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NEST SITES OF KENTUCKY WARBLERS IN BOTTOMLAND HARDWOODS OF SOUTH CAROLINA

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Abstract.—We examined nest sites of Kentucky Warblers (*Oporornis formosus*) in bottomland hardwood forests in the Coastal Plain of South Carolina to determine habitat features that might affect nesting success. We measured habitat features at 28 nests and at 28 non-use sites during the breeding seasons of 1993 and 1994. All nests were located on the ground and were supported by the bases of herbs and woody seedlings. Concealment of Kentucky Warbler nests was greater from the sides and from above than that of non-use sites. Nest patches were situated in tree-fall gaps; canopy coverage of nest patches was less than that of non-use patches, and tree stem density in nest patches was lower than in non-use patches. Understory vegetation was denser in nest patches than in non-use patches, particularly at nest level (0.0–0.5 m). Successful Kentucky Warbler nests (n = 19) did not differ from unsuccessful nests (n = 8) in any of the variables sampled. Nesting success of Kentucky Warblers may not be influenced strongly by vegetation at the nest site.

LUGARES DE ANIDAJE DE *OPORORNIS FORMOSUS* EN BOSQUES BAJOS DE ANGIOSPERMAS MADERERAS EN CAROLINA DEL SUR

Sinopsis.—Examinamos las áreas de anidaje de *Oporornis formosus* en los bosques bajos de angiospermas madereras de los planos costeras de Carolina del Sur para determinar características del hábitat que pueden determinar el éxito al anidar. Medimos las características del hábitat de 28 nidos y 28 lugares no usados durante las épocas reproductivas del 1993 y 1994. Todos los nidos se hallaron en el suelo y se sostenían por bases de hierbas y plántulas madereras. El encubrimiento de los nidos de esta especie era mayor por los lados y desde arriba que en las áreas no utilizadas. Parchos de nidos se situaron en áreas abiertas por caidas de árboles; la cubierta del dosel en los parchos de nidos fué inferior que en los parchos no usados, y la densidad de tallos en los parchos de nidos fué menor que en los parchos no usados. La vegetación del sotobosque fué más densa en parchos de nidos que en los parchos no usados, particularmente a nivel del nido (0.0–0.5 m). Nidos exitosos de esta especie (n = 19) no difirieron de nidos no exitosos (n = 8) en ninguna de las variables muestreadas. El éxito de anidaje de *Oporornis formosus* puede no estar fuertemente influenciado por la vegetación en la localidad del nido.

Bird community diversity generally is correlated positively with vertical vegetation diversity (James 1971, MacArthur and MacArthur 1961, Willson 1974). This relationship traditionally has been explained in terms of the increasing availability of foraging substrates with increasing numbers of vegetative layers. More recently, Martin (1993a, 1993b) and Steele (1993) suggested that an increase in the number of nest sites may explain the observed relationship. Conversely, the extirpation of a species from a forest fragment (i.e., its area-sensitivity) may be due to a decrease in the number of nest sites available for that species, rather than to area per se (Martin 1993a). Nest-site availability may be the critical factor determining habitat selection in many open-nesting species (MacKenzie et al. 1982, Martin 1993a, Sedgewick and Knopf 1992, Steele 1993). Management for area-sensitive species should benefit from knowledge of their nesting habitat requirements. If nesting requirements can be met, the species may persist in smaller fragments. However, nesting habitat information is needed for many species of Neotropical migratory passerines (Martin 1992). Most important is the need for information on specific features of nest-site vegetation that affect the success of the nest (Martin 1992). We examined nest-site selection of an area-sensitive (Wenny et al. 1993) Neotropical migrant, the Kentucky Warbler (*Oporornis formosus*), to determine habitat features related to nest-site selection and nest success.

STUDY AREA AND METHODS

The study was conducted at the U.S. Department of Energy's Savannah River Site. This 78,000-ha tract in Aiken, Barnwell, and Allendale Counties, South Carolina lies in the Upper Coastal Plain physiographic province. Elevation ranges from <25 m at the Savannah River to 80 m at headwater streams. Bottomland hardwood forests, found along stream courses, may be seasonally flooded during late winter–early spring. The bottomland overstory is dominated by sweetgum (*Liquidambar styraciflua*), swamp tupelo (*Nyssa sylvatica* var. *biflora*), red maple (*Acer rubrum*), water oak (*Quercus nigra*), and diamond-leaf oak (*Q. laurifolia*). The midstory includes such dominants as American holly (*Ilex opaca*), sweet bay (*Magnolia virginiana*), red bay (*Persea borbonia*), and ironwood (*Carpinus caroliniana*), and the understory is dominated by switchcane (*Arundinaria gigantea*) and dog hobble (*Leucothoe axillaris*). Netted chain fern (*Woodwardia areolata*) and Christmas fern (*Polystichum acrostichoides*) are the dominant ground cover (Workman and McLeod 1990).

We located Kentucky Warbler nests in 12 bottomland hardwood strips varying in width from <50 to >1000 m. Closed canopy pine forest was adjacent to both sides of all sites. Nests were located during May–July 1993 and 1994 by observing adult behavior (Ralph et al. 1993). We visited nests every 3–4 d (Ralph et al. 1993) to determine nest fate; nests that contained nestlings on the last visit before the expected fledging date were assumed to have fledged. Nests that fledged at least one nestling were considered successful. We measured vegetation at nests following termination of the nesting attempt. Measurements were taken at the nest and in the nest patch (5-m radius circle centered on the nest; Martin and Roper 1988). They were repeated at a non-use site within the stand, located by pacing 35 m (Ralph et al. 1993) upstream or downstream (determined by coin toss) in a direction parallel to the general bearing of the bottomland strip. This distance placed non-use sites outside of the nest patch while still sampling vegetation within the bottomland habitat. We centered non-use sites on the plant nearest the 35-m point that was of the same species and approximate size as the primary nest substrate plant (Ralph et al. 1993). We obtained success data from 27 nests, nine nests in 1993 (five successful, four unsuccessful) and 18 nests in 1994 (14 successful, 4 unsuccessful). One additional nest that was empty when found in 1993 was sampled and included in the comparison of nest sites versus non-use sites, but not in the analyses relating to nest success (Martin and Roper 1988).

All plant species providing support to the nest were recorded. Concealment indices (0–4: 0 = 0% concealed, 1 = 1–25% concealed, 2 = 26–50% concealed, etc.) were estimated by viewing the nest from above and from the sides at ground level at a distance of 1 m in each of the four cardinal directions (Martin and Roper 1988, Holway 1991). For concealment estimates at non-use sites, we placed an empty Kentucky Warbler nest at the base of the surrogate substrate plant (Holway 1991).

Our measurements in the nest patch included canopy cover, stem density of switch cane, stem density of saplings (woody plants 0.3–3.0 m in height), stem density of trees (woody plants >3 m in height), fern cover, other herbaceous ground cover, and vegetation profile. We estimated canopy coverage by taking five vertical hit-miss readings through an ocular tube, one at the nest plant and four from the perimeter of the patch at each of the cardinal directions. Plant stem densities were measured by counting stems in five 1-m^2 quadrats located randomly along the four cardinal directions. Percent foliar cover of ferns and of other herbaceous ground cover also was estimated (0–4 index) within the quadrats. Vegetation profile of the patch was determined using a 3-m vegetation profile board (Noon 1981, Nudds 1977) against which percentage cover was estimated (0–4 index) for each 0.5-m interval. We placed the profile board at the nest plant and read it from a distance of 5 m in each of the cardinal directions.

We made univariate comparisons between Kentucky Warbler nest sites and non-use sites and between successful and unsuccessful nest sites for each variable. Variables estimated with the 0–4 index were tested with Wilcoxon rank-sum tests. Comparisons involving count data were made with a two-sample t-test. We assumed variances were equal for comparisons involving equal sample sizes (Ott 1988). When sample sizes differed, we tested the equal variance assumption with the F-test for equality of variance. Equal variance tests always were appropriate. Because no differences ($P > 0.05$) were found between years for any variable, we pooled data from both years.

RESULTS

Kentucky Warblers built their nests among the bases of one or more plant stems, such that the bottom of the nest was on the ground and the cup was above ground level. Usually, several plants of different species were used to support the sides of an individual nest. More than 11 plant species were used: switchcane, 10 (36%); ferns (primarily netted chain fern and Christmas fern) 10 (36%); red bay, 3 (11%); sweet bay, 3 (11%); miscellaneous grasses, 3 (11%); dog hobble, 2 (7%); diamond-leaf oak, 2 (7%); common gallberry (*Ilex glabra*), 2 (7%); muscadine (*Vitis rotundifolia*), 1 (4%); red maple, 1 (4%); and blueberry (*Vaccinium elliottii*), 1 (4%) (because some nests were supported by multiple plants, the number of nests listed is greater than the number of nests observed). Con-

TABLE 1. Comparison of microhabitat variables (mean ± SE) at Kentucky Warbler nest sites (n = 28) with those at non-use sites (n = 28) within bottomland hardwood strips, Savannah River Site, South Carolina, 1993–1994.

Variable	Nest site	Non-use site	P
Nest concealment[a]			
side	3.3 ± 0.1	2.1 ± 0.2	0.000
above	3.2 ± 0.2	2.0 ± 0.2	0.000
Nest patch			
Canopy cover[b]	4.1 ± 0.2	4.8 ± 0.1	0.003
Fern cover[a]	1.4 ± 0.2	1.1 ± 0.2	0.274
Ground cover[a]	2.2 ± 0.2	2.0 ± 0.2	0.328
Switchcane density	35.6 ± 10.5	21.4 ± 6.6	0.254
Sapling density[c]	12.0 ± 1.9	10.1 ± 1.5	0.423
Tree density[d]	0.2 ± 0.0	0.3 ± 0.1	0.072
Vegetation profile[a]			
0.0–0.5 m	3.3 ± 0.1	2.5 ± 0.2	0.000
0.5–1.0 m	2.7 ± 0.1	2.3 ± 0.2	0.049
1.0–1.5 m	2.3 ± 0.2	1.9 ± 0.2	0.084
1.5–2.0 m	2.2 ± 0.2	1.8 ± 0.2	0.120
2.0–2.5 m	2.2 ± 0.2	1.7 ± 0.2	0.069
2.5–3.0 m	2.0 ± 0.2	1.7 ± 0.2	0.324
Mean	2.5 ± 0.1	2.0 ± 0.1	0.019

[a] Index of percent coverage: 0 = 0%, 1 = 1–25%, 2 = 26–50%, 3 = 51–75%, 4 = 76–100%. Index values were compared with the Wilcoxon rank-sum test; all other comparisons were made with a two-sample t-test.

[b] Estimated as the sum of five hit-miss readings taken within the patch (5 = total canopy closure).

[c] Density (No. stems/m^2) of woody stems 0.3–3.0 m tall.

[d] Density (No. stems/m^2) of woody stems > 3.0 m tall.

cealment of Kentucky Warbler nests was greater from the sides and from above than that of non-use sites (Table 1). Canopy coverage of nest patches was less than that of non-use patches and tree density in nest patches was lower than that in non-use patches (Table 1). Understory vegetation was denser in nest patches, particularly at nest level (0.0–0.5 m), than in non-use patches (Table 1). None of the vegetation variables we measured differed between successful and unsuccessful nests. However, nest concealment from above was greater for successful nests, and this relationship approached significance (P = 0.12).

DISCUSSION

Kentucky Warblers nested in patches with dense vegetation, particularly at ground level. The dense vegetation afforded concealment that presumably reduced predation (Martin 1992). Ground-nesting birds traditionally have been thought to suffer greater nest predation than shrub-nesting birds, but Martin (1993a) recently summarized several studies and demonstrated that success of ground-nesting birds in forested habitats actually is similar to or greater than that of shrub-nesting birds. Kentucky Warblers had higher nesting success than the shrub-nesting Hooded Warbler (*Wilsonia citrina*) at our study sites (R. A. Sargent, unpubl. data). The high degree of nest concealment may explain why Kentucky Warblers are able to nest successfully on the ground. Dense vegetation could inhibit predator efficiency by providing many potential nest sites to search (Martin and Roper 1988). We were unable to test this hypothesis adequately because Kentucky Warblers nested on the ground and used a variety of substrate plants, which made definition of potential substrates difficult. Ferns were used as a substrate in about 33% of the nests and they provided cover for several of the remaining nests. Thus ferns could be considered potential substrates for Kentucky Warbler nests. Wenny et al. (1993) found greater ground coverage in Kentucky Warbler territories than in Ovenbird (*Seiurus aurocapillus,* another ground-nesting species) territories. Therefore, we expected but did not detect a difference between fern coverage of nest patches and of non-use patches.

Generally, Kentucky Warbler nest patches were situated in small tree-fall gaps. Both canopy coverage and tree-stem density were lower in nest patches than non-use patches. Chapman (1907) observed that Kentucky Warbler nests throughout their range generally were well concealed but were located in a relatively open spot within forested habitat; De Garis (1936) reported a nest in a fence corner of a garden. However, Kentucky Warblers also have been described as birds of deep shade and dense, damp thickets (Bent 1953). Bent's (1953) description is somewhat similar to our findings. Canopy closure of the bottomland hardwood sites in which we found nests was nearly complete, with only scattered tree-fall gaps. Tree-fall gaps within a densely shaded forest apparently provided the conditions necessary for Kentucky Warbler nest sites.

Although Gibbs and Faaborg (1990) reported that Kentucky Warblers were not as sensitive to fragmentation as the Ovenbird, the nesting success of Kentucky Warblers may be influenced more by landscape factors than those of the nest site or nest patch. Though our sample of unsuccessful nests was small, we detected no microhabitat differences between successful and unsuccessful nests. Similarly, nesting success of Hooded Warblers, Black-throated Blue Warblers (*Dendroica caerulescens*), and Northern Cardinals (*Cardinalis cardinalis*), all open-cup, forest-nesting Passerines, is unrelated to degree of nest concealment (Conner et al. 1986; Holway 1991; Howlett and Stutchbury, in press; Kilgo et al., in press). We were unable to test landscape factors, such as stand size or adjacent land-use, because of small sample sizes and overall study design (adjacent uplands were in one land-use type, i.e., >20-yr-old pine forest). We recommend that future studies of Kentucky Warbler nesting ecology focus on landscape-scale effects on nesting success and the relationship between availability of suitable nest patches and nesting success.

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