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Nesting ecology of mourning doves in an urban landscape

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Abstract The expansion of urban areas into native habitat can have profound effects on avian populations and communities, yet little is known regarding the effects of urban features on avian reproductive success. The objective of this study was to examine the reproduction of an urban-enhanced species, the mourning dove, to determine how tree and urban landscape features affect nest-site selection and nest success. Mourning dove nests were located by systematically searching potential nest sites on a weekly basis from late-March through mid-September in 2003 and 2004. A total of 1,288 mourning dove nests were located and monitored on the Texas A&M University Campus. Of these nests, 337 (26.6%) were successful (fledged, ≥1). An equal number of potential nest sites were randomly generated in ArcGIS and assigned to non-nest trees to evaluate habitat variables associated with nest-site selection. Mourning dove nests were located in trees with a larger canopy diameter and diameter at breast height (DBH) than the computer generated potential nests and nest trees were located closer to roads and farther from buildings than non-nest trees. Within the study area, nest success was predominately influenced by the proximity of urban features with successful nests being located closer to roads and farther from buildings than unsuccessful nests.

Keywords Urbanization · Avian ecology · Morning doves · Nesting

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Introduction

The expansion of urban areas into native habitat can have profound effects on avian populations and communities (Chace and Walsh 2006; Marzluff 2001). Since the 1950s the number of studies on urban effects on bird communities has been increasing (Marzluff et al. 2001). Numerous studies have evaluated how species composition and population densities change along urban gradients (Blair 1996; Melles et al. 2003; Crooks et al. 2004; Fraterrigo and Wiens 2005; Chapman and Reich 2007). In general, these studies illustrate that increased urbanization leads to a reduction in species richness and increases in avian biomass (reviewed in Chace and Walsh 2006). In California, for example, Crooks et al. (2004) found “urban-enhanced” species to be ten times more abundant on urban transects than in natural habitats. Savard et al. (2000), however, found that reproductive success of an urban-enhanced species, the European Starling (*Sturnus vulgaris*) can vary based on the level of urbanization, and stressed the importance of considering and understanding the landscape factors that may affect breeding density and reproductive success. They proposed that differences in reproductive success associated with changes in the level of urbanization may result in source-sink dynamics across an urban gradient, indicating that bird presence within an urban sector may not necessarily equate a viable population. Thus, to fully understand the dynamics of urban-enhanced avian species, we must extend our investigations beyond biodiversity and abundance parameters to nesting ecology and reproductive success. Understanding the dynamics of urban enhanced species in changing urban landscapes (i.e., from suburban to urban, “urban succession”) is important, particularly with the projected increases in urbanization throughout the world (United Nations 2008).

The objectives of our study were to evaluate if and how the spatial proximity of urban landscape features such as buildings, roads and open space influence nest-site selection and nest success of an urban-enhanced species, in this case, the mourning dove (*Zenaida macroura*). A number of urban avian studies indicate that mourning doves respond positively to urbanization (Emlen 1974; Blair 1996; Bolger 2001; Hostetler and Knowles-Yanez 2003; Crooks et al. 2004) and it is a highly adaptable species that will nest in various habitats (Grue et al. 1983; Sayre and Silvy 1993). In addition, urbanization is considered to favor granivorous birds like the mourning dove (Emlen 1974; DeGraaf and Wentworth 1986; Fraterrigo and Wiens 2005; Kark et al. 2007). Other factors such as the increased availability of water and nesting substrate are also likely related to the mourning dove’s increased use of urban areas (Swank 1955; Emlen 1974). Although the use of urban areas by mourning doves has been well documented, this species may be sensitive to intense levels of human use and development. Blair (1996) found the average daily densities of mourning doves to be greater in suburban lands such as office parks, residential areas, golf courses, and open-space recreation areas than in urban lands containing high densities of buildings, pavement, and pedestrians. In our study, we evaluated how tree and urban landscape features affect nest-site selection and nest success of this species.

Methods

Study area

Research was conducted on a 30-ha section of the Texas A&M University (TAMU) main campus in College Station, Texas (Fig. 1). The campus supported 43,000 students and is comprised of a diversity of urban habitats ranging from urban areas to more typical

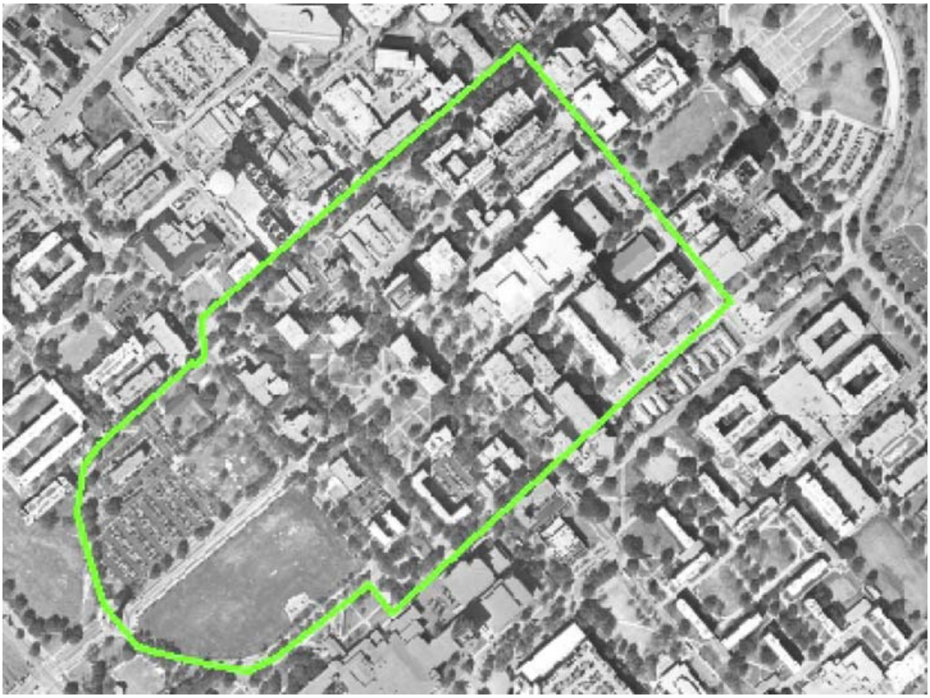

Fig. 1 Study area for nest searches of mourning doves, Texas A&M University, College Station, TX, 2004

suburban areas. The eastern half of the study area consisted of a dense arrangement of buildings and parking lots characteristic of urban lands (as defined by Marzluff et al. 2001), whereas the western portion was comprised of widely-spaced buildings interspersed with lawns and open fields characteristic of suburban lands. Over 30 different tree and shrub species were located within the study area with live oak (*Quercus virginiana)* being the predominant species, representing 65% of the total vegetation. Other representative tree species on campus include other oaks (*Quercus* spp.), elms (*Ulmus* spp.), pines (*Pinus* spp.), and other ornamental shrubs and trees.

Nesting demographics

Data was collected from March through September in 2003 and 2004. A comprehensive GIS database comprised of every tree located in the study area was used to identify all actual and potential nesting sites for our study. Nest trees were defined as trees in which active nesting of mourning doves were observed. Trees within the study area where nesting was never observed were defined as non-nest trees. The physical location of a nest was referred to as the nest-site, and nests were considered successful if a fledgling was observed to be ≥10 days old and/or fledglings were viewed in close proximity of the nest.

Nest searching and monitoring was conducted by systematically searching (Bivings 1980) potential nest sites (i.e., all trees and shrubs) on a weekly basis from late-March through mid-September of each year. Nest sites were recorded and mapped when doves were observed actively building or incubating and were checked every 1–3 days thereafter for nest outcome (success or failure). If additional nests were located during the course of nest monitoring activities, these nests were also recorded and mapped. During both weekly systematic searches and daily monitoring activities, cues such as observations of males doves actively seeking mates was used to help locate new nests.

Nests success was determined by visually observing the nests every 1–3 days and recording whether one or both parents were on or in the vicinity of the nest, the presence, number, and estimated age of fledglings, and the proximity of the fledglings to the nest. Nests were not disturbed by the observer and flushing did not occur. Applicable techniques using behavioral cues and precautions for minimizing researcher-induced mortality were followed (Martin and Geupel 1993). Young were aged according to changes in plumage as described by Hanson and Kossack (1963). Observations of plumage were conducted from a distance with the use of binoculars. Fledglings were not flushed or handled. Nests were considered to have successfully fledged when fledglings were ≥10 days old and/or were viewed in close proximity of the nest (Bivings 1980; Mathewson 2002). Nests were considered failed if adults were not seen on the nest during three consecutive visits prior to the observation of nestlings and/or if broken eggshells, extensive nest damage, feathers, or nestling (<10 days old) remains were found. When a nest failed or fledged, the site was checked for re-nests during subsequent visits. All nest locations were entered into ArcGIS (ESRI Institute, Redlands, CA, USA). An equal number of potential nest sites were randomly generated in ArcGIS and assigned to non-nest trees within the study area to evaluate habitat variables associated with nest-site selection for mourning doves.

Habitat measurements

Tree features For each nest, data were collected on six tree features: (1) tree species, (2) nest tree height (m), (3) nest height above the ground (m), (4) nest lateral distance (m) from tree trunk, (5) nest aspect (i.e., nest compass direction relative to the tree trunk), and (6) primary support substrate (Bivings 1980; Mathewson 2002). Tree height, nest height, and nest lateral distance were estimated by the observer to reduce potential disturbances to the nest site. Nest orientation relative to the trunk were categorized in the eight cardinal directions (north, northeast, east, southeast, south, southwest, west, or northwest). Primary support substrate was categorized as tree limb, tree fork, or other. Tree species were categorized as live oaks, other oaks, elms, other hardwoods, and pines. In addition, an extensive GIS database obtained from the Texas A&M University Department of Urban Forestry provided additional data including tree location, species, diameter at breast height (DBH), and tree canopy diameter for all trees within the study area.

Urban features Urban features were classified using 1-m digital-ortho quarter quads (DOQQs, year 2001) or obtained from an existing GIS database for the campus. The *buildings* classification consisted of all buildings within the study site, ranging from small storage sheds to multi-story buildings. The *roads* classification consisted of all roads and parking lots within the study area. *Fields* were defined as vegetated areas ≥0.5 ha with no buildings and minimal amounts of paved area within or adjacent to the study area. For each nest and all randomly selected potential nest trees, the minimum distance to each urban feature was determined in ArcView 3.3 (ESRI Institute) using the distance matrix extension (Jenness 2005).

Data analysis

To understand what habitat components of the urban environment may influence nesting demographics within the study area we generated and evaluated several *a priori* models for nest-site selection and nest success. Models were based on mourning dove nesting habitat literature and field observations and were limited in number to minimize over-fitting our data (Norman et al. 2004). Nest-site selection models compared actual nest trees with randomly selected non-nest trees. The variables considered for these models included the minimum distance to all urban features and 3 tree features (tree species, DBH, and canopy diameter). Nest success models evaluated data for successful and failed nest trees. In these models all tree feature and urban feature variables were considered. We ran general linear model regressions of these models using SAS (Proc Genmod, Link Logit, SAS version 9.1). For both nest-site selection and nest success, we evaluated five a priori models, a global model containing all variables considered (models 7 and 14, Table 1), and an intercept only model (models 1 and 8) using Akaike's Information Criterion corrected for small sample size (AICc, Simonoff 2003). For the models with the lowest AICc for each analysis, we presented averaged model parameters and averaged 95% confidence intervals (Burnham and Anderson 1998). The logistic regression analysis of the selected model was then log-transformed (logit) and exponentiated to derive a logistic prediction model that was used to evaluate how the given values of the independent variables in the model influence the estimated probability of nest-site selection and nest success (Guthery and Bingham 2007). We considered any model with a ΔAICc of ≤2 to be a best competing model.

Table 1 A priori and a posteriori models relating to mourning dove nest site selection and nest success to tree and urban habitat features in College Station, TX, USA

	Model	K	$-2\ln L$	AIC_c	ΔAIC_c	w_i
Nest-site selection a priori models						
1	None	1	3,569.71	3,571.7	225.4	0.00000
2	Tree species + canopy + DBH	4	3,375.14	3,391.2	44.9	0.00000
3	Tree species + DBH + fields	4	3,369.76	3,385.8	39.5	0.00000
4	Tree species + DBH + buildings	4	3,336.01	3,352.0	5.8	0.05308
5	Fields + buildings + roads	4	3,483.80	3,491.8	145.6	0.00000
6	DBH + fields + buildings + roads	5	3,363.73	3,373.8	27.5	0.00000
7	Tree species + canopy + DBH + fields + roads + buildings	7	3,324.23	3,346.3	0.0	0.94692
Nest success a priori models						
8	None	1	1,480.61	1,482.6	27.4	0.00000
9	Aspect + support + tree species + canopy + DBH + height	7	1,452.53	1,490.6	35.4	0.00000
10	Support + tree species + DBH	4	1,463.63	1,481.7	26.5	0.00000
11	Distance fields + distance roads + distance buildings	4	1,447.50	1,455.5	0.4	0.45581
12	Support + DBH + distance fields + distance buildings	5	1,456.60	1,568.6	113.5	0.00000
13	DBH + distance fields + distance buildings + distance roads	5	1,445.13	1,455.2	0.0	0.54417
14	Aspect + support + Trunkdist + Nheight + tree species + Trheight + canopy + DBH + distance fields + distance roads + distance buildings	12	1,428.35	1,476.6	21.4	0.00001

The Akaike Information criteria adjusted for small sample size (AICc), change in AICc from the smallest AICc value (ΔAICc), Akaike weights (w_i), and the number parameters (K) are displayed for each model

Variable notation: *none* intercept only, tree species, *DBH* diameter at breast height, *canopy* canopy diameter, *roads* distance to roads, *buildings* distance to buildings, *fields* distance to open fields, *Trheight* nest tree height, *Nheight* nest height, *Trunkdist* distance from tree trunk, *aspect* nest aspect, *support* support substrate

Results

During the 2003 and 2004 breeding seasons a total of 1,288 nests were located and monitored on the TAMU Campus. Of these nests, 337 (26.6%) were successful (fledged ≥1). Evaluating nest-site selection, we found the ΔAICc and w_i values from a priori model 7, the global model, to be the best approximating of the data. This model had a $w_i \geq 0.94$, suggesting there is ≥94% probability that this model yielded the best explanation of the data (Table 1). Our examination of individual parameters showed that the parameter estimate and 95% CI of fields, other oaks, elms, hardwoods, and pines contained zero, suggesting that the distance to fields and trees other than live oaks were not strong predictors of mourning dove nest-site selection (Table 2). Of the five tree groups included in the prediction model, only the inclusion of live oaks increased the probability of nest-site selection and the proportional use of live oaks was higher for actual nest sites (81%) than potential nest sites (60%; Table 3).

Examination of the relevant individual parameters by means of the logistic prediction model indicated that the probability of nest-site selection increased with increasing values of tree canopy diameter and DBH. Actual nest trees had a larger canopy (95% CI=37–38 ft) and greater DBH (95% CI=18–19 in.) than non-nest trees (95% CI=31–33 ft and 95% CI= 15–16 in., respectively). The prediction model also indicated that the probability of nest-site selection was positively related to distance to buildings and negatively related to distance to roads (Fig. 2). Actual nest sites were located further from buildings (95% CI=107–121 m) and closer to roads (95% CI=67–77 m) than potential nest sites (95% CI=71–81 m and 95% CI=83–93 m, respectively).

In evaluating nest success, we found the ΔAICc and w_i values from a priori models 11 and 13 were identified as competing best approximating models with a difference of ≤2 AICc units (Burnham and Anderson 1998; Norman et al. 2004). The models were similar in that each contained all of the urban feature parameters but model 13 also includes the DBH parameter. In situations where two models differ by one predictor, the larger model, although plausible, may include a "useless variable" that does not add anything to the fit of the model (Guthery et al. 2005); however, the inclusion of the additional predictor variable (DBH) in model 13 resulted a lower $-2\ln L$, indicating a better model fit for that model

Table 2 Averaged model parameter estimates and 95%CI relating mourning dove nest-site selection to tree and urban features for mourning doves on the Texas A&M University Campus, College Station, TX

Urban habitat features	$\widehat{\beta}$	95% CI
Canopy	0.0137	0.0024 to 0.025
DBH	0.0291	0.0077 to 0.0505
Fields	0.000220	−0.00015 to 0.000587
Buildings	0.00277	0.0019 to 0.0037
Roads	−0.00115	−0.00217 to −0.00013
Live oaks	0.4302	0.227 to 0.633
Other oaks	−0.1778	−0.562 to 0.261
Elms	0.0987	−0.191 to 0.388
Hardwoods	0.2323	−0.508 to 0.043
Pines	−0.5408	−1.086 to 0.004

Variable notation for urban habitat features: *canopy* canopy diameter, *DBH* diameter at breast height, *fields* distance to open fields, *buildings* distance to buildings, *roads* distance to roads

Table 3 Number and percent occurrence of actual nest trees and potential, non-nest trees by tree group for mourning doves on the Texas A&M University Campus, College Station, TX

Tree group	*N*		% of total *n*	
	Nest trees	Non-nest trees	Nest tree	Non-nest trees
Live oaks	1,042	773	80.8	60.0
Other oaks	33	65	2.6	5.0
Elms	75	118	5.8	9.2
Hardwoods	127	278	9.9	21.6
Pines	12	5	0.9	7.4

(Table 1). Examination of averaged individual parameters within the prediction model revealed a positive relationship between nest success and distance to fields and buildings. Nonetheless distance to fields appeared to have a negligible influence on the probability of nest success (Table 4 and Fig. 3). Increasing distance from buildings resulted in an increased probability of nest success (Fig. 3) with successful nests located farther from buildings (95% CI=126–158 m) than unsuccessful nests (95% CI=97–112 m). The probability of nest success increased with decreasing values of DBH and distances to roads (Fig. 3). Successful nests were located in trees with a smaller DBH (95%CI=17–19 in.) than unsuccessful nests (95% CI=18–19 in.), however the 95% CI values for DBH are not very different indicating that there was not a strong difference in DBH between trees that supported successful nests and those in which nests failed. Similar to the findings for nest-site selection, successful nests were located closer to roads (95% CI=46–63 m) than unsuccessful nests (95% CI=73–85 m).

Discussion

Nest-site selection

Tree and urban features were important indicators for nest-site selection and nest success for mourning doves within the study area. Specific tree features found to be important predictors in mourning dove nest-site selection were tree species and increasing values of DBH and canopy diameter. Structural stability, defined by Coon et al. (1981) as "the probability of eggs or entire nests falling to the ground as a result of wind, rain storms, parental activity, etc" (p. 389) has been shown to be important to mourning dove nest

Table 4 Averaged model parameter estimates and 95% CI relating mourning dove success to urban habitat features on the Texas A&M University Campus, College Station, TX

Urban habitat components	$\widehat{\beta}$	95% CI
DBH	−0.0141	−0.0253 to −0.0029
Fields	0.000463	0.00011 to 0.00081
Roads	−0.00232	−0.0033 to −0.0013
Buildings	0.002755	0.0018 to 0.0036

Variable notation for urban habitat features: *DBH* diameter at breast height, *fields* distance to open fields, *buildings* distance to buildings

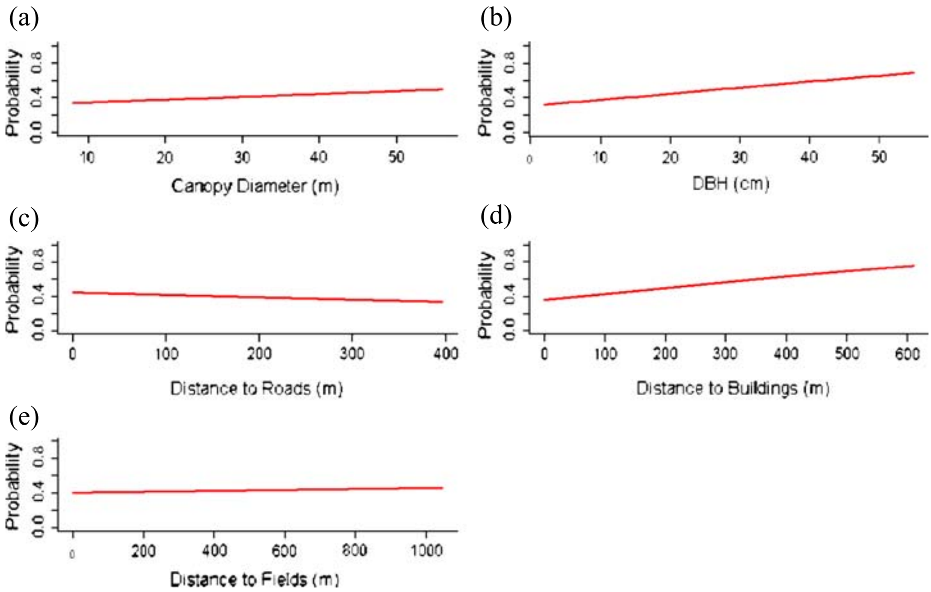

Fig. 2 The probability of tree nest-site selection as a function of (**a**) canopy diameter, (**b**) DBH, (**c**) distance to roads, (**d**) distance to buildings, and (**e**) distance to fields for mourning doves on the Texas A&M University Campus, College Station, TX

success. The increasing values of DBH and canopy diameter associated with nest-site selection may be a function of an increased structural stability associated with larger trees. The importance of structural stability also may contribute to the significance of tree species as a predictor of nest-site selection. The preference for live oaks by mourning doves has

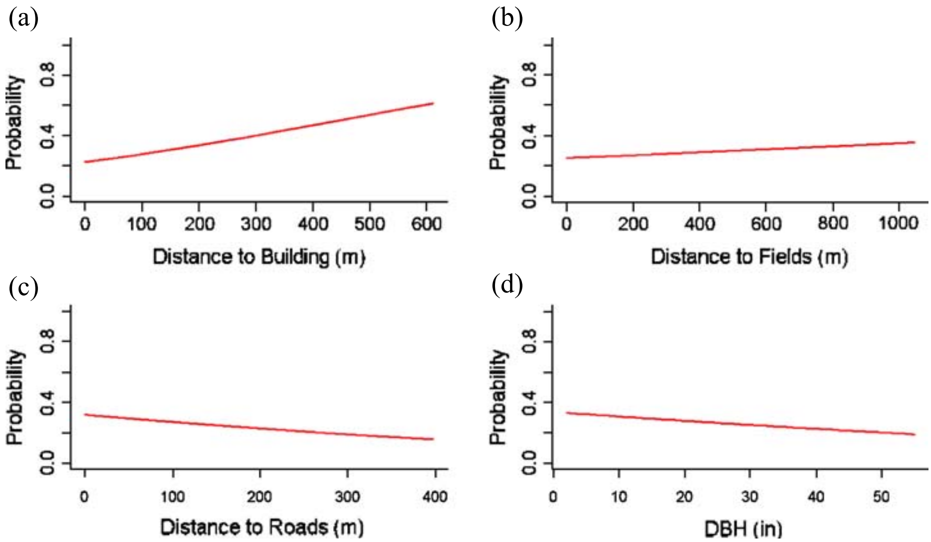

Fig. 3 The probability of mourning dove nest success as a function of (**a**) distance to buildings, (**b**) distance to fields, (**c**) distance to roads, and (**d**) DBH on the Texas A&M University Campus, College Station, TX

been documented on the TAMU Campus (Swank 1955; Bivings 1980) and elsewhere in Texas (Mathewson 2002). The horizontal limb structure and numerous diverging small twigs of live oaks serve to anchor mourning dove nests in place and the year-round foliage that provides cover earlier in the breeding season than other deciduous species may help explain mourning dove preference for this tree species (Swank 1955).

In our study, the spatial proximity of buildings and roads were important factors in mourning dove nest-site selection. Caldwell (1964) suggested tree characteristics alone may not be as important as the tree location in mourning dove nest-site selection. The negative relationship between buildings and nest-site selection may be due to an increasing human disturbance associated with buildings. Mourning dove densities have been shown to decrease in urban areas with high building density and the associated increases in pavement and pedestrians (Blair 1996). Whereas light to moderate urban development characteristic of suburban landscapes as discussed by Crooks et al. (2004) may create favorable conditions for mourning doves, mourning dove densities have been shown to decrease in urban areas with high building density and the associated increases in pavement and pedestrians (Blair 1996). Although distance to fields was not considered to be a relevant parameter in our model, the proximity of open areas has been cited as being an important factor in nest-site selection (Swank 1955; Armbruster 1973; George 1975; Rosenberg et al. 1987; Lewis 1993). When considering the habitats associated with urban landscapes such as lawns, landscaping, and other forms of bare ground or open areas, the criteria we set forth for the delineation of open fields as areas ≥0.5 ha may have been too large in scale to truly reflect the relative importance of open areas and bare ground for nest-site selection within our study area. Decreasing distances to roads was found to be an important predictor for both nest-site selection and nest success. Roads may be important to mourning dove nest-site selection because of the feeding ecology of doves. Grit, an essential component of the mourning dove diet, and water are frequently secured along road edges (Lewis 1993).

Nest success

Mourning dove nest success was almost exclusively influenced by the proximity of landscape features, illustrating the potential importance of urban succession in mourning dove nesting ecology. None of the tree features evaluated, with the exception of DBH, were relevant predictors of nest success. These findings are similar to those of Yahner (1983) who did not find nest-site characteristics to be associated with nesting success of mourning doves in Minnesota shelterbelts (trees planted as windbreaks). Although DBH was included as a relevant model parameter, there was minimal difference in DBH for successful nests as compared to failed nests. As with nest-site selection, nest success increased near roads and decreased near buildings and fields. The potential reasons for the increased success associated with these variables are likely to be similar to those related to nest-site selection.

Two potential confounding factors for both nest site selection and nest success that were not considered are the types, level and distribution of human disturbance within the study area and the role of predators, primarily blue jays (*Cyanocitta cristata*) and fox squirrels (*Sciurus niger*). Variations in the type of disturbance (i.e. vehicular traffic vs. foot traffic) and the level of disturbance in a given area (low vs. high) could influence the selection of nest sites and the success of established nests. In a study of urban parks, Jokimaki (1999) did not find human disturbance to affect the breeding occurrence of birds, however it was unclear whether this was due to low intensities of human activity or possibly, that the impact of human disturbances was less important than other variables. In contrast, Fernández-Juricic (2000) found that increased human disturbance in urban parks resulted in a decreased breeding density. Our general observation of mourning doves within the study area suggested they were relatively tolerant of high levels of human disturbance and were often found nesting successfully in areas of high foot and vehicular traffic. Movements of predators also could have influenced nest site selection success; however, we noted evidence of nest destruction as a result of predation, and found it was not a significant source of nest failure.

In conclusion, our study suggests that urban features were more important in predicting nest-site selection and nest success within our study area than tree characteristics. Although a moderate level of development characteristic of suburban areas (Crooks et al. 2004; Blair 1996) may not impact and may even be beneficial to mourning dove populations, increased development associated with urban areas that are characterized by high building density may negatively impact mourning doves. Caution should be taken in assuming that all urban landscapes are beneficial to mourning doves and other urban enhanced species. Although light to moderate urbanization may not affect and may even benefit urban-enhanced species initially, urban succession resulting in increased urban infrastructure (i.e., greater building density), and changes in the existing trees and vegetation (i.e., bare ground, lawns) may result in shifts in bird distribution and reproductive success. By understanding the influence of urban features on the reproductive ecology of the mourning dove and other urban-enhanced birds, land use planners and others can make better informed decisions regarding urban development by considering the impacts and trade-offs associated with such development. Future research that expands on these concepts and incorporates consideration of population dynamics at multiple scales and differing levels of urbanization (Clergeau et al. 2006) will allow for a greater understanding of the population ecology and habitat preferences of birds in urban areas.

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