2011

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Master of Science
Eastern Kentucky University
Richmond, Kentucky
2011

Submitted to the Faculty of the Graduate School of
Eastern Kentucky University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
May, 2011

ACKNOWLEDGMENTS

I would like to thank my faculty advisor, Dr. Gary Ritchison, for his guidance and wisdom. I would also like to thank my other committee members, Dr. Robert Frederick and Dr. David Brown, for their comments and assistance over the past two years. I would like to express my thanks to my wife, Christen, for her understanding, patience, and encouragement. I would also like to thank the members of my family in Louisville, KY: Reggie and Cheryl Van Stockum and the late Tom Rankin.

ABSTRACT

Because Sharp-shinned Hawks (*Accipiter striatus*) are the most secretive of North America's forest-breeding raptors, little is known about their breeding biology, including their preferred nesting habitat. In 2009 and 2010, I searched 248 forest stands in Kentucky and found 11 nests, all located in pines (*Pinus* spp.). Nests were at a mean height of 18.6 ± 1.4 m in trees with a mean height of 23.7 m and mean dbh of 38.2 cm. Nests were in mixed coniferous/deciduous forests, with a mean canopy cover of 77.6%. Comparison of the characteristics of nest sites and randomly selected unused sites revealed significant differences (P = 0.021). Discriminant analysis revealed that five variables (foliage cover, mean tree height, basal area, percent deciduous canopy cover, and distance from edge) permitted the best discrimination between used and random sites. Sharp-shinned Hawks nested in areas closer to edges and in areas with denser stands of taller conifers and denser understory. All nests were in stands of young (~25-50 years), even-aged conifers about 18 to 25 m in height, with the dense cover provided by the conifers likely providing protection from predators. Nest sites were also close to edges where stands of dense pines transitioned into areas with more, shorter deciduous trees and less foliage cover than nest sites. These adjacent areas may have provided better foraging habitat for nesting Sharp-shinned Hawks because small birds, their primary prey, are more abundant in mixed stands than in the dense stands of conifers where they nested.

TABLE OF CONTENTS

INTRODUCTION

Based on Breeding Bird Survey data (Sauer et al. 2008), populations of Sharp-shinned Hawks (*Accipiter striatus*) in North America are thought to be relatively stable, but almost nothing is known about the population status of these hawks in specific portions of their breeding range (Bildstein and Meyer 2000). Because so little is known about the abundance of Sharp-shinned Hawks at any level (continental, regional, state, and local), assessing possible effects of forest management practices and habitat loss and degradation on their population status is currently not possible. More specifically, nothing is known about the possible impacts of forest-patch size, age structure, and species composition on their breeding ecology and success (Bildstein and Meyer 2000).

The reason for this lack of information is that Sharp-shinned Hawks are the most secretive, and most difficult to census, of any of North America's forest-breeding raptors (Reynolds and Wight 1978, Fuller and Titus 1990, Bildstein and Meyer 2000). Therefore, in addition to questions about their population status and habitat requirements, little is known about their breeding biology, including their habitat requirements, nestling and fledgling behavior, and post-breeding behavior.

As is the case elsewhere, little is known about the abundance, distribution, and breeding biology of Sharp-shinned Hawks in Kentucky. Palmer-Ball (1996) noted that ". . . the breeding status of the Sharp-shinned Hawk in Kentucky has never been well known . . ." and, statewide, reported only four confirmed breeding records over a seven-year period (1985 – 1991). Few additional reports of breeding by Sharp-shinned Hawks in

Kentucky have been reported since 1991 (e.g., Palmer-Ball and McNeely 2004). Falconers have requested permits to take nestlings from Sharp-shinned Hawk nests in Hardin, Meade, Daviess, and Graves counties in Kentucky from 2005-2007, but the number of nests located and number of young actually taken is unknown (S. Vorisek, KDFWR, pers. commun.). In addition, Sharp-shinned Hawks are rarely observed during Breeding Bird Surveys in Kentucky (Sauer et al. 2008).

Based on few studies and small sample sizes, Sharp-shinned Hawks will apparently nest in most forest habitats, particularly those with at least some conifers. In Missouri, these hawks were found to nest in oak-hickory (*Quercus-Carya*) and pine (*Pinus*) stands with high tree densities and basal area (Wiggers and Kritz 1994). In Wisconsin, Sharp-shinned Hawks tended to nest in denser forests with younger, shorter trees and more conifers than Cooper's Hawks (*A. cooperii*; Rosenfield et al. 1991). In North and South Carolina, eggs are laid from early to mid-May and young fledge in early July (Meyer and Mueller 1982, Mitchell and Pitts 1992). In Kentucky, Palmer-Ball (1996) estimated that nesting activity begins in late March or early April and reports the observation of fledglings in July.

There is clearly a need to learn more about Sharp-shinned Hawks in Kentucky and throughout their breeding range. Successful management requires information concerning where and how many birds are breeding and their nesting habitat requirements. In addition, the possible impact of allowing falconers to take young from Sharp-shinned Hawk nests is unclear. Thus, my objectives were to: (1) survey several areas throughout Kentucky where previous observations indicate that Sharp-shinned

Hawks may currently be breeding to locate breeding pairs, (2) locate as many nests as possible and quantify those features of habitat apparently important in selection of nest sites by Sharp-shinned Hawks, (3) determine reproductive parameters for as many nests as possible, include clutch sizes, hatching success, and fledging success, and (4) monitor nests where falconers removed nestlings and determine the fate of remaining nestlings.

METHODS

Surveys. From April to July 2009 and March to June 2010, I conducted road and foot surveys in several counties throughout Kentucky (Table 1)[1]. Adjacent counties were surveyed in five regions in Kentucky, including: (1) Powell, Madison, Estill, Menifee, Montgomery, and Wolfe counties in eastern Kentucky, (2) Laurel, Pulaski, and Whitley counties in southern Kentucky, (3) Boone, Grant, and Owen counties in north-central Kentucky, (4) Meade, Hardin, and Jefferson counties in central Kentucky, and (5) Trigg, Calloway, Christian, Muhlenberg, and Lyon counties in western Kentucky. There have been reports of Sharp-shinned Hawks during the breeding season in all of these regions (Palmer-Ball 1996, S. Vorisek, pers. comm.). All of these counties contain stands of dense conifer and mixed conifer forests where, historically, Sharp-shinned Hawks have been found nesting.

For each set of selected counties, routes were established that traversed from 1.6 to 64 km of apparently suitable (coniferous or mixed conifer forest) habitat (using National Land Use Cover Data from 2001 and state and local road data layers on ArcMap 9.3.1). Routes and survey points along those routes were selected based on the presence of potentially suitable habitat. At some locations along these routes, I used playback of conspecific calls in an attempt to elicit a vocal response and determine if Sharp-shinned Hawks were present (see details below). At other locations, however, where, for example, traffic was deemed excessive (with noise making it potentially

[1]All tables and figures can be found in appendices A and B, respectively.

difficult to hear responding hawks) or where topography (e.g., cliffs or steep hillsides) would minimize transmission distance, I conducted surveys on foot without the use of playback.

Playback protocols followed that described by Iverson and Fuller (1991) and McLeod and Andersen (1998). Following a 1-min listening and observing period, Sharp-shinned Hawk calls (*kik-kik-kik* alarm call; Bildstein and Meyer 2000) were played for 30 sec and followedby a 1-min listening and observation period; this sequence (30-sec of playback followed by a 1-min listening period) was repeated three times during each stop. If a Sharp-shinned Hawk was detected at any time during the broadcast period, playbacks were discontinued. Calls for playback tapes came from commercially available recordings (and from several sources so that the calls of several different individuals were used). Calls were played over a loudspeaker (one facing each side of the road) at a volume audible to the human ear at a minimum of 150 m from the speakers. At survey points where Sharp-shinned Hawks were detected, all areas within 300 m were thoroughly searched.

Locating nests. I obtained historical Sharp-shinned Hawk nest data from KDFWR falconry acquisition records. Reports of incidental sightings from birdwatchers and wildlife biologists were also used to locate potential nesting habitat throughout the state. In addition, as already noted, I searched numerous plots or stands for the presence of Sharp-shinned Hawks and nests, i.e., forest stands with some (or all) conifers, with trees about 20 – 50 cm dbh and about 20 – 25 m in height. When searching for nests, I walked through stands (defined as an area where tree composition and height were similar) while scanning in all directions at the height where nests were usually found (about 20 m high). The mean size of stands searched was ~1.6 ha, but stands varied in size (range = 0.8 ha - 16 ha) and so the time spent searching for nests in these stands ranged from about 30 min to 4 hours (mean = ~ 1.4 hrs).

Once located, nests were monitored at least once per week either by direct inspection (for accessible nests) or using binoculars and spotting scopes from the ground. For as many nests as possible, I determined the number of eggs present (not necessarily the same as the clutch size because eggs were counted just once and some eggs could have been lost to predators during the period between clutch completion and when I counted eggs), hatching success, and fledging success. Nests were defined as successful if at least one young fledged.

After young fledged or a nest failed, the habitat characteristics of all nest sites were measured following a modified version of methods described by James and Shugart (1970; Table 2). A nest site was defined as a 16-m radius (0.08-ha) circle centered on the nest tree. To compare used sites to unused sites, one randomly selected, unused site was selected in each breeding territory. Although the actual size of territories in my study was unknown, previous studies indicate that mean distances between nests of Sharp-shinned Hawks are generally at least 1 km (Bildstein and Meyer 2000). Assuming territory boundaries would be about halfway between nests, then territories would have a radius of about 500 m. Thus, to select a random location that would likely be within a territory, I moved a randomly selected distance (≥ 150 and 480 m) in a randomly selected compass direction from nest trees and, at that point, selected a tree that could have potentially been selected as a nest site (i.e., a tree with a diameter at breast height within 5 cm of that of the nest tree). Randomly selected sites had to be at least 150 m from nest sites to avoid pseudoreplication (i.e., sites so close to nest sites that their characteristics would likely be influenced by their proximity). All random numbers (directions and distances) were generated using a random numbers table. Except for variables specific to the nest, the same measurements were made at random sites and nest sites.

Multivariate analysis of variance (MANOVA) was used to compare the characteristics of Sharp-shinned Hawk nests and those of randomly selected, unused sites. Variables important in discriminating between used and unused sites were determined by a stepwise discriminant analysis (backward procedure). The cross-validation technique was then used to evaluate model classification efficacy (Williams et al. 1990). All analyses were performed using the Statistical Analysis System (SAS Institute 2004).

RESULTS

I used playback of conspecific calls in an attempt to locate breeding pairs at 21 locations and Sharp-shinned Hawks responded at three (14.3%) of those locations. In all three cases, Sharp-shinned Hawks vocalized in apparent response to playback, but at distances < 100 m from the speaker. Once, a hawk responded with *kik-kik-kik* calls; on the other two occasions, responding hawks uttered high-pitched whistle calls, likely the 'squealing' call described by Bildstein and Meyer (2000). I subsequently searched the areas where Sharp-shinned Hawks responded to playback, but no hawks were observed and no nests were located. To further examine the responses of Sharp-shinned Hawks to playback, I played back *kik-kik-kik* calls at some active nest sites (with eggs or young; *N* = 4) where adults would likely be near enough to hear the calls. No Sharp-shinned Hawks responded (either vocally or by approaching close enough to be observed).

I searched 248 forest stands during my study and found nests in 11 stands (4.4%), with six Sharp-shinned Hawk nests located in 2009 and five in 2010. Of the 11 nests, four were located at Land Between the Lakes, three at Otter Creek, and one each in Pennyrile Forest State Resort Park, Camp McKee (near Jeffersonville, KY), Powell County (near Stanton, KY), and the Daniel Boone National Forest. At Otter Creek Park, a nest located in 2010 was only about 0.8 km from where a nest was found in 2009, suggesting that the same pair (or at least one individual) may have been present at both nests. All nests were located in conifers, with five in loblolly pines (*Pinus taeda*), four in eastern white pines (*P. strobus*), one in a shortleaf pine (*P. echinata*), and one in a pitch pine (*P. rigida*). By contrast, trees (*N* = 10) at randomly selected points within the territories of Sharp-shinned Hawks were 50% pine (three eastern white pines, one loblolly pine, and one shortleaf pine) and 50% deciduous (four *Quercus* spp. and one *Carya* sp.). This difference between used trees (all pines) and randomly selected trees (half pine and half deciduous) was significant (χ^2_1 = 5.8, P = 0.016).

Nests were located in trees with a mean height of 23.7 ± 1.7 m (range = 14 – 30 m) and a mean dbh of 38.2 ± 2.3 cm (range = 26 – 51 cm). Nests were located at a mean height of 18.6 ± 1.4 m (range = 12 – 26 m) and were, on average, located at a point that was 79.1 ± 2.4% (range = 66.7 – 91.5%) of the height of nest trees. Nest sites were in areas of mixed coniferous/deciduous forest, with 61.4 ± 8.4% of trees within 16 m of nest trees being conifers and 38.6 ± 8.4% deciduous. Mean canopy cover (conifers plus deciduous trees combined) was 77.6 ± 1.9%.

The mean number of eggs per nest was 3.6 (*N* = 5 nests; 4 with 4 eggs and 1 with 2), and eggs hatched during the period from 8 June through 26 June. The mean number of eggs that hatched per nest was 2.6 (*N* = 5 nests; 4 of 4 eggs hatched in each of three nests, 1 of 2 eggs in one nest, and none of 4 eggs in one nest). I determined the fate (i.e., whether or not young fledged) of 9 of 11 nests, and at least one young fledged from 7 of those 9 nests (77.8%). Although I estimate that the mean number of fledglings for all 9 nests was 1.1 (10 young fledged from 9 nests), some nests were visited several days after young had fledged and some fledglings may not have been observed either because they had moved some distance from nests or were hidden in dense overstory vegetation. Reynolds and Wight (1978) also noted the difficulty of locating fledgling Sharp-shinned Hawks. They studied all three species of accipiters in Oregon and found that fledgling Sharp-shinned Hawks were the most 'inconspicuous' of the three species and most difficult to follow after fledging. Therefore, my estimate should be considered the minimum number of young that fledged. For successful nests (N = 7), the estimated mean number fledglings per nest was 1.4.

Nestling Sharp-shinned Hawks fledged from nests during the period from 14 July through 1 August (2009 and 2010 combined). Prior to fledging, to my knowledge, falconers removed nestlings from two nests in 2009 (no nestlings were removed from nests in 2010). Both nests where nestlings were removed had four nestlings. Three nestlings were removed from one of those nests and the remaining nestling survived until fledging (assuming that these three nestlings, if not taken, would have fledged, the estimated mean number of fledglings per successful nest in my study would have been 1.4 rather than 1.1). Two nestlings were removed from the other nest when nestlings were < 1 week old. I checked the nest one week later (when nestlings would have been < 2 weeks old and too young to fledge), and the nest was empty (with only a few green leaves in the nest). Although I observed no signs of predation (e.g., nestling remains, feathers. or damage to the nest structure), some predators likely would not leave any such signs (e.g., a Great Horned Owl may simply remove nestlings from the nest). Therefore, the cause of nest failure was unknown.

The characteristics of Sharp-shinned Hawk nest sites and randomly selected unused sites differed significantly (Wilk's λ = 0.1, $F_{13,69}$ = 5.8, P = 0.021). Stepwise discriminate analysis revealed that six variables, including distance from road, distance from edge, foliage cover, mean tree height, basal area, and percent of deciduous canopy cover, permitted the best discrimination between used and random isolated perches. Classification analysis correctly categorized 88.9% (8 of 9) of randomly selected sites and 90.9% (10 of 11) of used nest sites. Compared to the randomly selected, unused sites, the nest sites of Sharp-shinned Hawks were located in areas closer to roads and edges, with denser stands of taller conifers, and denser understories (below 3 m; Table 3).

DISCUSSION

I found that playback of conspecific calls was not useful for locating Sharp-shinned Hawk breeding territories and nests. Few Sharp-shinned Hawks responded and, at those locations, no nests were subsequently found. Similarly, Faccio (2003) reported that no Sharp-shinned Hawks responded to playback of conspecific calls in Vermont. Montevecchi (1995) used playback during raptor surveys in Newfoundland and reported that only three Sharp-shinned Hawks responded. In contrast, broadcasting conspecific calls has been found to be an effective way of detecting the presence of some diurnal raptors, including Cooper's Hawks (*Accipiter cooperi*; Mosher et al. 1990) and Northern Goshawks (*A. gentilis*; Penteriani 1999). Thus, in contrast to other accipiters (Cooper's Hawks and Northern Goshawks), Sharp-shinned Hawks are generally not responsive to playback of conspecific calls, and the reasons for this are unclear.

Sharp-shinned Hawks are silent most of the year, but are known to vocalize during the breeding season (Bildstein and Meyer 2000). However, little is known about their vocal behavior and, specifically, about the possible functions of calls in their vocal repertoire. The *kik-kik-kik* call that I played back during surveys for Sharp-shinned Hawks in my study is thought to be an alarm call (Bildstein and Meyer 2000), and its possible importance in interactions with conspecifics, such as defending territories or attracting mates, is unknown. Thus, one possible explanation for the limited response of Sharp-shinned Hawks to playback of *kik-kik-kik* calls is that the call, as suggested by Bildstein and Meyer (2000), functions primarily (or only) as an alarm call. If so, then the call may be perceived as indicating that a possible predator is nearby and Sharp-shinned Hawks, rather than responding either vocally or approaching, may respond by taking evasive action (e.g., remain silent on a perch or, perhaps, even moving away from the source of the sound). Regardless of why they are generally unresponsive to playback *of kik-kik-kik* calls, my results and those of previous investigators indicate that playback of these calls is not an effective or efficient way to detect the presence of Sharp-shinned Hawks. Additional study is needed to determine if Sharp-shinned Hawks might respond better to playback of other calls in their vocal repertoire (e.g., squeal call; Bildstein and Meyer 2000).

I searched 248 forest stands during my study and found nests in only 11 stands (4.4%). Such results suggest that the total number of breeding pairs of Sharp-shinned Hawks in Kentucky may be rather low. However, some stands I searched may have been too small for use as nest sites by Sharp-shinned Hawks and, in addition, areas adjacent to some forest stands may not have provided suitable foraging habitat. As a result, my limited success in locating nests may not provide an accurate indication of how many Sharp-shinned Hawks breed in Kentucky. However, even given the possibility that some percentage of the stands were searched were not suitable for nesting, my results do suggest that densities of breeding pairs of Sharp-shinned Hawks are likely rather low and that suitable breeding habitat is, at best, patchily distributed and fragmented. Even in large areas of apparently suitable habitat in Kentucky, nesting densities appear to be low. For example, falconers searching for Sharp-shinned Hawk nests at Land Between the Lakes over a period 'exceeding 20 years' located only 32 nests (M. McDermott, pers. comm.). Several decades ago, Mengel (1965: 206) noted that Sharp-shinned Hawks were ". . . less numerous than indicated by the literature in general. In my experience [they are] far less numerous in Kentucky than in either the north-central or prairie states." Because Sharp-shinned Hawks are rarely observed during the breeding season (Bildstein and Meyer 2002), few investigators have attempted to estimate densities of breeding pairs in large tracts of apparently suitable habitat. However, based on small sample sizes, available estimates include 0.88 nests/km^2 in suitable habitat in New Brunswick (Meyer 1987), 0.08 – 0.32 nests/km^2 in Alaska (Clarke 1984), and 0.16/km^2 in Idaho (Thurow and Peterson 1978).

I located six Sharp-shinned Hawk nests in 2009 and only one of five nests located in 2010 was located near (within 0.8 km) a 2009 nest site. Other investigators have reported that Sharp-shinned Hawks typically do not re-use nests, but often do nest in the same forest stands in consecutive years. For example, Stephens and Anderson (2002) reported that Sharp-shinned Hawks did not display strong nest-site fidelity, but commonly reused particular forest stands. In Utah, Platt (1976) noted only one case where the same nest was used in consecutive years, but forest stands or groves were commonly reused. Joy (1990) found that one of four Sharp-shinned Hawk nests sites was used in consecutive years. In Alaska, Clarke (1984) reported that 33% of nest sites were used by Sharp-shinned Hawks in consecutive years. Rangewide, therefore, it appears that Sharp-shinned Hawks rarely reuse nest sites and, more often, nest in the same forest stands in consecutive years. The limited forest-stand fidelity exhibited by Sharp-shinned Hawks in my study may, at least in part, have been due to severe ice storm that impacted most of western Kentucky in February 2009 (National Weather

Service 2009). In many forests, including those where Sharp-shinned Hawks nested in my study, this ice storm opened up the forest canopy and the increased light levels caused increased growth of understory- and mid-story vegetation (M. McDermott, pers. comm.). As a result, stands used in 2009 may no longer have been suitable for use by Sharp-shinned Hawks in 2010.

Eggs of Sharp-shinned Hawks hatched during the period from 8 to 26 June in my study. Because the incubation period of these hawks is about 30-32 days (Reynolds and Wight 1978, Delannoy and Cruz 1988), hawks in my study likely initiated egg laying during the period from 7 – 27 May. Similarly, female Sharp-shinned Hawks initiated egg laying during the period from early to mid-May in North and South Carolina (Meyer and Mueller 1982, Mitchell and Pitts 1992) and in mid-May in New Brunswick (Meyer 1987). At some locations, egg laying occurs later in the season, e.g., from early May through late June in Oregon (Reynolds and Wight 1978) and from late May through late June in Missouri (Wiggers and Kritz 1994). Although little is known about the factors that influence the timing of egg laying by female Sharp-shinned Hawks, clutch initiation is likely timed so that hatching, and the nestling period when adults must provision young, corresponds to a period of peak food availability (Palmer 1988).

The mean clutch size of Sharp-shinned Hawks in my study was 3.6, but most clutches (four of five) consisted of four eggs. Throughout their range, clutch sizes of Sharp-shinned Hawks range from 3 to 8, but clutches of four or five eggs are typical (Bildstein and Meyer 2000). Mean clutch sizes reported at other locations include 4.3 in

Utah (34 clutches, Platt 1976), 4.5 in Missouri (8 clutches, Wiggers and Kritz 1994), and 4.6 in Oregon (5 clutches, Reynolds and Wight 1978).

Of nine Sharp-shinned Hawk nests in my study where the outcome was known, at least one young fledged from seven (77.8%). Nesting success (with success defined as ≥ 1 fledging) at other locations include 92% in Oregon (Reynolds and Wight 1978) and 59% in southern Quebec (Coleman 2001). Because few investigators have attempted to document the nesting success of nesting Sharp-shinned Hawks, causes of nest failure are not well understood. For most species of birds, predation is a major cause of nest failure (Ricklefs 1969, Martin 1995), but little is known about possible predators of Sharp-shinned Hawk eggs and nestlings. Bent (1937) noted that nestling Sharp-shinned Hawks were sometimes preyed on by Cooper's Hawks (*A. cooperii*) and Northern Goshawks (*A. gentilis*). Jones (1979) also noted that Cooper's Hawks will prey on Sharp-shinned Hawks. Other possible predators of Sharp-shinned Hawk nests in Kentucky include raccoons (*Procyon lotor*) and Great Horned Owls (*Bubo virginianus*). Weather can also influence nest success. For example, Coleman et al. (2002) suggested that cold, rainy weather may reduce nesting success of Sharp-shinned Hawks in Quebec by reducing prey availability and the hunting efficiency of adults, resulting in increased nestling mortality.

Because nestlings were only taken from two nests by falconers, I can say little about the possible effects of such removal. At one nest with four young, two were taken by falconers and the remaining two fledged. However, at a second nest with four young, two were taken and the remaining two nestlings did not fledge. These limited results indicate that adult Sharp-shinned Hawks do not abandon nests after nestlings are removed, but obviously permit no conclusions concerning the typical effect of such removal on nesting success. As noted previously, my results do seem to suggest that the number of breeding pairs of Sharp-shinned Hawks is likely relatively low compared to other areas within their breeding range. Because that number is unknown, the possible impact of removal of nestlings by falconers on the Sharp-shinned Hawk population in Kentucky also remains unknown.

All Sharp-shinned Hawk nests in my study were located in pines and, in addition, compared to randomly selected, unused sites, I found that nest sites were located in areas with denser stands of taller conifers and denser ground cover and were also closer to roads and edges (Figure 1). Similarly, Wiggers and Kritz (1991) located 17 Sharp-shinned Hawk nests in Missouri and all were in pine trees located in stands of either short-leafed pine or mixed species of pines. In addition, as in my study, Sharp-shinned Hawks in Missouri nested in high density stands of pine trees that averaged 16.7 m in height (Wiggers and Kritz 1991). In New Mexico, nesting Sharp-shinned Hawks were also found in dense stands (basal area = ~38 m^2/ha; canopy cover = ~78%) of ponderosa pine (*P. ponderosa*), Douglas fir (*Pseudotsuga menziesii*), and white fir (*Abies concolor*; Siders and Kennedy 1996). Similar results, with Sharp-shinned Hawks nesting in young, even-aged stands of conifers, have been reported in Oregon (Reynolds et al. 1982) and Wisconsin (Trexel et al. 1999). Although Sharp-shinned Hawks will nest in deciduous trees (Bildstein and Meyer 2000), my results and those of previous investigators indicate that conifers are more often used as nest sites and, specifically, conifers located in relatively dense stands of young (~25-50 years), even-aged conifers about 15 – 20 m in height. Reynolds et al. (1982) suggested that dense vegetation may provide cover and protection from possible predators and, in addition, that, having evolved primarily in shaded forest conditions, accipiters may have low tolerances for high temperatures and direct sunlight. Wiggers and Kritz (1991:575) also suggested that nests located in dense canopies 'appeared to be more concealed' and that such concealment may be beneficial for Sharp-shinned Hawks because, as noted by Newton (1979), smaller raptors experience greater predation pressure than larger raptors. In addition, dead limbs below the live crowns of conifers (Figure 1) where Sharp-shinned Hawks typically build nests provide both perch or roost sites and nest material (Reynolds et al. 1982).

The nest sites of Sharp-shinned Hawks in my study were closer to roads than were randomly selected, unused sites. However, that difference may simply have been an artifact of the methods I used to locate nests, i.e., locating and searching potentially suitable sites by driving along roads. Nest sites were also closer to edges than the randomly selected sites. In my study, edges typically represented the point where the nest stand (i.e., the dense stand of pines where Sharp-shinned Hawk nests were located) transitioned into areas with reduced densities of conifers and increased densities of deciduous trees. These adjacent areas (i.e., randomly selected sites located 150 – 480 m from nest sites), in contrast to Sharp-shinned Hawk nest sites, had more, shorter deciduous trees and less foliage cover. Because the ranges of Sharp-shinned Hawks are known to extend more than 1 km from nest sites (Platt 1973, Reynolds 1979), these areas were likely within the ranges of the hawks and, because the sites I analyzed were randomly selected, likely represent typical habitat adjacent to the dense stands of conifers used as nest sites. Other investigators have also noted that the nest sites of Sharp-shinned Hawks may be adjacent to clearings, brushy areas, or open deciduous forest (Palmer 1988). Such areas may provide better foraging habitat because small birds, the primary prey of Sharp-shinned Hawks, may be more abundant in mixed stands (with both coniferous and deciduous trees) than in dense stands of conifers (Palmer 1988). Thus, when choosing nest sites, Sharp-shinned Hawks likely prefer areas with dense stands of conifers that provide nest sites, but with adjacent areas within 1 – 1.2 km consist of mixed stands of forest where more potential prey are available.

MANAGEMENT RECOMMENDATIONS

My results, and those of other investigators, indicate that nesting habitat for Sharp-shinned Hawks includes dense, even-aged stands of conifers (typically pines) that are about 15 to 20 m in height and encompass an area of about 1 ha (based on the mean distance of nests in my study to the nearest edge). These stands provide nest-site habitat, but not good foraging habitat. Therefore, these dense stands of conifers should be adjacent to areas with fewer conifers and more deciduous trees; areas that provide better habitat for songbirds, the primary prey of Sharp-shinned Hawks. Because Sharp-shinned Hawks are known to range distances up to at least 1.2 km from nest sites, the mixed stands adjacent to nest sites should encompass an area of about 125 to 150 ha.

My results, those of previous investigators (Mengel 1965), and the limited number of observations of these hawks during the breeding season by birders throughout the state (Palmer-Ball 1996, 2003) suggest that nesting densities of Sharp-shinned Hawks in Kentucky are relatively low. Reasons for this are unclear, but may include a lack of suitable breeding habitat. It may also be the case that Kentucky is simply near the southern edge of the breeding range of Sharp-shinned Hawks, with most breeding in conifer-dominated areas further north (Figure 2). For many species, population density tends to decline near the edges of ranges and this may also be the case for Sharp-shinned Hawks. Regardless of the cause(s), Sharp-shinned Hawks are at best rare summer residents in Kentucky (Palmer-Ball 2003). As such, I recommend that removal of nestlings from nests by falconers in Kentucky be limited or prohibited. Impacts of such removal on the state population are clearly unknown. However, removal does reduce the number of young that fledge for some pairs and, in addition, adult Sharp-shinned Hawks may, after removal (i.e., partial predation), as is typical of birds, disperse to new breeding locations (perhaps out of state) in subsequent breeding seasons.

LITERATURE CITED

Bent, A. C. 1937. Life histories of North American birds of prey. Dover Publications, Inc., New York, NY.

Bildstein, K. L., and K. Meyer. 2000. Sharp-shinned Hawk (*Accipiter striatus*). The Birds of North America Online (A. Poole, ed.). Cornell Lab of Ornithology, Ithaca, NY. Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/482

Clarke, R. 1984. The Sharp-shinned Hawk in interior Alaska. M. S. thesis, University of Alaska, Fairbanks, AK.

Coleman, J. L. 2001. Ecology of the Sharp-shinned Hawk (*Accipiter striatus*) in southern Quebec. M. S. thesis, McGill University, Montreal, Quebec, Canada.

Coleman, J. L., D. M. Bird, and E. A. Jacobs. 2002. Habitat use and productivity of Sharp-shinned Hawks nesting in an urban area. Wilson Bulletin 114: 467-473.

Delannoy, C. A., and A. Cruz. 1988. Breeding biology of the Puerto Rican Sharp-shinned Hawk (*Accipiter striatus venator*). Auk 105:649-662.

Faccio, S. D. [online]. 2003. A biological inventory of breeding birds at the Marsh-Billings-Rockefeller National Historic Park and adjacent lands. Vermont Institute of Natural Science, Woodstock, VT. <http://www.vtecostudies.org/PDF/MABI_Bird_Report.pdf>

Fuller, M. R., and K. Titus. 1990. Sources of migrant hawk counts for monitoring raptor populations. In: Survey designs and statistical methods for the estimation of avian population trends (J. R. Sauer and S. Droege, eds.), pp. 41-46. U.S. Fish and Wildlife Service, Biological Report 90, Washington, D.C.

Jones, S. 1979. Habitat management series for unique or endangered species: the accipiters: Goshawk, Cooper's Hawk, Sharp-shinned Hawk. U .S. Dept. of Interior, Bureau of Land Management Technical Note 335, Washington, D.C.

Joy, S. M. 1990. Feeding ecology of Sharp-shinned Hawks and nest-site characteristics of accipiters in Colorado. M.S. thesis, Colorado State University, Fort Collins, CO.

Martin, T. E. 1995. Avian life history evolution in relation to nest sites, nest predation, and food. Ecological Monographs 65: 101–127.

Mengel, R. M. 1965. The birds of Kentucky. Ornithological Monographs No. 3, The American Ornithologists’ Union.

Meyer, K. D. 1987. Sexual size dimorphism and the behavioral ecology of breeding and wintering Sharp-shinned Hawks. Ph. D. dissertation, University of North Carolina, Chapel Hill, NC.

Meyer, K. D., and H. C. Mueller. 1982. Recent evidence of Sharp-shinned Hawks breeding in North Carolina. Chat 46: 78–80.

Mitchell, S., and I. Pitts. 1992. Observations on nesting Sharp-shinned Hawks in Greenville County, South Carolina. Chat 56: 45–51.

Montevecchi, W. A. 1995. Distribution and relative abundances of birds of prey in different habitats in the western Newfoundland model forest. Memorial University of Newfoundland, St. John’s, Newfoundland, Canada.

Mosher, J. A., M. R. Fuller, and M. Kopeny. 1990. Surveying woodland raptors by broadcast of conspecific vocalizations. Journal of Field Ornithology 61: 453-461.

National Weather Service [online]. 2009. Ice and snow storm of January 26-28, 2009. <http://www.crh.noaa.gov/lmk/?n=jan_2009_ice_and_snow>

Newton, I. 1979. Population ecology of raptors. Buteo Books, Vermillion, SD.

Palmer, R. S. (ed.). 1988. Handbook of North American birds, vol. 4. Yale University Press, New Haven, CT.

Palmer-Ball, B., Jr. 1996. The Kentucky breeding bird atlas. The University of Kentucky Press, Lexington, KY.

Palmer-Ball, B., Jr. 2003. Annotated checklist of the birds of Kentucky, second edition. Kentucky Ornithological Society and Gateway Press, Inc., Louisville, KY.

Palmer-Ball, B., Jr., and L. McNeely. 2004. The summer season 2004. Kentucky Warbler 80: 79-86.

Penteriani, V. 1999. Dawn and morning Goshawk courtship vocalizations as a method for detecting nest sites. Journal of Wildlife Management 63: 511-516.

Platt, J. B. 1973. Habitat and time utilization of a pair of nesting Sharp-shinned Hawks – a telemetry study. M. S. thesis, Brigham Young University, Provo, UT.

Platt, J. B. 1976. Sharp-shinned Hawk nesting and nest site selection in Utah. Condor 78:102-103.

Reynolds, R. T. 1979. Food and habitat partitioning among two groups of coexisting *Accipiter*. Ph. D. dissertation, Oregon State University, Corvallis, OR.

Reynolds, R. T., E. C. Meslow, and H. M. Wight. 1982. Nesting habitat of coexisting *Accipiter* in Oregon. Journal of Wildlife Management 46: 124-138.

Reynolds, R. T., and H. M. Wight. 1978. Distribution, density, and productivity of *Accipiter* hawks breeding in Oregon. Wilson Bulletin 90: 182–196.

Ricklefs, R. E. 1969. An analysis of nesting mortality in birds. Smithsonian Contributions to Zoology 9: 1–48.

Rosenfield, R. N., J. Bielefeldt, R. K. Anderson and J. M. Papp. 1991. Status reports: Accipiters. In: Proceedings of the Midwest raptor management symposium and workshop (B. G. Pendleton, ed.), pp. 42-49. National Wildlife Federation, Washington, D.C.

SAS Institute. 2004. SAS 9.1.2 user's guide. SAS Institute Inc., Cary, NC.

Sauer, J. R., J. E. Hines, and J. Fallon. 2008. The North American Breeding Bird Survey, results and analysis 1966 - 2007. Version 5.15.2008. U.S.G.S. Patuxent Wildlife Research Center, Laurel, MD.

Siders, M. S., and P. L. Kennedy. 1996. Forest structural characteristics of *Accipiter* nesting habitat: is there an allometric relationship? Condor 98: 123-132.

Stephens, R. M., and S. H. Anderson. 2002. Conservation assessment for the Cooper's Hawk and the Sharp-shinned Hawk in the Black Hills National Forest, South Dakota and Wyoming. U.S.D.A. Forest Service, Rocky Mountain Region, Custer, ND.

Thurow, T. L., and S. R. Peterson. 1978. A preliminary survey of raptorial birds in the Idaho primitive area. Wilderness Research Center, Station Note No. 31, University of Idaho, Moscow, ID.

Trexel, D. R., R. N. Rosenfield, J. Bielefeldt, and E. A. Jacobs. 1999. Comparative nest site habitats in Sharp-shinned and Cooper's hawks in Wisconsin. Wilson Bulletin 111: 7-14.

Wiggers, E. P., and K. J. Kritz. 1991. Comparison of nesting habitat of coexisting Sharp-shinned and Cooper's hawks in Missouri. Wilson Bulletin 103: 568–577.

Williams, B. K., K. Titus, and J. E. Hines. 1990. Stability and bias of classification in biological application of discriminant analysis. Journal of Wildlife Management 54:331-341.

APPENDIX A:

Tables

Table 1. Locations of playback and foot surveys conducted to determine the presence of possible breeding pairs of Sharp-shinned Hawks in Kentucky.

Region	**Month/year**	**No. of routes**	**Length of routes (km)**	**No. of plots searched**
West[a]	June 2009	3	80	23
	July 2009	2	64	15
	March 2010	4	144	40
	June 2010	6	155	45
Central[b]	April 2009	1	8	1
	July 2009	1	8	1
	Mar-Jul 2010	8	50	13
East[c]	April 2009	1	64	10
	June 2009	2	48	12
	June 2010	4	83	15
	July 2010	2	27	2
North[d]	April 2009	1	72	9
	May 2010	2	85	12
South[e]	April 2010	2	64	20
	July 2010	3	96	30

[a]Trigg, Lyon, Calloway, Christian, and Muhlenberg counties
[b]Jefferson, Meade, and Hardin counties
[c]Menifee, Wolfe, Madison, Estill, Powell, and Montgomery counties
[d]Boone, Grant, and Owen counties
[e]Laurel, Pulaski, and Whitley counties

Table 2. Description and measurement procedure for habitat variables used to characterize nest sites of Sharp-shinned Hawks in Kentucky.

Variable	Description and procedure
Coniferous canopy	Percent of coniferous canopy cover[a]
Deciduous canopy	Percent of deciduous canopy cover[a]
Total canopy cover	Percent total canopy cover[a]
Foliage cover	# of vegetation 'hits' (vegetation touching 3-m high pole), with pole placed at 5 equidistant points along each transect
Small shrubs	# of small (< 1.5 m height) shrubs in 0.08-ha plot
Large shrubs	# of large (1.5 - 3 m height) shrubs in 0.08 ha plot
Mean vegetation height	Mean height of plants located at 5 equidistant points along each transect
Understory trees	# of understory trees < 10 cm dbh in 0.08-ha plot
Overstory trees	# of overstory trees ≥ 10 cm dbh in 0.08-ha plot
DBH	Mean diameter (cm) of all trees (> 3 m in height) in 0.08-ha plot
Mean tree height	Mean height (m) of all trees (> 3 m in height) in 0.08-ha plot
Basal area	Basal area (m^2 within 0.08-ha plot; dbh^2 x 0.00007854)
Distance to nearest road	Distance (m) to nearest gravel or paved road
Distance to nearest edge	Distance (m) to nearest abrupt change in habitat features

[a]Percentages based on 5 densitometer readings along each of four 16-m transects (in the four cardinal directions) that intersected at nest trees.

Table 3. Mean (± SE) characteristics of nest sites of Sharp-shinned Hawks and of randomly selected unused sites in Kentucky, 2009 – 2010. Variables that permitted best discrimination between nest sites and randomly selected, unused sites are in bold font.

Variable	Nest sites (*N* = 11)	Randomly selected, unused sites (*N* = 10)[a]
Distance to road (m)	**126.8 ± 24.6**	**156.5 ± 47.6**
Distance to edge (m)	**52.3 ± 14.2**	**70.6 ± 19.0**
Foliage cover (no. of 'hits')	**34.5 ± 7.4**	**23.7 ± 4.7**
Mean tree height (m)	**15.4 ± 0.7**	**12.7 ± 0.8**
Basal area (m^2/0.08 ha)	**2.17 ± 0.18**	**1.61 ± 0.14**
Canopy cover, deciduous (%)	**12.3 ± 4.3**	**37.5 ± 9.5**
Number of small (< 1.5 m in height) shrubs	215.1 ± 68.1	173.9 ± 53.3
Shrubs of large (1.5 – 3 m in height) shrubs	61.5 ± 19.5	29.2 ± 8.6
Understory trees (dbh < 10 cm)	12.7 ± 2.4	17.0 ± 3.5
Overstory trees (dbh ≥ 10 cm)	33.5 ± 3.6	21.9 ± 3.6
Mean vegetation height (cm)	41.1 ± 11.6	32.9 ± 6.7
Mean dbh (cm)	24.3 ± 1.7	22.0 ± 1.5
Total canopy cover (%)	78.5 ± 2.8	76.6 ± 2.5
Coniferous canopy cover (%)	51.4 ± 4.6	34.5 ± 9.5

[a]Except distance from edge (*N* = 9)

APPENDIX B:

Figures

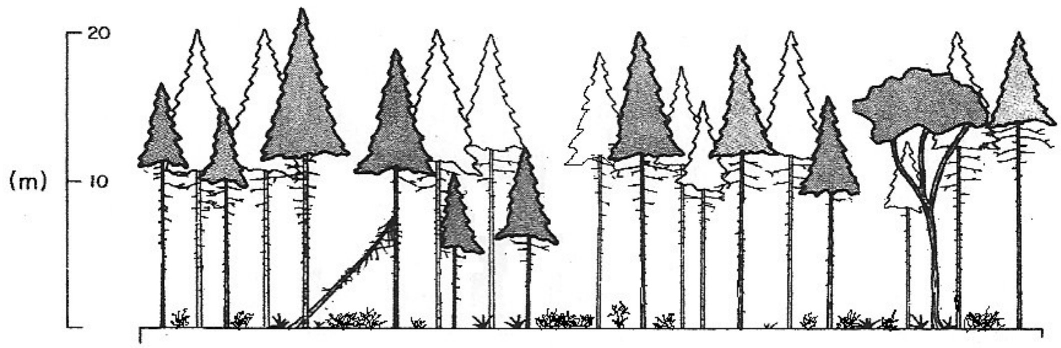

Figure 1. Schematic of the vegetation structure typical of nest sites of Sharp-shinned Hawks in my study. Note the generally dense, primarily coniferous overstory (with most trees 15 – 20 m in height) with a few openings, a relatively open midstory, and the presence of relatively dense, scattered ground cover.
(Source: Reynolds, R. T., E. C. Meslow, and H. M. Wight. 1982. Nesting habitat of coexisting *Accipiter* in Oregon. Journal of Wildlife Management 46: 124-138.)

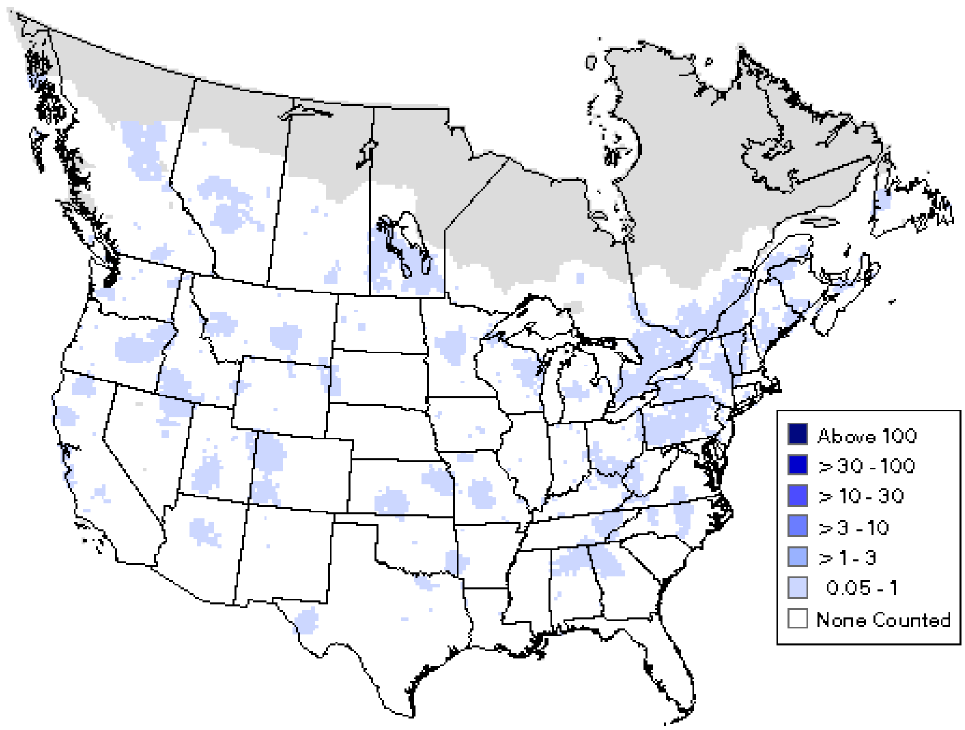

Figure 2. The distribution and abundance of Sharp-shinned Hawks in the United States and southern Canada during the summer (1994 – 2003) based on numbers observed during Breeding Bird Surveys.
(Source:http://www.mbrpwrc.usgs.gov/bbs/htm03/ra2003_blue/ra03320.htm)