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NEST SITE SELECTION AND PRODUCTIVITY OF SUBURBAN RED-SHOULDERED HAWKS IN SOUTHERN OHIO[1]

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Abstract. We measured nest site selection and productivity of suburban-nesting Red-shouldered Hawks (*Buteo lineatus*) in southwestern Ohio and rural-nesting Red-shouldered Hawks in south-central Ohio. At both the suburban and the rural locations, nest sites had greater canopy height and overall tree basal area than paired random plots, and were located closer to water than were paired random plots. Nest trees also had greater diameter and height than random plot-center trees. Reproductive rates at suburban and rural sites were similar, averaging 2.6–3.1 nestlings per successful nest. Results indicated that suburban-nesting Red-shouldered Hawks were very similar to rural-nesting hawks in both nest site selection and productivity, suggesting that Red-shouldered Hawks were habituated to their suburban environs.

Key words: Buteo lineatus, *nest site selection, productivity, Red-shouldered Hawk, suburban, urban.*

INTRODUCTION

Although nest site selection by Red-shouldered Hawks (*Buteo lineatus*) has been documented in several locations throughout the species' breeding range in North America (Titus and Mosher 1981, Crocoll and Parker 1989, Bosakowski et al. 1992), published accounts of suburban- or urban-nesting Red-shouldered Hawk populations are rare. The urban-nesting western Red-shouldered Hawks (*Buteo lineatus elegans*) of southern California (Bloom et al. 1993, Bloom and McCrary 1996) provide the notable exception. Many of these hawks nested successfully in urban areas, near private residences, public buildings, and significant human activity, using native and non-native trees as nest sites. Within the range of the eastern subspecies (*Buteo lineatus lineatus*), published information on suburban- or urban-nesting Red-shouldered Hawks is limited to brief references to some nests located very near houses in Minnesota (Eliason 1988), Ontario (Campbell 1975, Dent 1994), and Quèbec (Morris and Lemon 1983) and to nests located near roads or human activity in Missouri (Parker 1986) and Ontario, Canada (Szuba et al. 1991).

Thus, very little is known about the ecology of such suburban-nesting Red-shouldered Hawks, particularly the eastern subspecies. Suburban-nesting birds may select for habitat features different than those chosen by birds nesting in more typical remote woodland habitat, or may make use of novel habitats not found in remote woodlands, such as lawns, buildings, and pastures. It is possible that suburban habitat is suboptimal for Red-shouldered Hawks and that suburban-nesters might be the less-competitive members of the population, pushed into the marginal habitat by more fit or more mature birds. Less-fit birds, or birds nesting in suboptimal habitat, may have depressed reproductive success compared to others in the population. Thus, reproductive rate might yield important information about habitat quality in a particular area. The purpose of this investigation was to document the preferences and productivity of suburban-nesting Red-shouldered Hawks in southwestern Ohio and compare their preferences and productivity to those of more typical Red-shoul-

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dered Hawks nesting in a sparsely-settled wooded region of nearby southeastern Ohio.

METHODS

STUDY SITES

The southwestern Ohio study area (SW, hereafter) is a hilly, unglaciated area in the Interior Plateau ecoregion (Omernik 1987). The hills are dissected by many small streams located in ravines and by two large rivers, the Great Miami River and the Little Miami River. Native forests are dominated by second-growth oak-hickory (*Quercus* sp., *Carya* sp.) and beech-maple (*Fagus grandifolia, Acer saccharum*) associations, with lowland, riparian forests characterized by sycamores (*Platanus occidentalis*) and beech. Elevation ranges from approximately 140 to 270 m.

The SW study area consisted of Hamilton County, Clermont County, and southwestern Warren County, Ohio; however, the nests studied were actually located in a wide band of suburban development surrounding the city of Cincinnati, Ohio. Suburban areas varied from densely-populated (residential lots approximately 20 × 35 m) to sparsely-populated (> 2.5-ha residential lots, as well as undeveloped private land). Most residences and other buildings were surrounded by lawns and other non-native vegetation, but residences tended to be located on level ground, with steep slopes and riparian areas left in native vegetation. Areas of public land within the study area contained no residences, but were heavily used for sports and other recreation.

The Hocking Hills study area (HH, hereafter) is a hilly, unglaciated region located within the Western Allegheny Plateau ecoregion in southeastern Ohio (Omernik 1987). This region contains numerous small, high-gradient streams, as well as one large river, the Hocking River, and many mid-size streams. Elevation ranges from approximately 200 to 310 m. Predominant forest type is oak-hickory. Drier sites include chestnut oak (*Quercus prinus*) and black oak (*Q. velutina*), whereas mesic slopes are characterized by tulip-tree (*Liriodendron tulipifera*). Plantations of white pine (*Pinus strobus*) and red pine (*P. resinosa*) also are common. Lowland forests are characterized by sycamores, silver maple (*Acer saccharinum*), beech, and river birch (*Betula nigra*).

The HH study area consisted of Hocking County, eastern Vinton County, northern Athens County, and southern Perry County, including the Athens District of Wayne National Forest, Hocking State Forest, Zaleski State Forest, and associated private lands. Proximity to human activities varied widely, with some areas containing residential development, some areas containing recreational development such as picnic areas and trails, and some areas fairly remote.

NEST LOCATION TECHNIQUES

Nests were located primarily in February through early April, using several techniques. We searched historic nesting territories and near survey stations where Red-shouldered Hawks had responded to conspecific broadcasts in a related study (C. Dykstra, unpubl. data). We sighted some nests from roads while traveling in the study areas, and interested biologists, birders, and landowners reported some nests or territories.

REPRODUCTIVE RATE

We conducted occupancy surveys of all known nests from the ground using binoculars on 3–5 March 1997 (n = 13 SW nests), 3–6 March 1998 (n = 24 SW nests), and 4–8 March 1999 (n = 68 SW nests and 41 HH nests). Nests were considered occupied if sticks had been added to the nest, or if green vegetation had been placed on the nest. We conducted activity surveys during 26 March–3 April 1997 (n = 25 SW nests), 5–9 April 1998 (n = 33 SW nests and 40 HH nests), and 5–9 April 1999 (n = 64 SW nests and 38 HH nests). Nests were considered active if there was evidence that eggs had been laid (i.e., incubating adult, presence of small down feathers on the edges of nest, or broken eggshells below nest). We climbed to nests between 29 April–3 June 1997, 11–26 May 1998, and 9 May–5 June 1999 to count and band nestlings. Nestlings were counted if they were at least 3 weeks old, based on the first and second secondary feather lengths, using the age-feather length regression model determined for Red-shouldered Hawks by Penak (1982).

Reproductive rate was reported as the number of nestlings per occupied nest, the number of nestlings per active nest, and the number of nestlings per successful nest, where occupied and active nests were defined as above and where a successful nest was defined as one that contained at least one young > 3 weeks old. Success rate was defined as the percentage of active nests that contained at least one young > 3 weeks old. Reoccupancy rate was defined as the percentage of active territories from one year that were found to be occupied during the occupancy survey in the successive year. This rate included birds occupying the same nest or a new nest within the same territory, and represented a minimum reoccupancy given that not all territories were thoroughly searched.

NEST SITE AND PAIRED, RANDOM-PLOT HABITAT CHARACTERIZATION

Habitat measurements were conducted between 26 June–22 August 1997 and 5 July–15 August 1998, after nestlings had fledged. In 1997, we characterized habitat at all active nests found in each region (n = 33 in SW, n = 18 in HH). In 1998, we located more nests/territories in both study areas, and characterized habitat at 12 additional active nests in HH, selected randomly from a total of 21 new nests found that year. In 1998, active nests found within the same territory as an active nest studied in 1997 were not considered new nests and were not characterized.

We used a modification of the methods of James and Shugart (1970) to characterize habitat at each nest site, and at a paired, random plot located near each nest. Each paired random plot was located in a random direction from the nest tree, at a randomly-selected distance (limited to 75–200 m, as in McLeod 1996). A circular plot of 0.04 ha was centered on the nest tree. Paired random plots were centered on the tree nearest the random point which had a diameter ≥ 33 cm dbh (equal to the smallest Red-shouldered Hawk nest tree in SW in 1997). We measured and derived several habitat characteristics (Appendix) at each nest plot and paired random plot.

NEST-SITE DATA ANALYSES

Before performing univariate comparison of habitat variables, we tested habitat variables for normality using Kolmogorov-Smirnov tests. For normally-distributed variables, we used two-tailed paired t-tests to compare nest plots and paired random plots at each location separately, and at both locations combined. For non-normally distributed variables, we used Wilcoxon tests. Chi-square tests for independent distributions were used for the two categorical variables. To evaluate any differences between SW nests and HH nests, we used Mann-Whitney U-tests.

For multivariate comparison of nests and paired random plots, we used logistic regression to determine which combination of habitat variables was most useful in separating nest plots from paired random plots. Habitat variables were used in a stepwise logistical regression, no-intercept model, with α-to-enter = 0.10 and α-to-remove = 0.10, using the computer program SAS (SAS Institute 1997).

Results are presented as mean ± SE. P-values ≤ 0.05 were considered significant.

RESULTS

NESTS

We located 48 active nests in SW in 1997 and 1998, and 39 active nests in HH in 1997 and 1998. Nests were located in many species of trees, most frequently sycamores, ash, and oaks. The overall distribution of tree species at SW and HH could not be compared due to small sample sizes, but the distribution of sycamores and "non-sycamores" was significantly different at the two sites, with more HH nests in sycamores (χ^2_1 = 8.68, P = 0.003).

Two nests in SW were not built in trees, but were located on human-made structures. One of these was on the roof of a three-story multi-family building in a complex of many such buildings (Hays, in press). The other was built on a gas grill standing on the deck of a private residence.

REPRODUCTIVE RATE

Reproductive rate was relatively consistent in the two areas over the three years measured, averaging 1.8 ± 0.1 young per active nest, or 2.8 ± 0.1 young per successful nest (Table 1). Success rate ranged from a low of 55% in SW in 1998 to a high of 67% in HH in 1999.

NEST SITE SELECTION

Red-shouldered Hawk nest sites at both SW and HH differed from the randomly selected points in several ways. Several significant variables indicated that forests at nests sites were more mature than forests at paired random sites. At both SW and HH, nest-trees were taller (NESTHT) and had greater diameter (NESTDBH) than paired, random plot-center trees (Table 2). Nest plots had greater canopy height (CANHT) and overall tree basal area (BASAL) than paired random plots. At SW, nest plots were closer to water (WATER) than paired random plots, and

TABLE 1. Reproductive success of Red-shouldered Hawks in southwest Ohio and Hocking Hills, 1997–1999.

	Southwest Ohio			Hocking Hills		
	1997	1998	1999	1997	1998	1999
Young per occupied nest (*n*)	1.9 ± 0.6 (11)	1.2 ± 0.3 (24)	1.2 ± 0.2 (41)			1.5 ± 0.4 (22)
Young per active nest (*n*)	1.9 ± 0.4 (19)	1.6 ± 0.3 (29)	1.5 ± 0.2 (50)		1.9 ± 0.3 (29)	2.1 ± 0.3 (27)
Young per successful nest (*n*)	2.8 ± 0.2 (21)	2.7 ± 0.2 (23)	2.6 ± 0.2 (30)	2.8 ± 0.2 (11)	2.9 ± 0.2 (19)	3.1 ± 0.1 (19)
Success rate (*n*)	63% (19)	55% (29)	58% (50)		66% (29)	67% (27)
Reoccupancy rate (*n*)		62% (34)	66% (38)			61% (28)
Total active nests	33	36	51	18	29	28

there was a trend for HH nests to be closer to water as well. Nest plots at SW, but not HH, were at lower elevations (ELEV) and contained fewer snags (SNAGS) than paired random plots. Additionally, SW nests tended to be farther from roads (ROAD) than were paired random sites (Table 2).

When both HH and SW were combined, the results were similar: nest plots had greater NESTHT ($P < 0.001$), NESTDBH ($P < 0.001$), CANHT ($P < 0.001$), and BASAL ($P = 0.001$) than paired random plots, smaller ELEV ($P = 0.001$) and WATER ($P = 0.001$), and greater canopy closure within the plot (CANPLOT, $P = 0.04$).

Nests at SW differed from nests at HH in only three variables, all related to the suburban nature of SW study area. Nests at SW were closer to buildings (75 ± 20 m, $n = 48$) than were nests at HH (333 ± 48 m, $n = 30$; Mann-Whitney *U*-test, $U = 111.5$, $P < 0.001$). Nest plots at SW were more likely than those at HH to have lawn as the dominant ground cover (16 of 48 plots vs. 1 of 30 plots, $\chi^2_1 = 9.75$, $P = 0.002$), and contained significantly fewer snags (0.9 ± 0.2 m vs. 2.7 ± 0.4 m, $n = 33$ and $n = 30$ respectively, Mann-Whitney *U*-test, $U = 224.0$, $P < 0.001$). Nest sites at SW also contained more human-made structures (STRUCT) than sites at HH (Table 2; not analyzed statistically due to low sample size).

Results of multivariate analyses using stepwise logistic regression were very similar to those obtained by univariate analyses, and are not presented here.

DISCUSSION

Red-shouldered Hawks at both SW Ohio and Hocking Hills selected nest sites in areas of relatively mature forest that were near a water source. Several of the inter-related variables that differed between nest sites and paired random plots were related to the size of the nest tree and the surrounding forest (i.e., NESTHT, NESTDBH, CANHT, and BASAL). Nest sites also were closer to water than paired random plots at SW and probably at HH. Distance to available water sources may have influenced the significance of the variable ELEV. ELEV, which was significant in univariate tests at SW, was significantly, but weakly, correlated to WATER ($r = 0.26$, $P = 0.003$). Most of the water sources nearest to nests at SW were small streams running through

TABLE 2. Selected habitat characteristics at nest plots and paired random plots, 1997–1998.

	SW Ohio (n = 33)					Hocking Hills (n = 30)				
	Nest		Random			Nest		Random		
Variable	x̄	SE	x̄	SE	P	x̄	SE	x̄	SE	P
NESTHT (m)	31.6	1.3	22.9	1.1	<0.001	30.2	0.9	24.2	1.2	0.001
NESTDBH (cm)	66.9	4.2	49.3	3.0	0.001	64.4	3.5	46.6	3.3	0.001
ELEV (m)	221.6	6.3	227.2	6.0	0.001	226.2	3.2	231.0	4.0	0.12
BASAL (m^2 ha^{-1})	35.8	3.1	23.4	2.1	0.002	32.5	2.0	26.0	2.2	0.06
CANHT (m)	27.1	1.0	20.9	1.0	<0.001	27.4	0.7	23.4	1.0	0.003
SNAGS (No.)	0.9	0.2	2.4	0.5	0.03	2.7	0.4	2.1	0.4	0.20
WATER (m)	33.1	10.4	69.3	12.4	0.003	27.1	6.2	46.6	9.6	0.08
ROAD (m)	86.2	9.1	66.1	8.8	0.08	135.5	31.0	143.9	29.7	0.65
BUILDING (m)	60.1	8.3	55.9	7.5	0.57	332.9	48.0	357.4	51.1	0.12
STRUCT (No.)[a]	6		4		0.49	0		0		
LAWN (No.)[a]	10		10		1.00	1		0		

[a] Chi-square test for independence.

the bottom of valleys or ravines; thus, it was logical that nest sites, which were closer to water than paired random sites, would also have slightly lower elevations than paired random sites. In contrast to SW, nest sites at HH tended to be located in the larger flood plains of mid-size streams: here the paired random plots were often located within the floodplain at the same elevation as the nest.

The significance of the variable SNAGS in univariate tests at SW may have been a statistical anomaly or, possibly, may have been related to the weak correlation between SNAGS and WATER (r = 0.30, P = 0.001). There was little ecological evidence to indicate that snags were important to Red-shouldered Hawks at either location.

The vegetative characteristics apparently preferred by Red-shouldered Hawks in SW and HH were generally similar to those preferred by Red-shouldered Hawks in studies elsewhere. Elsewhere, nest sites were located in areas of mature forest in many locations (Morris and Lemon 1983, Preston et al. 1989, Moorman and Chapman 1996). As in SW and HH, nests were frequently located close to water, with distances to water generally very low (30 m, this study; ranging from 29 to 240 m elsewhere, Bryant 1986, Preston et al. 1989).

Nest sites of suburban Red-shouldered Hawks in SW Ohio differed from those of more typical rural-nesting Red-shoulders in Hocking Hills only in variables that were clearly related to the suburban habitat. Fully 33% of the suburban birds might be called "backyard birds," with lawn being the dominant ground cover at the nest plots. To our knowledge, the two nests on buildings comprise the only such record published (Hays, in press). Radio-tagged suburban Red-shouldered Hawks were occasionally seen perching on structures such as utility poles and lines, fences, lawn furniture, and rooftops (Dykstra et al., unpubl. data). These birds also frequented the edges of human-made ponds, foraging from low perches in native and non-native vegetation. In their utilization of the suburban habitat, Red-shouldered Hawks in southwestern Ohio were similar to those in southern California (Bloom and McCrary 1996).

Suburban-nesting Red-shouldered Hawks in SW Ohio did not appear to be compromised in any way that we measured. The habitat they selected was not apparently suboptimal in comparison to habitat selected in HH, as they were able to choose mature forests close to water sources. Additionally, the productivity of suburban birds was similar to or only slightly lower than that of the Hocking Hills birds, suggesting that SW birds were not compromised by their unusual habitat, at least in comparison to birds of HH. Reproductive rate among Red-shouldered Hawks varies widely, averaging 1.1–2.9 fledglings per nest (Crocoll 1994). However, it should be noted that comparisons between studies may be somewhat inaccurate due to different or unreported techniques of counting active nests and "fledged" young. In our study in particular, the productivity of both SW and HH might be somewhat overestimated in comparison to published records because we counted nestlings as young as 3 weeks old. Additional circumstantial evidence suggesting that suburban Red-shouldered Hawks fared well in SW Ohio may be found in the density of nesting birds in some areas. In 1997, two active nests that hatched young were only 250 m apart. Additionally, at the site we searched most intensively, we found 1.2 pairs km^{-2}. The nearest-neighbor distance between pairs in this area averaged 467 m ($n = 8$ pairs). The nest density within this area of SW Ohio, although not likely representative of our entire study area, was similar to that in north-central Minnesota (1 nest km^{-2}, McLeod and Andersen 1998), but greater than that in New York and New Jersey (0.2–0.6 nests km^{-2}, Crocoll and Parker 1989, Bosakowski et al. 1992).

It is not clear whether suburban-nesting populations of Red-shouldered Hawks differ from populations in more traditional remote locations in their tolerance of human presence and activities. Red-shouldered Hawks preferentially selected sites far from human activities (particularly buildings) in some studies. Nests in New York averaged 1,300 m from the nearest home (Johnson 1989). In New Jersey, nests were 1,013 m from the nearest human habitation and 812 m from the nearest road (Bosakowski et al. 1992). Areas occupied by Red-shouldered Hawks in New Jersey contained no suburban development within 300 m (Bosakowski and Smith 1997). In contrast, several studies have shown that Red-shouldered Hawk nest sites were no farther from roads than were random plots (Johnson 1989, Moorman and Chapman 1996, McLeod et al., unpubl. data). Additionally, in southern Quèbec (Morris and Lemon 1983), and in HH, birds did not select nest sites distant from either roads or buildings. Red-shouldered Hawks at SW did not avoid nesting near buildings, and, although they may have selected sites slightly farther from roads than random sites, they nonetheless placed their nests relatively close to roads. One caveat to the inter-study comparisons above is that for nest site descriptions to be properly compared between locations, the nests studied must be an unbiased sample of the nests within a population (McLeod et al., unpubl. data), a standard rarely achieved in nest site selection studies.

Suburban Red-shouldered Hawks in SW Ohio, although apparently maintaining their population and reproducing well, face at least two threats to their current status. On the outer edges of the study area most distant from the city of Cincinnati, agriculture dominates the landscape, and Red-tailed Hawks may outcompete Red-shouldered Hawks (Bednarz and Dinsmore 1982, Bryant 1986). The second major threat to Red-shouldered Hawks of SW Ohio is continued urban sprawl and suburban development. Red-shouldered Hawks have been pushed out of traditional nest sites by development, even within the last 30 years. In a sample of 22 nests studied in SW Ohio in 1963–1977 (J. Holt, unpubl. data), only 10 of them still held Red-shouldered Hawks by the time of our study (J. Hays, unpubl. data). Given this history, it is unclear whether the suburban Red-shouldered Hawk population in SW Ohio can sustain itself in the future.

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APPENDIX. Habitat variables of Red-shouldered Hawk nest sites.

NESTHT	Height of nest tree or plot central tree (m)
NESTDBH	Dbh of nest tree or plot central tree (m)
SLOPE	Slope of plot, measured with clinometer (deg)
ELEV	Elevation of plot, from 7.5′ USGS topographical maps (m)
OVERST	Number of overstory trees in plot (stems > 8 cm dbh whose major foliage fell within the upper third of overall stand height)
UNDERST	Number of understory trees in plot (stems > 8 cm dbh whose major foliage fell within the lower two-thirds of overall stand height)
TOTAL	Total number of trees in plot
SNAGS	Number of snags (dead trees) in plot
BASAL	Basal area of all trees in plot (m^2 ha^{-1})
DBH1	Percentage of trees with dbh 8–12.4 cm
DBH2	Percentage of trees with dbh 12.5–22.6 cm
DBH3	Percentage of trees with dbh 22.7–37.8 cm
DBH4	Percentage of trees with dbh ≥37.9 cm
SHRUB	Number of shrubs < 8 cm dbh and > 50 cm tall within 5 m of plot center
SHRUBHT	Estimated height of dominant shrub species (m)
GRCOVER	Percentage ground cover, measured with ocular tube (James and Shugart 1970) at 1-m intervals between 1 and 10 m from plot center in cardinal directions
UNCOVER	Percentage understory cover, measured in same manner as GRCOVER
CANHT	Canopy height of plot, measured in each quadrant and averaged (m)
CANNEST	Percentage canopy closure at the nest, measured with a convex densiometer in each cardinal direction, and averaged
CANPLOT	Percentage canopy closure in the plot, measured with a convex densiometer in the four cardinal directions at the nest and in the four cardinal directions at four points 8.5 m from plot center, and averaged
WATER	Distance to nearest permanent or seasonal water (m)
ROAD	Distance to nearest road (m)
BUILDING	Distance to nearest building (m)
STRUCT	Presence or absence of human-made structures within the plot
LAWN	Presence or absence of lawn as the dominant ground cover within the plot