Relationships Between Habitat and Snag Characteristics and the Reproductive Success of the Brown-headed Nuthatch (Sitta pusilla) in Eastern Texas.

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Relationships Between Habitat and Snag Characteristics and the Reproductive Success of the Brown-headed Nuthatch (*Sitta pusilla*) in Eastern Texas

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Abstract - Habitat use and reproductive success of the Brown-headed Nuthatch (*Sitta pusilla* Latham) were studied in East Texas during the 2001–2002 breeding seasons. We compared nest cavity selection at used and randomly selected non-used areas. Height of nest trees, midstory density, and percent leaf litter were negatively correlated with nest site selection. Brown-headed Nuthatches showed a strong preference for short snags; yet placed their nest cavity entrances near the top of the snags. While nuthatches may be selecting for habitats with little or no midstory density, percent of leaf litter in the nest sites is most likely the consequence of frequent burning. No significant differences among habitat variables and snag characteristics were found between successful and failed nest cavities. Additionally, no habitat variables were correlated with the number of chicks fledged per nest. Predation was the major cause of nest failure in this study.

Introduction

Brown-headed Nuthatches (*Sitta pusilla* Latham) are permanent residents of open pine habitats in the Southeastern US (Emlen 1977, Imhof 1976, Norris 1958). The Brown-headed Nuthatch is a pine specialist (Herb and Burt 2000, O'Halloran 1984) and is most abundant in sub-mature to mature longleaf pine (*Pinus palustris* Mill) stands that are regularly thinned (Emlen 1977, Haney 1981, O'Halloran 1984) or burned (Bent 1948) to produce habitat with an open midstory and little understory growth (Withgott and Smith 1998). Nuthatch density is influenced by the foraging and nesting habitat quality. Preferred sites include those periodically burned to control hardwoods and understory growth, and those that have a mean diameter at breast height (DBH) of 25.6 cm, a mean canopy closure of 15% and a mean pine basal area of 5.6 m^2/ha (O'Halloran and Conner 1987).

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Brown-headed Nuthatches select snags for nesting that are in open habitat and within or adjacent to stands of mature pines (Herb 1999, O'Halloran and Conner 1987, Withgott and Smith 1998). Although this species forages high in the canopy, it selects nesting cavities relatively low in the midstory. Brown-headed Nuthatches characteristically nest in moderately decayed (Harrison 1975, Headstrom 1965) to well-decayed pine or hardwood snags (Miller and Jones 1999, O'Halloran and Conner 1987) and show a strong preference for snags blackened by fire (Harrison 1975, Withgott and Smith 1998), lacking crowns, and missing bark (O'Halloran and Conner 1987).

Reproductive success or failure of nuthatches at the individual and population level is dependent on factors such as nest site availability, nest predation, and habitat quality. Nest site availability and competition with other species for nest sites may influence nesting success (Thompson 2000). Nest predation is a major cause of nest failures (Matthysen 1998). Confirmed nest predators include Blue Jays (*Cyanocitta cristata* L.) (Haney 1981), Red-bellied Woodpeckers (*Melanerpes carolinus* L.; Dunn 1984), various other woodpecker species (McNair 1984), Rat Snakes (*Elaphe obsolete* Say; Thompson 2000, Withgott and Amlaner 1996), Southern Flying Squirrels (*Glaucomys volans* L.), and feral cats (*Felis domesticus* Erxleben; Matthysen 1998, Withgott and Smith 1998). If the nest fails early in the season, a replacement clutch may be attempted within the same cavity or at a new nest site (Norris 1958). Poor habitat quality may have a direct effect on food availability and indirectly reduce the reproductive success of the breeding pair in that habitat.

Timber harvest practices have reduced Brown-headed Nuthatch breeding habitat resulting in range contraction and population declines (Withgott and Smith 1998). In the past 30 years, longleaf pine forests have been progressively replaced with slash and loblolly pine plantations, row crops, pastures, and lakes in the southeastern United States. In Florida, these changes have resulted in the decline and local extirpation of Brown-headed Nuthatch populations (Repenning and Labisky 1985). Habitat alteration in eastern Texas probably will have similar effects on local populations of Brown-headed Nuthatch.

In many areas, Brown-headed Nuthatch populations overlap populations of the endangered Red-cockaded Woodpecker (*Picoides borealis* Vieillot). Both species prefer regularly burned stands of mature longleaf pine (Emlen 1977, Repenning and Labisky 1985). Therefore, management techniques used for the Red-cockaded Woodpecker also benefit the Brown-headed Nuthatch.

Snag availability is an important characteristic of nesting habitat for the Brown-headed Nuthatch (Thompson 2000). Understanding nesting habitat preferences is crucial to developing management techniques that sustain optimal breeding habitat specific for the Brown-headed Nuthatch. Our study documents habitat characteristics associated with Brown-headed Nuthatch nest sites in eastern Texas. Our objectives were two-fold: 1) we sought to identify habitat characteristics important to nesting nuthatches by comparing habitat features at active nest cavities to randomly selected unused snags, and 2) we compared habitat and nest cavity characteristics between failed and successful nest sites to identify habitat variables associated with Brown-headed Nuthatch nesting success in eastern Texas.

Methods

Data for this study were collected within the Angelina and Davy Crockett National Forests in East Texas during the nesting seasons of 2001 and 2002. The Angelina National Forest, a longleaf pine-savannah with low midstory and understory densities, is considered an optimal habitat for the Brown-headed Nuthatch (O'Halloran 1984). The Davy Crockett National Forest is a sub-optimal habitat comprised primarily of loblolly pine with dense understory and slight midstory densities. We located and followed paired individuals at both sites in early February before the nesting season commenced to locate cavity excavation sites. We then monitored nest cavities every two days for nesting activity with a small, telescoping, pole-mounted video camera linked to a LCD monitor. The camera was inserted into cavity entrances as small as 2.54 cm in diameter. At each site, we recorded the number of eggs and date laid, the number of hatchlings and date hatched, the occurrence and dates of nestling mortality, the number of fledglings and date fledged, and the occurrence of second and replacement clutches. Any pair that fledged one or more offspring was considered a successful nest. We also determined the number of adults contributing to brood rearing for each nest, as this species is known to show cooperative breeding behavior (Norris 1958).

For each active nest site, we selected control snags by walking a minimum of 200 m from the true nest snags in a random direction until the first snag was found. We established sampling sites around nest snags and control snags, and measured vegetation using 100-m transects extending in the four cardinal directions. We estimated percent ground cover and canopy closure along each transect at 10-meter increments using a 4 cm diameter by 12 cm long ocular tube (Conner and Saenz 1996, James and Shugart 1970). Percent ground cover was categorized as fern, herbaceous, monocot, bare ground or leaf litter. We measured basal area of pines and hardwoods with a metric one-factor prism and ground cover height with a meter stick at the cavity snag and at 50 and 100 m intervals from the nest snag. We also measured dominant tree species, dominant tree height, and midstory density. Midstory density was ranked on a scale of 1 (absent) to 4 (heavy).

We measured each cavity and control snag for height, diameter, tree species, cavity height (for cavity snags) and percent of total bark remaining on the snag. Diameter at breast height was measured with a diameter tape at 1.4 m above ground level. A clinometer was used to calculate snag height (Avery and Burkhart 1983).

During 2001, we monitored three nests on the Stephen F. Austin State University campus. Although the primary motivation of our study was to determine microhabitat selection within forested areas, some nest data were collected within urban settings but were not included in the analyses of forest nests.

We performed statistical analyses using SAS for Windows version 8.2.0 (SAS Institute 2001). There was no significant difference among means for nest success and habitat variables between 2001 and 2002; therefore, we combined data in all subsequent analyses. We used Mann-Whitney U-tests to determine differences between the nest cavity and control sites and differences between nest sites that had successful broods and sites that had brood failure. Spearman ranks correlations were used to determine correlations between the independent habitat variables and the number of fledged young at each cavity. Cavity entrance and snag heights were analyzed using the Chi-square Goodness of Fit Test. Mean values are reported with standard errors. An Alpha level of 0.1 was chosen for statistical significance for all tests.

Results

We monitored 24 nests during the 2001 and 2002 nesting seasons. Three habitat variables (height of nest tree, midstory density, and percent leaf litter) were significantly different between nest cavity sites and control sites (Table 1). Nest snags were shorter (3.2 ± 0.3 m) than control snags (12.0 ± 1.8 m). Nest sites also had less dense midstories (1.9 ± 0.1) and less leaf litter (29.3 ± 2.0) than did control sites (2.5 ± 0.2 and 36.7 ± 2.8, respectively).

Mean snag (3.2 ± 0.3 m) and cavity entrance (2.2 ± 0.2 m) heights were analyzed for all nests. Ninety-two percent (22 of 24) of the nest cavities were located in the top half of the snags. We found that nest cavities were not equally distributed on the nest snags ($n = 24$, $\chi^2 = 16$, $P < 0.001$), suggesting that nuthatches prefer the top portion of the nest snags (Fig. 1).

We found no significant differences among habitat variables and snag characteristics between successful and failed nest cavities (Table 2). Additionally, no habitat variables were correlated with the number of offspring fledged per nest.

Ten of the 24 nests in this study failed. Successful pairs fledged three to six offspring per nest. The mean number of individuals fledged per nest site in 2001 was 3.0 (n = 9, S.E. = 0.82) and 2.5 (n = 15, S.E. = 0.65) in 2002. For combined years, the mean number of individuals fledged per nest site was 2.7 (n = 24; S.E. = 0.5) (Table 3). In 2002, two nests exhibited cooperative breeding behavior. Both groups consisted of the breeding pair and one helper. The first group

Table 1. Means and standard errors for habitat variables in nest cavity and control sites with Mann-Whitney U-test statistics and associated P-values for 2001–2002 data.

	Nest cavity n = 24		Control n = 24			
Variable	Mean	S.E.	Mean	S.E.	U-statistic	P-value
Midstory density	1.9	0.1	2.5	0.2	707.5	0.0150[a]
% Leaf[b]	29.3	2.0	36.7	2.8	676.5	0.0760[a]
% Woody[b]	28.5	3.4	26.5	3.4	591	0.9591
% Herb[b]	10.3	1.4	11.4	1.5	562.5	0.6086
% Mono[b]	17.7	1.6	14.6	1.6	524	0.1967
% Fern[b]	5.2	1.4	4.3	1.0	634	0.3288
% Bare[b]	9.0	3.1	6.4	1.8	602	0.7818
% Canopy closure	29.6	2.4	33.5	2.5	639.5	0.2983
Ground cover height	36.2	2.3	33.9	2.2	561	0.5873
Basal area pine	10.4	1.0	11.2	1.0	613	0.6158
Basal area hardwood	0.8	0.2	1.5	0.4	626	0.4425
Dominant tree height	25.2	0.6	25.2	0.9	564.5	0.6368
Cavity tree height	3.2	0.3	12.0	1.8	756	0.0012[a]
% Bark	46.0	7.9	48.0	7.8	624.5	0.4584
DBH	31.3	1.8	33.5	2.6	621.5	0.4995

[a]Significant P-values at the 0.1 alpha level.
[b]Percent of the variable in the ground cover.

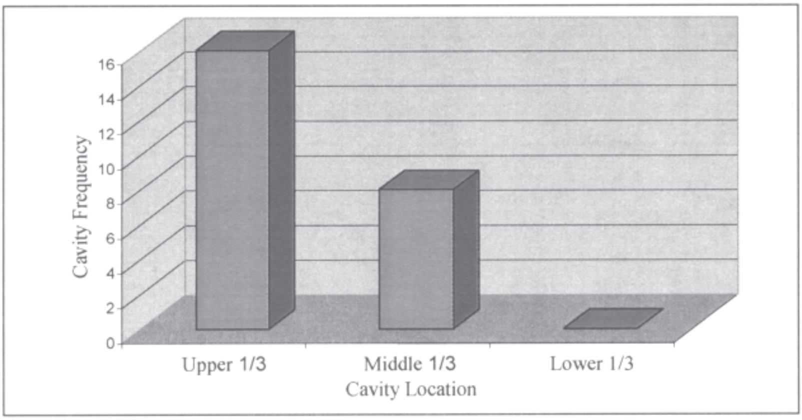

Figure 1. Frequencies of Brown-headed Nuthatch cavity locations (n = 24) on snags (lower 1/3, middle 1/3, and upper 1/3 portion of snag) in eastern Texas. $\chi^2 = 16$; $P < 0.001$.

was unsuccessful, losing the nest during the incubation period. The second group was successful and fledged five young.

Of the nests monitored on the Stephen F. Austin State University Campus, one pair was located in a nest box and successfully fledged five young. The remaining two pairs nested in the tops of two 9-m streetlights. Both of these nests were successful and both had double-broods. The first pair fledged five young in the first nesting attempt and three in the second. The second pair fledged two young in the first attempt and two in the second. We recorded brood reduction from four to two nestlings in the first nest of the latter pair. These data were not included in the analysis of forest-nesting pairs.

Table 2. Means and standard errors for habitat variables in successful and failed nests with Mann-Whitney U-test statistics and associated P-values for 2001–2002 data.

	Successful n = 14		Failed n = 10			
Variable	Mean	S.E.	Mean	S.E.	U-statistic	P-value
Midstory density	1.8	0.2	2.0	0.2	137.5	0.4644
% Leaf[b]	29.2	2.7	29.5	3.1	132.0	0.7070
% Woody[b]	29.7	4.3	26.8	5.7	118.0	0.7070
% Herb[b]	11.0	1.8	9.2	2.1	113.0	0.5072
% Mono[b]	18.5	2.1	16.7	2.7	117.0	0.6646
% Fern[b]	5.0	1.6	5.4	2.5	121.5	0.8527
% Bare[b]	6.6	2.4	12.4	6.7	138.0	0.4714
% Canopy closure	32.8	2.7	25.3	4.1	100.0	0.1648
Ground cover height	39.0	2.2	32.3	4.4	105.0	0.2651
Basal area pine	11.2	1.2	9.4	1.7	113.0	0.5073
Basal area hardwood	0.5	0.1	1.2	0.5	146.0	0.2414
Dominant tree height	25.9	0.7	24.3	1.1	108.5	0.3573
Cavity tree height	3.8	0.6	2.6	0.3	105.5	0.2761
% Bark	57.5	9.8	30.0	12.0	96.0	0.1065
DBH	30.9	2.2	31.8	3.2	128.0	0.8849

[a]Significant P-values at the 0.1 alpha level.
[b]Percent of the variable in the ground cover.

Table 3. Means (with standard errors and date ranges in parentheses) for Brown-headed Nuthatch nest attempts in 2001 and 2002.

Year(s)	Number of adults	Incubation initiation	Number of eggs	Number hatched	Date hatched	Number fledged
2001	2.0	4/2	4.4	3.7	4/14	3.0
(n = 9)	(0.00)	(3/17–5/1)	(0.30)	(0.84)	(3/31–5/15)	(0.82)
2002	2.1	3/16	5.1	4.1	3/27	2.5
(n = 15)	(0.65)	(2/22–4/19)	(0.28)	(0.61)	(3/8–4/18)	(0.65)
2001–2002	2.1	3/22	4.9	4.0	4/3	2.7
(n = 24)	(0.06)	(2/22–5/1)	(0.22)	(0.49)	(3/8–5/15)	(0.50)

Discussion

Snag and cavity site selection

Most eastern woodpeckers prefer snags or trees that have wood softened by decay, typically caused by basidiomycete fungi, insects, and bacteria (Conner et al. 1976, Kilham 1971, Kimmey and Furniss 1943), but that still retain their structural integrity. The Brown-headed Nuthatch is much smaller than any North American woodpecker species, and based on excavating morphology, the nuthatch has been suggested to require softer, more decayed snags (Norris 1958). However, excavation behavior may not be predicted solely by morphology (Schepps et al. 1999). If this is true, then the combination of competition with other hole-nesters and relative snag decay may provide the best explanation for snag selection and cavity site placement in nuthatches.

Cavity site competition. Brown-headed Nuthatches exhibited a strong preference for short snags. Higher nest sites provide better protection from predators than sites lower to the ground; however competition for higher cavity sites may force the Brown-headed Nuthatch to nest in shorter snags. Larger woodpecker species typically excavate their cavities higher above the ground and in taller snags than do smaller woodpecker species. Pileated Woodpecker (*Dryocopus pileatus* L.), Red-bellied Woodpecker, and Red-headed Woodpecker (*Melanerpes erythrocephalus* L.) nest cavity heights average 13.6 m (Conner et al. 1975), 7.6 m, and 7.0 m, respectively (Jackson 1976). The Hairy (*Picoides villosus* L.) and Downy (*Picoides pubescens* L.)Woodpeckers are smaller species within the same habitat type that nest in cavities with mean heights of 8.8 m and 4.7 m, respectively (Conner et al. 1975).

In our study, the Brown-headed Nuthatch nested in snags that averaged 3.2 m ($n = 24$) tall and excavated cavities in these snags 2.2 m ($n = 24$) above the ground. Although nuthatch nest snag heights were found to be considerably lower than those of the aforementioned woodpecker species and in shorter snags than those randomly available, we found a strong positive correlation between the cavity height and the height of the nest snag. This result is likely due to patterns of decay where the upper, more exposed portions of the snag exhibit a faster decay rate. We suggest that fungal entry and decay progression may influence cavity placement on the nest snag.

Snag decay and nest loss. Wood hardness has been associated with both the fungal infection and the progression of decay in snags. In certain oak species, the top rot, bacidiomycete fungus, *Spongipellis pachyodon* (Pers. comm., Kotlaba & Pouzar), is the primary source of decay. Snags infected with this fungus decay in a downward progression

(Conner et al. 1976). Schepps et al. (1999) found the same trend in quaking aspens (*Populus tremuloides* Michx.), and although the fungal species was not identified, hardness was found to decline toward the tops of the snags.

As wood hardness decreases, the snag becomes more suitable for cavity excavation. As suggested in oaks and aspens, the top of the snag may become favorable before lower portions (Conner et al 1975, Schepps et al. 1999). Cavity excavators require some degree of decay before snags can be used as nest sites. Tall snags, sufficiently softened by decay, would be more susceptible to breakage from wind. Although snags with less decay may be less susceptible to breakage, they may, however, also be too hard for the cavity excavators to use.

Trade-offs between competition and nest loss. Nesting in low sites is likely a trade-off between competition and nest loss. A nuthatch attempting to nest within tall snags may be constrained to the softer, upper portion, and thus must contend with competition with larger species. Nesting low on taller snags may not be an option if decay initiates in the upper portions of the snag and has not yet softened the lower sections. However, by nesting in shorter snags, the nuthatch is challenged with increased predation. Therefore, by selecting the upper portions of shorter snags, Brown-headed Nuthatches can reduce the competitive interactions with other species and minimize predation, while selecting sufficiently decayed wood and reducing the risk of nest loss by wind damage.

Nest site selection

In our study, the Brown-headed Nuthatch selected nest sites that had low midstory densities. Like the Red-Cockaded Woodpecker, Brown-headed Nuthatches select certain habitat characteristics when establishing nesting territories. As previously described, the habitat of the nuthatch can be characterized as an open, pine savannah where nesting snags are available. While the Brown-headed Nuthatch forages within the canopy of the forest, nest placement is low in the midstory. Habitats in which the midstory is dense could possibly conceal short cavity snags and entrances (Van Balen and Doerr 1978, Wilson and Watts 1999). Additionally, a dense midstory may inhibit movement between the high foraging sites and low nesting sites (Wood 1983). Therefore, by selecting for low cavity sites, nuthatches are constrained to habitats that have little or no midstory. In longleaf pine habitat of the southeast, site conditions are created through frequent burning and typically have reduced leaf litter accumulation (Chapman 1932, Conner 1981). Although our study also found leaf litter to be significantly lower at nest sites, we feel this is consequence of the fire regimen and not a direct factor associated with nest site selection.

Nest success

No habitat variables were correlated with nest success in this study. The failure to detect significant relationships between habitat variables and nest success might be due to small sample sizes, or due to certain variables not considered in this study, such as age or experience of the breeders or thermodynamics of the snag. Ten of the 24 nests in this study that failed were due either to predation or other natural causes. We suspected predation to be the single cause of nest failure based on the lack of remains of eggs or nestlings present in the cavities on the day of the final nest check.

In our study, the Rat Snake was confirmed as a nest predator. The Rat Snake is semi-arboreal and exhibits crepuscular activity (Withgott and Amlaner 1996). Rat Snakes, which locate prey by visual and vomeronasal cues, are exceptional climbers and will eat eggs, nestlings, and roosting adults. They are able to perceive movement more than one meter above the substrate, and may use the visual stimulus of nest provisioning to locate prey (Mullin and Cooper 1998).

Although not confirmed by our study, Flying Squirrels, White-footed Mice (*Peromyscus leucopus* Rafinesque), and possibly Broadhead Skinks (*Eumeces laticeps* Schneider) (pers. comm., J. Cox, Tallahassee, FL) are predators of Brown-headed Nuthatch nests. Williams and Wood (2002) confirmed that both Flying Squirrels and *Peromyscus* sp. take eggs as well as nestlings of Wood Thrush (*Hylocichla mustelina* Gmelin). Therefore, it is quite possible that mice and squirrels could consume Brown-headed Nuthatch eggs.

Broadhead Skinks are arboreal and diurnal, occupying decayed snags and logs. The Broadhead Skink is one of the larger species within the genus *Eumeces*. Larger skinks are capable of preying on eggs and young nestlings (Conant and Collins 1998). J. Cox (pers. comm., Tallahassee, FL) suspected Broadhead Skink predation on Brown-headed Nuthatches in areas that had appreciable amounts of dead wood in a study conducted in the Tall Timbers Research Station, Tallahassee, FL.

Although the Brown-headed Nuthatch is regarded as a single brooded species (Norris 1958, Harrison 1975), recent studies indicate the frequency of double-broods may be more common than once thought (Thompson 2000). Two of three nests observed in an urban environment double-brooded, one of which fledged a total of eight young during one breeding season. These records may help to illustrate the effect of predation on the overall reproductive success of the Brown-headed Nuthatch in forested area. The high reproductive success of these urban-nesting pairs may be due in part to the inability of predators to access the nest and to the lack of predators from the urban environments which prey on cavity nests, thereby allowing for a greater opportunity for double-broods.

Habitat management

The Brown-headed Nuthatch and the Red-cockaded Woodpecker both evolved to inhabit a fire-dependent ecosystem (Emlen 1977). Prior to European settlement, fire was created naturally by lightning (Komarek 1964) or by indigenous people (Ware et al 1993). These frequent (3–5 year intervals) (Krusac et al. 1995) and low-intensity fires maintained open stands (Platt et al. 1991). In addition to burning, small clearings within wooded areas may be produced by weather (lightning and wind throws), beetles, or disease (Withgott and Smith 1998).

Management techniques used for the Red-cockaded Woodpecker, such as controlled burning, can also be applied to the Brown-headed Nuthatch if the techniques can preserve snags. Frequent burning facilitates herbaceous growth and eliminates leaf litter (Society of American Foresters 1981) in addition to reducing understory vegetation that often conceals snags (Wilson and Watts 1999). Although frequent burning decreases the existence time of snags, hot burns can kill trees creating new snags (Conner 1981).

The persistence of Brown-headed Nuthatches is dependent upon the availability of foraging habitat and nesting snags. Previous studies have documented preferred habitat of the Brown-headed Nuthatch as regularly thinned, mature longleaf pine stands older than 45 years (Emlen 1977, Haney 1981, O'Halloran 1984). While our study did not identify habitat features associated with reproductive success it did identify some of the snag and habitat preferences of this species. Understanding these preferences will allow us to coordinate management efforts with those of the Red-cockaded Woodpecker.

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