Notes

Use of Anthropogenic Nest Materials by Black-Crested Titmice Along an Urban Gradient

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Abstract

Numerous avian species use anthropogenic materials in constructing nests, particularly in urbanized environments. Researchers have demonstrated anthropogenic materials, including plastics, to have both beneficial and harmful effects on survival and reproduction. During the spring of 2018, we collected 45 black-crested titmouse *Baeolophus atricristatus* nests in San Marcos, Texas, with two objectives: 1) to assess and compare the mass and proportion of nest materials along an urban gradient and 2) to examine the relationship between nest materials, clutch size, and hatching success. We categorized each nest based on collection location as urban, residential, park, or rural and separated nest materials into six categories: leaves, snake skin, twigs, moss, plastic, and nonplastic artificial materials. We then compared raw mass and proportion of mass of each nest material among urbanization categories. Nests in the urban category were 1.6–1.9 times lighter in mass than nests in other locations along the urban gradient ($P = 0.01$) and contained 4–5 times greater proportion, but not mass, of plastic compared to nests in all other locations. Nests in residential areas contained the greatest mass of combined anthropogenic materials. Neither clutch size nor hatching success differed based on urbanization category, nest mass, or proportions of anthropogenic or natural nest materials. The differences in mass of nests and increased proportion of plastics could have been due to a lack of natural nesting materials; however, we did not estimate availability of nesting materials at any location. Results add to the growing literature that the use of anthropogenic materials in nests varies across an urban gradient, and the effect of anthropogenic materials on nesting parameters varies among species.

Keywords: anthropogenic materials; avian ecology; *Baeolophus atricristatus*; black-crested titmouse; nest materials

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Introduction

Anthropogenic materials are used by many avian species to construct nests, especially in urbanized areas (Antczak et al. 2010; Townsend and Barker 2014; Tavares et al. 2016), which can both negatively impact and benefit survival and reproduction. For example, adults and hatchlings have been injured or killed from ingesting small plastic items and becoming entangled in larger items (Ryan and Moloney 1990; Laist 1997; Townsend and Barker 2014; Kühn et al. 2015). Conversely, anthropogenic material may strengthen the nest structure (Antczak et al. 2010), repel ectoparasites (Suárez-Rodríguez et al. 2013), increase chances for successful mating by use of bright materials as decoration (Borgia 1985), and signal occupation of territory (Sergio et al. 2011). In nonnatural habitats, birds may use plastics in nests as a replacement for natural nesting material that is not readily available or preferentially select anthropogenic materials for a perceived benefit (Wang et al. 2009; Lee et al. 2015; Hanmer et al. 2017). Currently, research on the effects of anthropogenic material use on nesting success is limited across species and geographic locations, which underlines a need to understand how the use of anthropogenic material in nest structure affects survivorship on a wider range of species that inhabit an urbanization gradient.

The black-crested titmouse *Baeolophus atricristatus* (BCTI) is a common inhabitant of suburban and urbanized areas with adequate vegetation in southwestern Oklahoma and western and central Texas in the United States, and in northern Mexico (Dixon 1978; Patten and Smith-Patten 2008), making this species an ideal candidate for studying the impacts of anthropogenic materials in bird nests along an urbanization gradient. The BCTI typically builds its nest using fresh moss and lines the cup with pieces of fur, snake skin, and sometimes leaf litter (Patten and Smith-Patten 2008). Furthermore, the BCTI is known to use nest boxes during the breeding season (March–July), as well as in the winter season as a reprieve from cold winter temperatures (Farrell et al. 2018; Rylander et al. 2020), allowing researchers to study BCTI nests in a noninvasive manner.

We used nest boxes to study use of anthropogenic material by BCTI in nests. Our objectives were to 1) assess the mass and proportion of natural vs. anthropogenic nest materials used by the BCTI along an urbanization gradient and 2) examine the relationship between natural vs. anthropogenic nest materials, clutch size, and hatching success. We hypothesized that nests in urban and rural areas would vary in mass (Reynolds et al. 2019), potentially due to differences in nesting materials, and nests would vary in proportion of various nest materials (Hanmer et al. 2017), with urban nests containing a greater proportion of anthropogenic material (Garcia-Cegarra et al. 2020; Potvin et al. 2021). Finally, we hypothesized that the use of plastic in nests would not affect clutch size or hatching success (Jagiello et al. 2018). This study adds to the limited data on how incorporation of anthropogenic material in nests impacts clutch size and hatching success.

Methods

We conducted the study in San Marcos, Texas, a rapidly growing city located along the Edwards Aquifer between Austin and San Antonio along the I-35 corridor (DataUSA 2019). We used a series of nest boxes that were installed during the winter of 2016–2017 in three locations within the city (Rylander 2021): Texas State University Campus ("urban"; 29.8884, –97.9384; 40 nest boxes), San Marcos single-family-home residential areas ("residential"; 86 nest boxes), and San Marcos City Parks ("parks"; 29.8860, –97.9351; 34 nest boxes). We used a Texas Parks and Wildlife Department 30 $\times$ 30 m pixel GIS vegetation landcover file incorporated through ArcGIS Pro 2.6.1 (ESRI 2020) to identify the proportion of high urbanization and low urbanization landcover types within each of the three locations (TPWD 2020). The urban site (Texas State University campus) had the greatest proportion of total urban landcover (combined high and low urbanization landcover) at 87%, whereas residential areas had 57%, and parks had 50%. In addition, we used a system of 146 nest boxes previously installed in 2012, 2013, and 2017 at a rural field site (0% total urbanization landcover; Rylander et al. 2020, Rylander 2021), the Freeman Center ("rural"; 29.9363, –98.0049) that is $\sim$ 10 km northwest from downtown San Marcos. Across all sites, the dominant hardwood species included plateau live oak *Quercus virginiana*, Texas oak *Quercus buckleyi*, Ashe juniper *Juniperus ashei,* southern pecan *Carya illinoinensis*, sugarleaf hackberry *Celtis laevegata*, and cedar elm *Ulmus crassifolia*.

Figure 1. Photo of a black-crested titmouse *Baeolophus atricristatus* in a nest box in a residential area in San Marcos, Texas, in spring of 2018.

During the spring of 2018 (March–July), we conducted biweekly visual nest-box checks for signs of BCTI nests (moss, fur, and snake skin; Patten and Smith-Patten 2008; Figure 1). When we confirmed BCTI using a nest box, we recorded data on the nesting cycle during each visit. This included clutch size and number of hatchlings (Rylander et al. 2020). We collected nests and nest box contents once no longer active and placed each in a marked plastic bag.

We dissected nests and separated materials into six main categories: leaves, snake skin, twigs, moss, plastics, and nonplastic anthropogenic materials. We weighed the contents of each material category for every nest and compared raw masses of each material type and proportion of mass of each material type to account for potential differences in total mass of nests among urbanization categories. Masses of the leaves and snake skin categories were negligible, and many nests had neither. Thus, we did not compare these individually but summed them with twigs, moss, and snake skin as "natural" material types. We summed plastics and nonplastic anthropogenic materials as "anthropogenic" material types for comparisons.

We compared raw masses and proportions of materials among urbanization categories using a variety of univariate statistical methodologies. We used each material category mass and proportion as a separate response variable and assessed each response variable for normality using a Shapiro–Wilk test (Shapiro and Wilk 1965). We examined the homogeneity of variances of the urbanization categories across all response variables using a Bartlett's test (Arsham and Lovric 2011). No response variables met the normality assumption for a univariate analysis of variance, thus we used a univariate Kruskal–Wallis test (Kruskal and Wallis 1952) or 1-way analysis of means (Welch 1951) if the assumption of homogeneity of variances was not met for comparisons. When the Kruskal–Wallis test was significant, we conducted pairwise comparisons using Dunn's test with a Bonferroni correction.

First, we compared total nest mass among the four urbanization categories using a Kruskal–Wallis test. We then compared the raw masses of each nest material among urbanization locations. We calculated the proportions of each material category by dividing the mass of each material category by the total nest mass. We compared the proportion of individual nest material categories similarly to the raw masses. We considered differences between pairwise comparisons significant if $\alpha < 0.025$ to consider the Bonferroni correction.

To assess the influence of urbanization categories on clutch size and hatching success (number of hatchlings), we conducted univariate generalized linear models with a Poisson distribution with either the clutch size or hatching success as the response variable. We used one of the following independent variables for each: urbanization category, total nest mass, total mass of plastic, proportion of plastic, proportion of natural materials, or proportion of anthropogenic materials. We considered an independent variable as a significant predictor of the clutch size or hatching success if the 95% confidence interval did not overlap 0. We conducted all analyses in RStudio, R version 4.1.0 (RStudio Team 2020; R Core Team 2021).

Results

We collected 45 BCTI nests during the spring of 2018, which were all nests from nest boxes occupied by BCTI in that year; 7 urban, 12 residential, 5 park, and 21 rural (Table S1, *Supplemental Material*). Results of all Kruskal–Wallis comparisons and associated *P* values are in Table 1. Total mass of nests differed among urbanization category with urban nests having a mass 1.82 ($P = 0.018$) and 1.85 ($P = 0.005$) times lower than park and residential, respectively (Figure 2A). Total mass of nests in urban areas maintained the same trend when compared to rural areas and were 1.62 times lighter than in the rural area; however, the *P* value was 0.03. Total mass of the summed anthropogenic materials differed among urbanization categories with residential nests having approximately twice as much as urban ($P = 0.02$) or rural nests ($P = 0.002$; Figure 2B). The total mass of plastic differed among urbanization categories; however, no urbanization categories differed with the Bonferroni correction (Figure 2C). The total mass of nonplastic anthropogenic materials differed among urbanization categories with residential nests having approximately twice as much nonplastic anthropogenic material as urban ($P = 0.02$) or rural ($P = 0.003$) nests (Figure 2D). We used a 1-way analysis of means test to compare the total mass of the summed four natural material types, which differed among urbanization categories with urban nests having half the mass of natural materials as both rural ($P = 0.008$) and park ($P = 0.023$) nests and 60% as much as residential areas ($P = 0.01$; Figure 2E). The mass of twigs did not differ among urbanization categories. The mass of moss differed among urbanization categories with urban nests having a 1.6 times lower mass of moss than residential ($P = 0.007$) and rural nests ($P = 0.024$; Figure 2F).

Table 1. Comparisons of masses and proportions of nest materials of 45 black-crested titmice *Baeolophus atricristatus* collected in spring 2018 across four urbanization categories (urban, residential, parks, rural) using Kruskal–Wallis tests (except for one 1-way analysis of means test due to a lack of homogeneity across categories) in San Marcos, Texas.

Covariate	Kruskal–Wallis χ^2	*P* value
Nest mass	11.570	0.009
All anthropogenic mass	15.800	< 0.001
Plastic mass	9.980	0.020
Nonplastic anthropogenic mass	15.780	0.001
All natural mass	$F = 16.63$	< 0.001
Twig mass	6.690	0.082
Moss mass	10.820	0.013
All anthropogenic proportion	4.900	0.180
Plastic proportion	10.200	0.020
Nonplastic anthropogenic proportion	4.980	0.173
All natural proportion	8.580	0.040
Twig proportion	6.360	0.100
Moss proportion	0.340	0.950

The proportion of all anthropogenic materials combined did not differ among urbanization categories. Plastic comprised a mean of 1% (minimum = 0% and maximum = 4.2%) of the proportion by mass of nests. The proportion of plastic differed among urbanization categories with urban nests having over five times ($P = 0.011$) and four times ($P = 0.007$) greater proportions of plastics than park or rural nests, respectively (Figure 3A). The proportion of nonplastic anthropogenic materials did not differ among urbanization locations. The proportion of the four natural material types combined differed among urbanization categories with rural nests having 1.3 times greater proportion of natural materials than residential nests ($P = 0.004$; Figure 3B). The proportion of twigs and moss did not differ among urbanization categories.

Clutch size did not differ among urbanization categories and was (mean ± SD) urban = 5.86 ± 1.44, residential = 6.55 ± 0.55, park = 6.60 ± 1.19, and rural

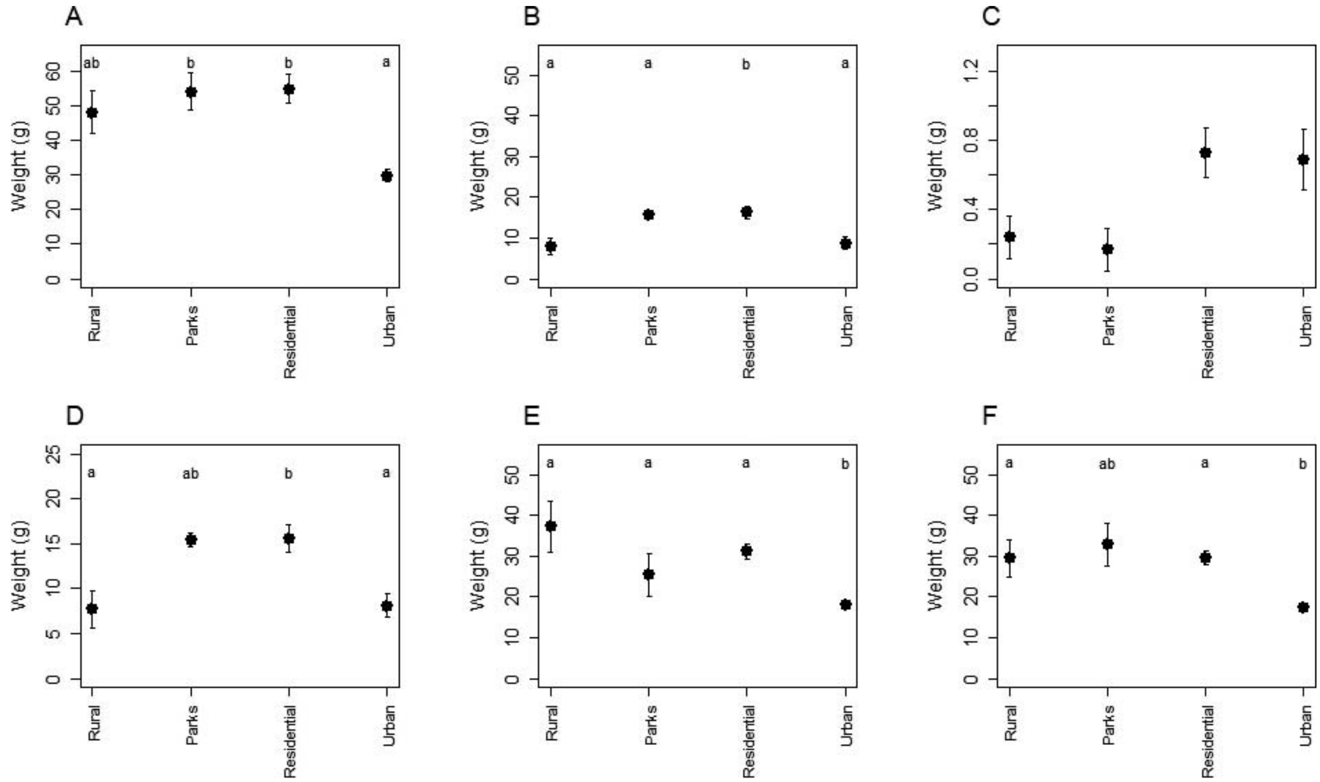

Figure 2. Mean and 95% confidence interval of raw weights (g) of total nest (A), all anthropogenic material combined (B), plastic (C), nonplastic anthropogenic materials (D), all natural material combined (E), and moss (F) in 45 black-crested titmouse *Baeolophus atricristatus* nests during the spring of 2018 across four urbanization categories in San Marcos, Texas. Letters indicate significance at $\alpha = 0.025$ to account for a Bonferroni correction.

= 5.71 ± 0.00. Similarly, hatching success did not differ among urbanization category (urban = 5.57 ± 1.13, residential = 6.00 ± 0.84, park = 6.20 ± 1.96, and rural = 4.86 ± 0.00). Additionally, weights and proportions of nest materials were not predictors of clutch size or hatching success. Specifically, neither clutch size nor hatching success were influenced by total nest mass, total mass or proportion of plastic, proportion of natural material or proportion of anthropogenic materials (Table 2).

Discussion

Urban BCTI nests were lighter in mass and contained a greater proportion of plastic materials compared to nests in the other three urbanization categories; however, neither clutch size nor hatching success varied across the urbanization gradient nor did they have a relationship with mass or proportion of anthropogenic materials contained in nests. Additionally, nests in residential areas were comparable in mass to those in rural environments yet contained the greatest mass of anthropogenic materials. Previous research suggests that some species preferentially select anthropogenic materials whereas other species use materials in proportion to availability (Surgey et al. 2012; Hanmer et al. 2017; Jagiello et al. 2018). We did not compare availability of nesting materials across the urbanization gradient and thus have no conclusive evidence that BCTI selected nesting materials based on availability. However, we speculate that residential areas contained more natural and anthropogenic materials as the neighborhoods in the study area typically are wooded and campus workers clean trash daily in the urban area whereas the residential area does not have this level of cleaning. Moreover, moss, a commonly used material in BCTI nests (Patten and Smith-Patten 2008), may have been lacking in the urban environment or BCTI may have opted out of using moss for a replacement, as has been documented in other species when natural materials are not available in unnatural habitats (Antczak et al. 2010; Wang et al. 2009). Results add to the growing literature that many avian species use anthropogenic materials in nests, particularly in more urbanized environments.

Although researchers have demonstrated nest materials and urbanization to have various influences on reproductive success in other avian species (Cantarero et al. 2014, Hanmer et al. 2017), neither nest materials nor urbanization category were related to clutch size or hatching success of BCTI. In other species, such as the blue tit *Cyanistes caeruleus*, the amount of anthropogenic material has been documented to not influence breeding success; however, increased urbanization has been associated with lower fledging success (Hanmer et al. 2017). Our results, however, do not give conclusions

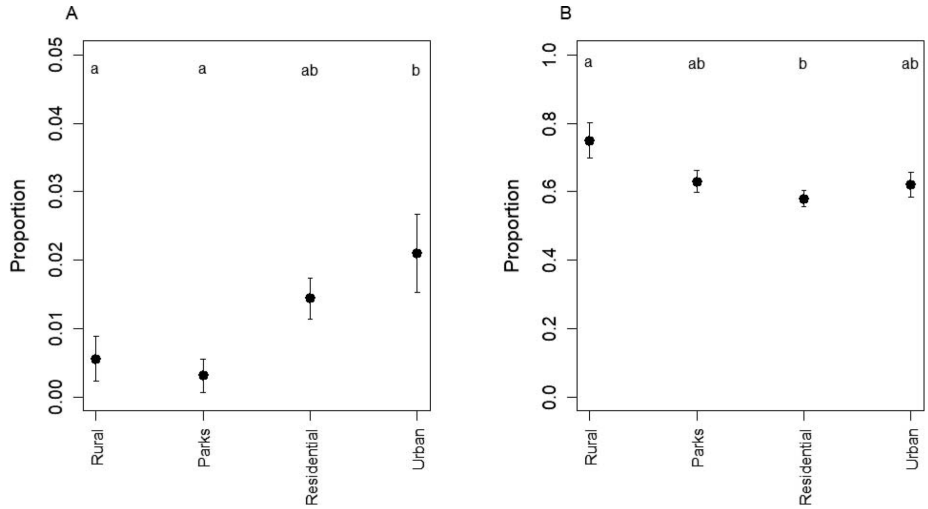

Figure 3. Mean and 95% confidence interval of proportion of each nest by mass of plastic materials (A) and all natural materials combined (B) in 45 black-crested titmouse *Baeolophus atricristatus* nests during the spring of 2018 across four urbanization categories in San Marcos, Texas. Letters indicate significance at $\alpha = 0.025$ to account for a Bonferroni correction.

on potential differences in overall breeding success as we did not record fledging success, which could still relate to the proportion of anthropogenic materials including plastic. Further, there may be a threshold for the amount of plastic contained in a nest before causing major issues, which nests in this study may not have reached, as average plastic proportion was only 1%.

For future research we first suggest a continuing examination of BCTI nest materials across urban gradients with a larger sample, as well as a focus on assessing nest success to provide comprehensive information of how anthropogenic nest material use impacts this species. Further, birds may select nesting materials based on insulation properties, which in turn can affect nesting success (Reynolds et al. 2016); thus, we suggest conducting a study to assess the insulation properties of commonly used anthropogenic materials in nests and understand how the influence of plastic and anthropogenic material can affect nest success and body condition. Lastly, because the insulation properties of nests correlate with materials (Mainwaring et al. 2012), we suggest assessing microhabitat variations in nests constructed of anthropogenic vs. natural materials. These studies can increase our understanding of how managers could mitigate the damage caused by birds using anthropogenic materials in nests, whether by replanting native plants that provide high quality insulation, working to reduce the availability of plastics in these environments, or limiting nest box availability in highly urbanized areas if plastics impact BCTI.

Supplemental Material

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Table S1. Raw data of 45 black-crested titmouse *Baeolophus atricristatus* nests collected during the spring of 2018 in San Marcos, Texas, with urbanization category of collection location, total mass of nest, mass of each nest material, proportion of each nest material, clutch size, and hatching success.

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Table 2. Results of linear regression models to assess relationships between clutch size or hatching success and mass or proportion of nesting materials of 45 black-crested titmice *Baeolophus atricristatus* collected in spring 2018 in San Marcos, Texas.

Response	Covariate	β	SE	*z* value	*P* value
Clutch size	Total nest mass	0.001	0.003	0.139	0.889
Hatching success	Total nest mass	0.001	0.003	0.236	0.813
Clutch size	Mass of plastic	0.093	0.123	0.759	0.448
Hatching success	Mass of plastic	0.050	0.128	0.394	0.694
Clutch size	Proportion of anthropogenic	0.355	0.419	0.847	0.397
Hatching success	Proportion of anthropogenic	0.792	0.448	1.768	0.077
Clutch size	Proportion of plastic	3.359	4.590	0.732	0.464
Hatching success	Proportion of plastic	− 0.016	4.833	− 0.003	0.997
Clutch size	Proportion of natural	− 0.175	0.399	− 0.438	0.661
Hatching success	Proportion of natural	− 0.596	0.427	− 1.395	0.163

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