yet no House Sparrow nests were detected. We were able to confirm that the observed yards with nest boxes did not have more House Sparrow nests than expected. Installing nest boxes has widespread support from households aiming to provide nesting opportunities for cavity nesting species (Davies et al. 2009, Lepczyk et al. 2004). However, these actions can have negative implications, for example, they might ease access for predators (Bailey and Bonter 2017) or provide additional nesting opportunities for invasive species and increased interspecific competition (Charter et al. 2013). Most of the nest boxes in our study were installed to attract Eastern Bluebird *(Sialia sialis* Linnaeus), Black-capped Chickadee (*Poecile atricapillus* Linnaeus) and House Wren (*Troglodytes aedon* Vieillot), with the latter nest box having smaller entry holes and thus, not as suitable for the larger House Sparrows. Nest box predator guards represent another effective solution to exclude potential predators or competitors' access to nest boxes (Bailey and Bonter 2017). Our results suggest that the well-intentioned action of installing nest boxes has some unintentional consequences but is not the only factor attracting House Sparrows to nest in private yards.

Results from our study might benefit conservation efforts in the United Kingdom and Europe, though it is not clear whether the two populations are comparable. Despite their proliferation in North America and other introduced areas, House Sparrow populations have declined in their native range, particularly in urban areas, where it has become a species of conservation concern (Shaw et al. 2011). Numerous hypotheses have been suggested regarding the cause of the decline, including increased cat predation, pollution, pesticide use, and

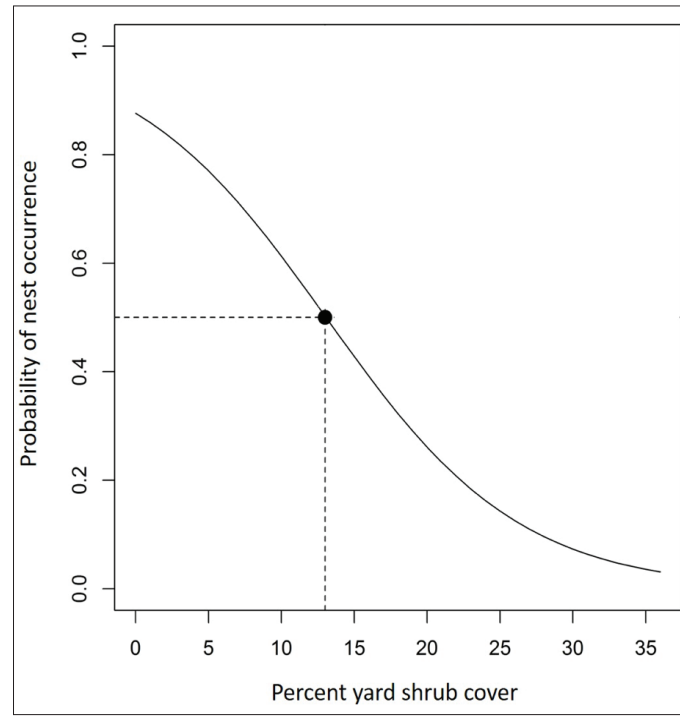

Figure 2. Probability of House Sparrow (*Passer domesticus*) nest occurrence in yards in Springfield, MA, as a function of shrub cover while holding impervious surface at 30%. Nest occurrence values were derived from application of the logistic regression model with most support (shrub cover + impervious surface) compared to a suite of candidate models (that also included the variables canopy cover and unmanaged grass). For management considerations, the probability of a House Sparrow nest in the yard is 0.50 when the landscape is 30% impervious surface and the yard shrub cover is 13% (black dot on line).

loss of nesting sites (Summers-Smith 2003). Research has also linked declines with socioeconomic status whereby more affluent parts of cities have witnessed the greatest decline (Shaw et al. 2008). The authors attribute these patterns largely to changes in habitat structure and allude to implications on nest success, predation and foraging behavior (Shaw et al. 2008). For example, House Sparrows often nest in building cavities such as the wooden eaves of houses. When the material rots, more affluent householders might have the means to repair or replace with plastic and other unsuitable nesting materials (Shaw et al. 2008).

While shrub cover and impervious surface contributed strongly to our modeling framework, additional explanatory variables that had some support included unmanaged grassy areas and canopy cover. Having "messy" yards, including unmanaged areas can benefit wildlife (van Heezik and Ludwig 2012). However, the differences we detected in our study were nominal (Table 1), though taken together with shrub cover and impervious surface could help contribute to making yards and neighborhoods less attractive for House Sparrows. Increasing canopy cover through local tree planting efforts could augment citywide canopy goals. In addition to the many ecosystem services a robust urban canopy provides (Nowak et al. 2001), it also supports wildlife habitat for a host of many native species (Lerman et al. 2014). High canopy coverage also has the benefit of discouraging House Sparrow nesting. We recognize that our study did not capture high-density urban areas as indicated by the relatively moderate percentage of impervious surface for our most urban site (36%) and was limited in geographical scope. Nonetheless, even at this level of development, we detected habitat features suitable for providing initial recommendations to better manage for this species. Further, it is unclear how these habitat relationships compare with Western European habitat relationships given different housing stock and urban development patterns between the two continents. We recommend future research simultaneously address the ecological contexts of these two populations of House Sparrows.

Conclusions

Our threshold provides urban planners and practitioners with realistic targets for managing House Sparrow populations. Although reducing impervious cover would have the greatest impact, this is often not feasible. Increasing shrub cover and structural complexity has the potential to discourage House Sparrows, while possibly encouraging native species. We demonstrated that when impervious cover was 30%, yards with at least 13% shrub cover reduced the probability of a sparrow nest occurrence in a yard to below 50%. The ability to exploit suburban and even a few rural properties indicates that House Sparrows are not restricted to the most built up parts of our cities. Suburban areas make up a significant component of urban areas (as much as 50%; Loram et al. 2007) and likely serve as connections for disparate urban House Sparrow populations. Although protecting large tracts of contiguous forest can both encourage the persistence of many forest interior specialists (Robinson et al. 1995) and detract invasive species, once the land becomes developed, identifying other opportunities for intervention, particularly at the yard scale, becomes essential for disrupting metapopulation dynamics of this invasive species.

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