Wilson Bull., 102(3), 1990, pp. 480–486

NEST-SITE CHARACTERISTICS AFFECTING SUCCESS AND REUSE OF RED-SHOULDERED HAWK NESTS

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ABSTRACT.—Characteristics of nest sites were studied to determine which attributes are related to repeated use of nests and nesting success of Red-shouldered Hawks (*Buteo lineatus*). Nests in large trees with large support branches and surrounded by a dense understory were most likely to fledge at least one bird. Nests built in pin oaks (*Quercus palustris*) had a higher probability of not fledging any young than nests in other species of tree, although 50% of nests were placed in pin oaks. Nests in large trees with a greater number of support branches in an area with a closed canopy were more likely to be used in successive years than nests in other locations. Hawks using old nests may have a higher nesting success rate than those building new nests. *Received 26 June 1989, accepted 20 Jan. 1990.*

Although several studies have investigated and quantified nesting habitat characteristics (Titus and Mosher 1981, Bednarz and Dinsmore 1982, Morris and Lemon 1983), only a few have commented on the relationship between vegetation structure and the success and frequency of reuse of Red-shouldered Hawk (*Buteo lineatus*) nests (Bednarz 1979, Morris et al. 1982). Bednarz (1979) suggested that Red-shouldered Hawks nest in large trees because this may reduce nest predation and damage from wind and rain. Here we quantify the effects of nest-site characteristics on nesting success and reuse of nest sites in a year-round resident population in southeast Missouri.

STUDY AREA AND METHODS

The study was conducted on the Mingo National Wildlife Refuge located on the Mississippi River floodplain in southeast Missouri. The 8770-ha area is primarily composed of lowland hardwood forest (Korte and Fredrickson 1977). In lesser amounts are cypress swamps, upland hardwood forest, cropland, pasture, and moist soil units. Moist soil units are areas that are seasonally flooded to promote the growth of herbaceous plants to be used by waterfowl. Dominant tree species in the lowland forest include pin oak (*Quercus palustris*), overcup oak (*Q. lyrata*), willow oak (*Q. phellos*), sweetgum (*Liquidambar styraciflua*), elm (*Ulmus* spp.), ash (*Fraxinus* spp.), and hickories (*Carya* spp.).

Woodlands were searched systematically for nests during March and April of 1982 and 1983 using the methods of Craighead and Craighead (1956). Vegetation was measured within a 15-m radius circle circumscribing the nest. The species and diameter were recorded for each nest tree. Nest tree height, nest height, and canopy height were measured with a Haga altimeter. The diameter of all trees greater than 5 cm dbh within the 15-m radius circle was

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measured, and the mean was calculated. Basal area was also computed from dbh measurements. Canopy closure was measured with a spherical densiometer. Diameter of nest support branches was directly measured on three nests and optically estimated with binoculars for the remaining nests, using the measured branches as a reference. Nest location was categorized by the placement of nests in tree crotches formed with the trunk or placement in crotches away from the main tree bole. The nest-tree difference was defined as the distance the nest was from the top of the nest tree, which was determined by subtracting the nest height from the nest tree height. The relative nest height is the nest height divided by the nest tree height multiplied by 100. Stem densities (stems/ha) of trees within four diameter size classes are represented by saplings, 5.0–10.2 cm; small trees, 10.3–25.4 cm; trees 25.5–50.8 cm; large trees ≥50.9 cm, and, for all size classes, number of trees.

Nest success was determined for a total of 34 nests in 1982 and 1983. Vegetational characteristics associated with successful nests, which fledged at least one bird, were compared with unsuccessful nest, from which no young were fledged, using the Student *t*-test and discriminant function analysis (Nie et al. 1975). Similar comparisons were made for nests used in two consecutive breeding seasons between 1982 and 1985 versus nests used for only one breeding season. To meet the assumption of normality for discriminant function analysis, canopy closure was transformed by squaring and the number of support branches was transformed with a square-root transformation. Occupancy of a particular nest tree during a given breeding season was determined by direct observation of a nest in use, knowledge that an alternate nest site was in use, or knowledge that the nest was in an obvious location that couldn't have been overlooked during the previous year's nest search.

RESULTS

Nest success.—Of the 34 nests monitored during the 1982 and 1983 breeding seasons, 25 successfully fledged at least one bird. An average of 1.79 young were fledged per breeding pair. Successful nests were in significantly larger diameter nest trees surrounded by smaller diameter trees than were unsuccessful nests (Table 1).

Maximum discrimination between successful and unsuccessful nests was found with nest tree dbh, density of saplings, mean support branch diameter, and relative nest height (canonical correlation coefficient = 0.60, Wilks lambda = 0.644, 4 df, $P < 0.010$). The discriminant function analysis was able to classify correctly 100% of the successful nests and 56% of the unsuccessful nests, for an overall classification of 88% based on these four variables. Each nest was then iteratively excluded from the development of the discriminant function and then classified by it. This gave an unbiased estimation of the error rate (Lachenbruch and Mickey 1968). Through this leave-one-out technique, the discriminant function correctly classified 92% of the successful nests and 56% of the unsuccessful nests for an overall classification of 82%.

Ten different tree species were used as nest trees (Table 2). Although pin oak was the most frequently used, it had a significantly higher rate of nest failures (89%) than the other species combined ($\chi^2 = 6.465$, df = 1, $P = 0.013$, corrected for continuity).

TABLE 1

COMPARISON OF NEST-SITE VARIABLES FOR SUCCESSFUL AND UNSUCCESSFUL RED-SHOULDERED HAWK NESTS

	Successful nests (N = 25)		Unsuccessful nests (N = 9)		
Variable	Mean	(±SD)	Mean	(±SD)	*P*-value[a]
Nest tree height (m)	27.8	(3.3)	29.3	(2.5)	0.236
Nest tree dbh (cm)	64.1	(12.0)	53.4	(14.9)	0.038
Canopy closure (%)	90.2	(10.7)	93.9	(8.5)	0.358
Canopy height (m)	22.3	(4.5)	24.1	(3.7)	0.282
Mean tree dbh (cm)	16.4	(3.1)	21.1	(4.1)	0.001[b]
Basal area (m^2/ha)	25.4	(10.2)	33.5	(11.6)	0.056
Branch diameter (cm)	24.5	(5.2)	20.2	(6.6)	0.057
Support branches (n)	2.4	(0.6)	2.4	(0.5)	0.984
Nest-tree difference (m)	10.5	(3.2)	12.3	(2.0)	0.135
Nest height (m)	17.3	(2.9)	17.0	(1.6)	0.778
Relative nest height (%)	62.5	(9.1)	58.2	(4.5)	0.079
Saplings (stems/ha)	361.6	(196.8)	243.6	(143.6)	0.111
Small trees (stems/ha)	250.1	(126.3)	207.4	(53.9)	0.179
Trees (stems/ha)	103.5	(55.6)	136.6	(51.5)	0.128
Large trees (stems/ha)	26.6	(20.5)	40.7	(32.0)	0.135
Number trees (stems/ha)	741.9	(277.1)	628.7	(212.9)	0.276

[a] For comparison of successful and unsuccessful nests by *t*-test.

[b] Means significantly different ($P < 0.05$) when adjusted for experimentwide error for all 16 comparisons.

Successive use of nest.—Twenty-six nests were examined in successive breeding seasons from 1982 until 1985 to determine if they were reused. Nine of the 26 nests were used in at least two consecutive breeding seasons. These nest were located in significantly taller nest trees (Table 3) and in

TABLE 2

NEST-TREE SPECIES OF SUCCESSFUL AND UNSUCCESSFUL RED-SHOULDERED HAWK NESTS

Species	Successful nests (N = 25)	Unsuccessful nests (N = 9)
American sycamore (*Platanus occidentalis*)	2	1
Pin oak (*Quercus palustris*)	8	8
White oak (*Quercus alba*)	2	
Willow oak (*Quercus phellos*)	3	
Swamp white oak (*Quercus bicolor*)	1	
Overcup oak (*Quercus lyrata*)	2	
Sweetgum (*Liquidambar styraciflua*)	3	
Red maple (*Acer rubrum*)	1	
Eastern cottonwood (*Populus deltoides*)	1	
Dead tree	2	

TABLE 3

COMPARISON OF NEST-SITE VARIABLES FOR REUSED NESTS AND NESTS USED ONCE

Variable	Nests used once (N = 17) Mean	(±SD)	Nests reused (N = 9) Mean	(±SD)	*P*-value[a]
Nest tree height (m)	27.1	(3.4)	29.9	(2.1)	0.036
Nest tree dbh (cm)	61.1	(13.2)	63.4	(16.2)	0.690
Canopy closure (%)	87.2	(10.9)	98.1	(2.0)	0.001
Canopy height (m)	21.8	(5.2)	23.0	(2.8)	0.519
Mean tree dbh (cm)	17.6	(3.6)	18.0	(2.8)	0.773
Basal area (m^2/ha)	31.2	(10.9)	26.4	(10.7)	0.295
Branch diameter (cm)	22.2	(6.9)	24.3	(4.9)	0.429
Support branches (n)	2.3	(0.5)	2.7	(0.9)	0.256
Nest tree difference (m)	10.6	(3.5)	12.2	(3.4)	0.277
Nest height (m)	16.5	(2.0)	17.7	(3.3)	0.265
Relative nest height (%)	61.5	(8.9)	59.2	(10.5)	0.567
Saplings (stems/ha)	380.3	(226.6)	275.0	(111.6)	0.126
Small trees (stems/ha)	259.6	(130.6)	224.7	82.6)	0.476
Trees (stem/ha)	116.4	(54.9)	111.5	(56.7)	0.832
Large trees (stems/ha)	34.9	(23.9)	29.8	(21.7)	0.601
Number trees (stems/ha)	791.4	(310.4)	641.3	(165.8)	0.192

[a] Comparison by *t*-test.

[b] Means significantly different ($P < 0.05$) when adjusted for experimentwide error for all 16 comparisons.

areas having a higher percentage canopy closure than nests not used consecutively. Successively used nests had a mean canopy closure of 98.1%, whereas nests used for only one season had a mean canopy closure of 87.2%. The discriminant function separating nests used for one breeding season and nests used successively was positively weighted by both canopy closure and number of support branches (canonical correlation coefficient = 0.59, Wilks lambda = 0.655, df = 2, $P < 0.008$). The discriminant function correctly classified 67% of the nests used in consecutive breeding seasons and 94% of those used for one breeding for an overall classification of 85%. Through the leave-one-out method, the discriminant function analysis correctly classified 67% of the nests used in consecutive breeding seasons and 76% of the nests used for only one season. The overall rate of classification was 73%. Although eight of nine reused nests were successful their first season, the number of successful nests was not significantly greater than nests used for only one season ($\chi^2 = 0.32$, df = 1, $P = 0.59$, corrected for continuity).

DISCUSSION

Large diameter support branches were found to be associated with Red-shouldered Hawk nests by Bednarz and Dinsmore (1982). In our study, successful nests were most often in crotches of large-diameter trees having large diameter support branches. Large tree diameter and support branch diameter probably increase nest stability in high winds. Many of the nest failures occurred by nest abandonment early in the nesting chronology. Instability of nest locations may not have become apparent until nests were constructed. One nest was blown completely out of the tree during high winds.

The higher success rate of Red-shouldered Hawk nests surrounded by high densities of small-diameter trees may be partly attributed to the additional protection from high winds. Nest visibility is also reduced decreasing the likelihood of aerial predation and disturbance from the ground.

Relative nest height reflects the location of the nest within the tree crown. Successful nests tended to be placed proportionally higher within the tree crown than unsuccessful nests.

Although Bent (1937) and Bednarz (1979) concluded that nest tree species was a relatively unimportant factor to nest site selection, it was an important factor to nest success in our study. Nests in pin oaks were much more likely to fail than nests in other trees. Bent (1937) reported that most nests were placed in the main fork of the trunk and two or more branches at an acute angle and that horizontal branches against the trunk or in the forks of branches were rarely used. Similarly in our study, only four of the 34 nests we examined were in forks of branches away from the trunk, although all were successful. Remaining nests were in main forks of the trunk and side branches. However, because pin oak has a strongly excurrent growth form (Fowells 1965) with nearly horizontal branching, it may not provide ideal branching structure for nest placement.

Morris et al. (1982) found no relationship between structural characteristics of nest sites and nest success in their study area in Quebec. They also did not believe that there was any shortage of adequate nesting sites at the time of their study. However, in years of high breeding pair densities, ideal nest sites may be in short supply in areas where nesting sites are limited. Henny et al. (1973) concluded that Red-shouldered Hawk nesting success was inversely proportional to the number of breeding pairs present at Patuxent Wildlife Research Center.

Bent (1937) was impressed with the constancy with which each pair, or its successors, clung to its chosen territory. As breeding pair densities increase and new pairs try to establish territories among the mosaic of established territories, they may have to accept less than prime nest sites, thus reducing the probability of a successful nesting.

Nests that are used successively may reflect sites that have physical attributes that improve the probability of successful nesting. Although 89% of the nests used in consecutive years were successful compared to 71% for nests used for only one season, the success rates were not significantly different. This may be due to small sample size or a small value in one cell of the Chi-square test.

In comparing Red-shouldered Hawk nest sites to randomly selected plots, Tannenbaum et al. (unpubl. data) found nest tree height to be an important characteristic. In our study, only nest trees 26 m or taller were used in consecutive years. The taller nest trees associated with successively used nests reflect the overall tree size necessary to provide adequately stout branches at an advantageous height for nesting. Management to enhance lowland hardwood forests for Red-shouldered Hawk nesting habitat should provide for large-diameter trees with many large diameter branches in areas with a high percentage canopy closure and high densities of small-diameter trees.

ACKNOWLEDGMENTS

We thank G. Clawson and the staff of Mingo National Wildlife Refuge for their excellent cooperation in providing access to and information about the study area. We also thank the staff of Gaylord Memorial Laboratory, especially J. Ware, who provided locations of nests from previous nesting seasons. We thank S. O'Black for his assistance in data collection and J. Bednarz, S. Chaplin, and J. Dinsmore for their constructive criticism of this manuscript.

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