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# COMPARISON OF NESTING HABITAT OF COEXISTING SHARP-SHINNED AND COOPER'S HAWKS IN MISSOURI

ERNIE P. WIGGERS[1] AND KEVIN J. KRITZ[2]

ABSTRACT.—We studied the vegetative structure at nest sites of Cooper's Hawks (*Accipiter cooperii*) in two different habitats and of Sharp-shinned Hawks (*A. striatus*) in one habitat in Missouri. Sixteen Sharp-shinned Hawk nests occurred in pine (*Pinus* spp.) habitat and one in mixed pine-hardwood habitat. Thirty-three Cooper's Hawk nests occurred in pine habitat and 10 in oak-hickory (*Quercus-Carya*) hardwood habitat. Sharp-shinned Hawks nested primarily in trees with normal growth form and placed nests in the tree canopy, whereas Cooper's Hawks used mostly deformed trees and tended to place nests below the tree canopy. Vegetative structure at nest sites in pine habitat was similar for both accipiters. Cooper's Hawk nest sites in pine and hardwood habitat were similar in vertical structure but differed in horizontal structure. Vertical structure is probably a more important factor in accipiter nest-site selection than horizontal structure. *Received 15 Nov. 1990, accepted 10 June 1991.*

Quantifying the vegetative structure of nesting habitat is useful to understanding habitat selection and resource use by sympatric species. This information can be used by resource management agencies to develop strategies for enhancing habitat suitability. In Missouri, Sharp-shinned (*Accipiter striatus*) and Cooper's hawks (*A. cooperii*) have been designated as rare (Missouri Dept. of Conservation 1991). However, there has been a paucity of research directed at either species in the state and hence little is known about their habitat requirements.

Several studies have quantified and compared nest-site habitat for these accipiters in Utah (Fischer 1986), Utah-Idaho (Hennessey 1978), and Oregon (Reynolds et al. 1982, Moore and Henny 1983). Fischer (1986) concluded that each accipiter selected distinct nesting habitats. Reynolds et al. (1982) reported that these species used nest sites with different structures and that these differences were associated with stand age. Reynolds et al. (1982) also indicated that there was overlap in nesting habitat used by Sharp-shinned and Cooper's hawks as did Moore and Henny (1983).

Although nesting habitat has been described in other regions of the country, this information cannot be extrapolated to the pine and oak-hickory forests in Missouri. Therefore our objectives were to determine the vegetative structure of nest sites used by Cooper's and Sharp-shinned

[1] School of Natural Resources, 112 Stephens Hall, Univ. of Missouri, Columbia, Missouri 65211.
[2] Bureau of Land Management, Coos Bay District, 1300 Airport Lane, North Bend, Oregon 97459.

hawks and to determine if interspecific differences existed in nest sites used by these two accipiters in Missouri.

## STUDY AREA AND METHODS

This study was concentrated in the Ozark and Ozark Border Natural Divisions of Missouri (Thom and Wilson 1980). Most of the forest cover of Missouri occurs in these divisions (Spencer and Essex 1976). Oak-hickory is the major forest type of the divisions, although shortleaf pine (*P. echinata*), shortleaf pine-oak-hickory, and bottomland hardwood types are also prominent. Oak-hickory hardwoods comprise about 77% of the forest cover of the state, shortleaf pine about 1%, and shortleaf pine-oak-hickory about 2% (Spencer and Essex 1976).

*Data collection.*—Two approaches were used to locate accipiter nests in 1985 and 1986. We solicited information regarding the nesting activity of accipiters through mail surveys and notices published in conservation newsletters (Kritz 1989). We also searched forest tracts. Our survey was sent statewide to about 400 wildlife biologists and managers, foresters, conservation agents, park naturalists, falconers, and birdwatchers. The first survey was sent prior to the start of the 1985 breeding season to solicit information about historic nest locations. Surveys also were sent at the end of the 1985 and 1986 breeding seasons.

We systematically searched tracts of forest cover that in most instances corresponded to a forest stand. Because we wanted to locate the maximum number of nests, searches were concentrated in stands we believed provided suitable nesting habitat. Thus, most searches were conducted in pine habitat because nests in Missouri have been found primarily in pine habitat. This resulted in a disproportionate number of searches in pine habitat.

Before each search, territorial calls of Sharp-shinned and/or Cooper's hawks or Great Horned Owls (*Bubo virginianus*) were broadcast using a cassette tape player (Fuller and Mosher 1981, Rosenfield et al. 1985). If accipiters responded to the tape, the vocalizations and/or flights were followed directly to their origin, which was usually near the nest. If there was no response to the calls, the tract was still searched until either a nest was found or the tract was searched completely. We used a similar procedure in 1986 for rechecking all nest sites located during 1985 except taped calls were broadcast starting at the 1985 nest tree, and all forest habitat within a 300 m radius of the nest tree was searched.

We conducted nest-site habitat evaluation after young had fledged. A nest site was defined as the nest tree and a 0.04-ha circular plot centered on it (Titus and Mosher 1981). Habitat evaluation procedures followed James and Shugart (1970) and Titus and Mosher (1981) (Table 1). Variables measured at nest sites and associated with overstory coverage, understory coverage, ground coverage, and canopy height were collectively used to characterize the vertical vegetative structure at nest sites (Table 1). Variables associated with stem densities, stem diameters, and basal areas were used to characterize the horizontal vegetative structure at nest sites.

*Statistical analysis.*—Nests were grouped according to the habitat where they occurred. The habitat categories were pine (>50% of the overstory trees were pine), hardwood (>50% of the overstory trees were oak and hickory), and mixed pine-hardwood (>25% of the overstory trees were pine and oak-hickory but neither category alone made up >50%). Only one nest (Sharp-shinned Hawk) was found in the pine-hardwood habitat, and data for this nest were not included in the analysis.

Chi-square analysis (Snedecor and Cochran 1980) was used to test for intra- and interspecific differences in the frequency nests occurred in trees having different growth forms (normal or deformed) and nest placement relative to the canopy (below or within). Nest trees with normal growth form had one main bole and normal branching patterns. Trees

TABLE 1

DESCRIPTION AND MEASUREMENT PROCEDURE FOR HABITAT VARIABLES USED TO CHARACTERIZE NEST SITES OF SHARP-SHINNED AND COOPER'S HAWKS IN MISSOURI, 1985–1986

| Variable | Description and procedure |
|---|---|
| Coniferous canopy | Percent of coniferous canopy cover[a] |
| Deciduous canopy | Percent of deciduous canopy cover[a] |
| Total canopy | Percent total canopy cover[a] |
| Coniferous understory | Percent of coniferous understory cover[a] |
| Deciduous understory | Percent of deciduous understory cover[a] |
| Total understory | Percent total understory cover[a] |
| Total ground cover | Percent total ground cover[a] |
| Canopy height | The mean of five measures (m) taken to the top of the canopy (measured with clinometer) |
| Small shrubs | Number of small (≤2.5 cm dbh and 0.5–1.4-m height) shrubs per ha[b] |
| Large shrubs | Number of large (≤7.6 cm dbh and ≥1.5-m height) shrubs per ha[b] |
| Understory trees | Number of understory trees >9 cm dbh per ha[c] |
| Overstory trees | Number of overstory trees per ha[c] |
| Total trees | Number of over and understory trees per ha[c] |
| Overstory trees <25 | Number of overstory trees <25 cm dbh per ha[c] |
| Overstory trees 25–50 | Number of overstory trees 25–50 cm dbh per ha[c] |
| Overstory trees >50 | Number of overstory trees >50 cm dbh per ha[c] |
| DBH | Average diameter (cm) of all overstory trees in 0.04 ha plot (diameter tape) |
| Basal area | Basal area ($m^2$/ha) (taken at center of 0.04 ha plot with 10 BAF prism) |
| Age | Age of stand nest site was in (estimated by increment boring of ≥ two dominant trees) |
| Stand size | Size (ha) of stand nest site was in (taken from aerial photos) |
| Slope | Percent slope for nest site (measured with clinometer) |
| Elevation | Elevation (m) of the nest site (taken from USGS 7.5 min. topographic maps) |

[a] Percentages based on 10 ocular tube readings each along four 11.3-m transects that intersected at the nest tree. Overstory trees had the majority of their foliage in the forest canopy layer, and understory trees had the majority of their foliage below the forest canopy layer.

[b] Extrapolated to per ha basis from measurements within four 11.3 × 1.8-m strip transects that intersected at the nest tree.

[c] Extrapolated to per ha basis from counts in 0.04-ha plot.

with deformed growth form had either a main bole that split into ≥ two large forks and/or an abnormal whorl of branches near the top. At four sites, we could not determine growth form and/or nest placement because of logging (N = 1) or because nests fell out of nest trees before we evaluated habitat (N = 3).

We analyzed quantitative nest-site data using SAS programs (SAS Institute 1985). Distributions of nest-site variables were tested for normality using Shapiro-Wilk tests, and

variance was tested using *F*-tests. Most variables had distributions that were not normal and/or variance was heterogeneous. Transformations were ineffective in normalizing distributions or stabilizing variance. Therefore, Mann-Whitney tests were used to determine if there were differences in habitat variables between Cooper's and Sharp-shinned hawk nest sites in pine habitat and between Cooper's Hawk nest sites in pine and hardwood habitat. Because of the numerous (N = 51) comparisons made, and to minimize the chance for a Type I error, we used $\alpha/N$ (0.05/51) = 0.001 as the significance level in all analyses.

## RESULTS

We conducted searches in 394 forest tracts. Fifty-one percent of the searches were in shortleaf pine stands, 23% were in stands of oak-hickory hardwoods, 17% were in stands of shortleaf pine mixed with exotic pines (shortleaf is the only pine species native to Missouri) or exotic pines without shortleaf, and 9% were in stands of mixed pine-hardwoods or other coniferous and hardwood types.

Fifty-two (87%) nests were found through tract searches and eight (13%) were found by cooperators. Overall, 43 Cooper's Hawk and 17 Sharp-shinned Hawk nests were located. The total of 60 nests represents 46 distinct accipiter nesting territories when considering reoccupancy of 1985 sites in 1986. Of these, 31 were Cooper's Hawk and 13 were Sharp-shinned Hawk nesting territories. Two nesting territories were used by both species, but they used them in alternate years. A nesting territory is an area containing one or more nests within the range of one mated pair of birds (Steenhof 1987).

*Sharp-shinned Hawk.*—Sixteen nests occurred in pine habitat; 15 were in shortleaf pine stands, and one was in a mixed species pine stand. One nest was in shortleaf pine-oak habitat. All of the pine stands used, except two, were planted pine plantations. Pine sites were medium-aged (range 25–49 years) with high tree density and basal area and high percent canopy coverage (Table 2). Most overstory trees were <25 cm dbh, and the mean diameter for overstory trees was 20.8 cm (Table 2).

All nests were found in shortleaf pine trees except one that was in a Virginia pine (*P. virginiana*). Ten of 15 (67%) nest trees had normal growth form but the difference in the number of normal and deformed trees used was not significant ($\chi^2 = 1.7$, df = 1, $P > 0.001$). More nests (80%, 12 of 15) were located in the live canopy than below the canopy, but the difference was not significant ($\chi^2 = 5.4$, df = 1, $P > 0.001$).

*Cooper's Hawk.*—Thirty-three nests occurred in pine habitat; 17 were in shortleaf pine stands, 15 were in mixed species pine stands, and one was in a scotch pine (*P. sylvestris*) stand. Ten nests occurred in hardwood habitat. All of the pine stands used except one were pine plantations. Pine nest sites were medium-aged (range 25–49 years) and dense with high percent canopy coverage, tree density, and basal area (Table 2). Most

TABLE 2

COMPARISONS OF MEAN VALUES FOR HABITAT VARIABLES MEASURED AT SHARP-SHINNED AND COOPER'S HAWK NEST SITES IN MISSOURI, 1985–1986

| Variable | Pine habitat | | Hardwood habitat |
|---|---|---|---|
| | Sharp-shinned | Cooper's | Cooper's |
| Coniferous canopy (%) | 78.0 ± 2.9[a] (14) | 75.7 ± 2.8 (31) | 0.0 ± 0.0 (9) |
| Deciduous canopy (%) | 4.3 ± 2.5 (14) | 5.2 ± 1.2 (31) | 82.5 ± 3.2[c] (9) |
| Total canopy (%) | 82.3 ± 1.7 (14) | 80.9 ± 2.1 (31) | 82.5 ± 3.2 (9) |
| Coniferous understory (%) | 9.4 ± 3.1 (11) | 5.2 ± 1.1 (29) | 0.5 ± 0.5 (9) |
| Deciduous understory (%) | 37.4 ± 7.0 (11) | 38.9 ± 4.7 (29) | 56.0 ± 5.1 (9) |
| Total understory (%) | 46.8 ± 7.8 (11) | 44.1 ± 4.6 (29) | 56.5 ± 5.2 (9) |
| Total ground cover (%) | 35.5 ± 4.0 (12) | 41.1 ± 3.9 (29) | 34.2 ± 5.9 (9) |
| Canopy height (m) | 16.7 ± 0.6 (15) | 18.4 ± 0.4 (33) | 20.0 ± 0.8 (10) |
| Small shrubs (No./ha) | 6617 ± 1340 (15) | 8176 ± 953 (32) | 4650 ± 1484 (10) |
| Large shrubs (No./ha) | 4467 ± 553 (15) | 4733 ± 595 (32) | 2863 ± 837 (10) |
| Understory trees (No./ha) | 382 ± 55 (15) | 300 ± 34 (33) | 320 ± 44 (10) |
| Overstory trees (No./ha) | 988 ± 113 (15) | 838 ± 65 (33) | 243 ± 31[c] (10) |
| Total trees (No./ha) | 1370 ± 132 (15) | 1138 ± 79 (33) | 563 ± 44[c] (10) |
| Over. trees <25 (No./ha) | 857 ± 140 (15) | 685 ± 78 (33) | 123 ± 32[c] (10) |
| Over. trees 25–50 (No./ha) | 131 ± 35 (15) | 153 ± 23 (33) | 113 ± 20 (10) |
| Over. trees >50 (No./ha) | 0 ± 0 (15) | 0 ± 0 (33) | 7 ± 5 (10) |
| DBH (cm) | 20.8 ± 0.9 (15) | 21.8 ± 0.6 (33) | 30.8 ± 2.2[c] (9) |
| Basal area ($m^2$/ha) | 37.2 ± 2.0 (15) | 36.8 ± 1.5 (32) | 17.8 ± 2.3[c] (10) |
| Age (years) | 32.7 ± 1.9 (15) | 32.0 ± 1.1 (33) | 87.1 ± 12.2[c] (10) |
| Size (ha) | 11.8 ± 4.7 (16) | 4.1 ± 0.7 (33) | 52.6 ± 12.8[c] (10) |

TABLE 2
CONTINUED

| Variable | Pine habitat | | Hardwood habitat |
|---|---|---|---|
| | Sharp-shinned | Cooper's | Cooper's |
| Slope (%) | 5.1 ± 1.1 (16) | 10.0 ± 1.7 (33) | 16.1 ± 3.7 (10) |
| Elevation (m) | 308 ± 17 (16) | 263 ± 11 (33) | 263 ± 20 (10) |

[a] All values are means ± SE; sample size is in parentheses and varies due to logging or late sampling.
[b] Indicates significant difference ($\alpha = 0.05/51 = 0.001$ significance level) for Sharp-shinned Hawk vs Cooper's Hawk in pine habitat.
[c] Indicates significant difference ($\alpha = 0.05/51 = 0.001$ significance level) for Cooper's Hawk in pine vs oak-hickory habitat.

overstory stems were <25 cm dbh, and the mean diameter for overstory trees was 21.8 cm (Table 2).

Nests sites in hardwood habitat were in moderately dense stands with a mean age of 87.1 years (range 34–154 years) and high percent canopy coverage (Table 2). The proportions of overstory trees <25 cm dbh and those 25–50 cm dbh were similar, and the mean diameter for overstory trees was 30.8 cm (Table 2).

In the pine habitat, 22 nests were located in shortleaf pine trees, six were in scotch pine trees, two were in eastern white pine (*P. strobus*) trees, two were in jack pine (*P. banksiana*) trees, and one was in an eastern red cedar (*Juniperus virginiana*) tree. In the hardwood habitat, northern white oak (*Q. alba*) was used most often (60%, 6/10) as the nest tree; whereas, black oak (*Q. velutina*), southern red oak (*Q. falcata*), northern red oak (*Q. rubra*), and blackjack oak (*Q. marilandica*) were each used once.

*Intraspecific comparisons (Cooper's Hawk).*—Horizontal structure of nest sites differed between habitats. Nest sites in pine habitat had significantly more overstory trees ($P = 0.0001$) of smaller average diameter ($P = 0.0001$), more total trees ($P = 0.0001$), more trees <25 cm dbh ($P = 0.0001$), and greater basal area ($P = 0.0001$) than sites in hardwood habitat (Table 2). On the other hand, there were no differences ($P > 0.001$) in vertical structure between pine and hardwood sites as measured by overstory and understory canopy cover (total), total ground cover, and canopy height. Nest sites in pine habitat occurred in younger ($P = 0.0001$) and smaller ($P = 0.0001$) stands than in hardwood habitat (Table 2).

Including both pine and hardwood habitats, 28 of 43 nest trees used by Cooper's Hawks were deformed, but the difference in the proportion

of normal (35%) and deformed (65%) trees used was not significant ($\chi^2 = 3.9$, df = 1, $P > 0.001$). Twenty-two of 40 nests were located below the live canopy. However, the proportion below the canopy (55%) and in the canopy (45%) was not significantly different ($\chi^2 = 0.4$, df = 1, $P > 0.001$). A higher percentage of coniferous than deciduous nest trees were deformed (73% vs 40%), but the difference was not significant ($\chi^2 = 3.6$, df = 1, $P > 0.001$).

*Interspecific comparisons (pine habitat).*—Habitat variables at nest sites associated with topography, stand age, and either horizontal or vertical structure did not differ between accipiters ($P > 0.001$) (Table 2). However, Sharp-shinned Hawks nested primarily on ridgetops (69%, 11/16), whereas Cooper's Hawks tended to nest along ridge slopes (52%, 17/33).

Most (73%, 24/33) Cooper's Hawk nest trees were deformed and most (67%, 10/15) Sharp-shinned Hawk nest trees were normal but interspecific difference in the growth form of the nest tree was not significant ($\chi^2 = 6.8$, df = 1, $P > 0.001$). Most (80%, 12/15) Sharp-shinned Hawk nests were within the live canopy of the nest tree whereas Cooper's Hawk nests tended to be below the canopy (60%, 18/30), but nest placement relative to tree canopy was not significantly different between accipiters ($\chi^2 = 6.2$, df =1, $P > 0.001$).

## DISCUSSION

Sharp-shinned and Cooper's hawks both used dense stands of pine of similar age for nesting. The vegetative structure of nest sites overlapped greatly between species. Accipiter use of dense forest stands in this study agrees with results from other comparative studies (Hennessey 1978, Reynolds et al. 1982, Moore and Henny 1983, and Fischer 1986). The interspecific overlap in nest-site habitat also was consistent with other studies (Reynolds et al. 1982, Moore and Henny 1983) although the degree of overlap in our study was much greater. In contrast, Fischer (1986) reported that these species used distinct habitats.

Reynolds et al. (1982) and Moore and Henny (1983) reported that differences in nest-site habitat selection between accipiters were associated with forest successional development and that Sharp-shinned Hawks used younger stands of earlier successional development than Cooper's Hawks. Fischer (1986) noted that interspecific differences in nesting habitat did not correspond directly with successional development but that the structure of his nest sites differed in the same way as in the other studies. However, we were unable to detect any clear pattern in habitat selection between accipiters associated with forest successional development.

We were unable to detect differences in the vegetative structure at nest sites in pine habitat between accipiters. Also, we were unable to detect

significant differences between accipiters in the type of nest trees used and the placement of nests within the nest tree. However, we did observe a strong tendency for Sharp-shinned Hawks to use trees with normal growth form and to place nests in the nest tree canopy. On the other hand, Cooper's Hawks tended to use trees with deformed growth form and tended to nest below the canopy. Although these differences were not significantly different at the adjusted $\alpha = 0.001$ level, they were significant at the $\alpha = 0.05$ level.

Differences in the type of nest tree used and placement of nest within the nest tree may be the result of differences in accipiter body size (Moore and Henny 1983, Fischer 1986). The smaller Sharp-shinned Hawk may nest in the canopy more often because it can fly in and out of dense canopies more easily than the larger Cooper's Hawk. Most (79%, 19/24) deformed trees used by Cooper's Hawks had top deformities and the branch whorls associated with these deformities generally provided more support than branches extending from boles of trees with normal growth form. Also top deformities usually occurred below the nest tree canopy. Thus Cooper's Hawks may use deformed trees more often because they build larger nests than Sharp-shinned Hawks that require more support and their nests would tend to be below the canopy. We did not determine the availability of deformed trees, but in all cases most trees at the nest sites had normal growth form.

Interspecific differences in predation pressure (Moore and Henny 1983, Fischer 1986) also may explain differences in nest placement. In our study, nests placed in the canopy appeared to be more concealed that those below the canopy because live branches were present both above and below them. Smaller raptors experience greater predation pressure than larger raptors (Newton 1979), and Cooper's Hawks will prey upon Sharp-shinned Hawks (Jones 1979).

Vertical structure was similar in the pine and hardwood habitats used by Cooper's Hawks, whereas horizontal structure differed. Fewer hardwood tree stems, of larger mean diameter, were required to provide the same vertical structure provided by pine habitat. However, the trees were much older in hardwood habitat than in pine habitat. Thus, it generally takes longer to develop this vertical structure in hardwood habitat. Because vertical structure was similar in both habitat types it is probably a more important factor, at least on a gross level, than horizontal structure in nest-site selection.

The vegetative structure of Cooper's Hawk nest sites in pine habitat in this study was similar to that reported by Reynolds et al. (1982) and Moore and Henny (1983). Nest sites in hardwood habitat (Hennessey 1978, Titus and Mosher 1981) were similar to our hardwood sites. Al-

though nests in hardwood habitat occurred in stands that were larger in size than in pine habitat, hardwood stands in Missouri are generally larger than pine stands, and this likely explains the difference.

Although we did not find Sharp-shinned Hawk nests in hardwood forest, we do not believe this species avoids this habitat in Missouri. The Sharp-shinned Hawk nests in hardwood habitats in other parts of its range (Hennessey 1978, Reynolds et al. 1982, and Fischer 1986), and it is likely it uses this habitat in Missouri. Our inability to find nests in hardwood habitat may be more a reflection of the scarcity of this species in Missouri and/or our concentrating search efforts in pine habitat.

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## WILSON ORNITHOLOGICAL SOCIETY MEETINGS—1992

The Wilson Ornithological Society will meet with the Florida Ornithological Society at the Hilton Inn Gateway, U.S. Highway 192, Kissimmee, Florida, 9–12 April 1992. Sponsoring organizations are Archbold Biological Station, Florida Audubon Society, Kissimmee Valley Audubon Society, Lake Region Audubon Society, Orange Audubon Society, and Sea World. HERBERT W. KALE II, Florida Audubon Society, 460 Highway 436, Suite 200, Casselberry, FL 32707 (407-260-8300, FAX 260-9652) will chair the Local Committee. KEITH L. BILDSTEIN, Dept. of Biology, Winthrop College, Rock Hill, SC 29733 (803-323-2111, FAX 323-2347) will chair the Scientific Program Committee. Deadline for submittal of abstracts is 1 February 1992. The Circular of Information was mailed to WOS and FOS members in early December. Others should write to Dr. Kale for a copy. Students desiring to share room costs with other students at the Hilton should contact Dr. Kale for assistance no later than February 1 and prior to sending reservations to the hotel. The meeting will include a reception at Sea World, an art exhibit by Florida bird artists, and field trips to see Florida specialties. Walt Disney World, EPCOT, MGM Studios, Universal Studios, Sea World, Cypress Gardens, and many other attractions are in the immediate vicinity. This will be a good meeting to bring spouses and family.