Wilson Bull., 103(3), 1991, pp. 486–491

Characteristics of Yellow-crowned Night-Heron nests in lowland hardwood forests of Missouri.—Published information on the nesting ecology of many Ardeids is largely restricted to coastal areas and consists of qualitative descriptions of specific nest sites (Eyles 1938, Ralph and Ralph 1958, Maxwell and Kale 1977). However, application of quantitative multivariate techniques, in conjunction with behavioral observations, has led to the supposition that subtle but significant differences in nest-site characteristics exist between species within a colony (Beaver et al. 1980). Limited information also is available regarding intraspecific differences in nest-site characteristics caused by shifts in vegetation communities between physiographic regions (McVaugh 1975, Bagley and Grau 1979).

Yellow-crowned Night-Herons (*Nyctanassa violaceus*) often nest alone or scattered in loose aggregations (Parnell and Soots 1979). Studies in coastal areas indicate that nest-site characteristics of Yellow-crowned Night-Herons vary and may depend on several factors, including vegetation structure and social conditions (e.g., presence of other heron species). In swamps, nests often are positioned over water in understory vegetation (Wischusen 1979). Nests also have been reported in hardwood timber (Price 1946, Sutton 1967) and in pines (*Pinus* spp.) (Wayne 1906, Watts 1989). In mixed-heron colonies, night-herons tended to nest on the ground (Burger 1979).

Regardless of social conditions or the type of macrohabitat selected, minimizing exposure to avian predators (Burger 1978) or inclement environmental conditions (Beaver et al. 1980) appears to be a common feature of nest position. This hypothesis has been used to explain the placement of nests low in tree canopies (Watts 1989). The goals of this study were to examine the variability in vegetation characteristics among Yellow-crowned Night-Heron nest sites detected in a lowland hardwood wetland and to evaluate the similarity between the vegetation characteristics useful in describing Yellow-crowned Night-Heron nest sites in coastal and inland wetlands.

Study area and methods.—The study was conducted in the Mingo Swamp of southeastern Missouri, the largest remaining tract of lowland hardwood wetlands in the state (Korte and Fredrickson 1977). Situated at the northern terminus of the Mississippi alluvial delta, Mingo Swamp encompasses about 9312 floodable ha. Mingo National Wildlife Refuge (MNWR) and adjacent Duck Creek Wildlife Management Area (DCWMA) are charged with management responsibility of these lands. A series of wells and ditches are used to manipulate water levels within marshes and leveed impoundments, primarily for waterbirds. Approximately 637 ha are managed for the production of moist-soil vegetation or row-crops, 6038 ha as forested impoundments (live forest = 4502 ha, dead tree = 456 ha, scrub/shrub = 550 ha, and greentree reservoir = 530 ha), and 1476 ha as marsh (Heitmeyer et al. 1989).

Searches for Yellow-crowned Night-Heron nests were conducted from April through August of 1989 and 1990. Nests were located by walking systematic transects through about 500 ha of contiguous forested impoundments and searching specific areas where Yellow-crowned Night-Heron activity had been reported in past years. Within forested areas, open areas resulting from clearcuts and thinning operations also were searched. Based on 1983 information (Heitmeyer et al. 1989), about nine percent of the macrohabitats (i.e., live forest, greentree reservoir, and scrub/shrub) potentially suitable for nesting by Yellow-crowned Night-Herons were surveyed. Openings within forested habitats represented about 2% (10 ha) of the surveyed area. Nest trees were mapped, labeled as to year of activity, and visited periodically to confirm the use of nests by Yellow-crowned Night-Herons.

Nine vegetation characteristics were recorded at each nest site (Table 1). Height of the nest tree and the nest were measured to the nearest 0.5 m at a horizontal distance of 20 m from the nest tree, using the Bitterlich angle method. Diameter at breast height (dbh) of the

TABLE 1

CHARACTERISTICS OF 33 YELLOW-CROWNED NIGHT-HERON NEST SITES IN MINGO SWAMP, SOUTHEASTERN MISSOURI

Variable	$\bar{x}$	SE	Range
Nest tree			
Height (m)	29.1	0.7	20.0–35.5
Diameter breast height (cm)	52.8	2.9	27.0–87.0
Horizontal nest position (%)[a]	73.6	1.8	50.0–87.0
Nest height (m)	18.3	0.6	10.5–25.0
Nest branch angle (°)	77.0	1.3	60.0–90.0
Habitat			
Tree density			
Poletimber (trees/ha)	920	98	200–2400
Sawtimber (trees/ha)	139	14	50–400
Total trees (trees/ha)	1059	95	350–2500
Basal area (ms^2/ha)	22.8	0.9	10.3–32.1

[a] Calculated as 100 × distance of nest from tree center/nest branch length.

nest tree was determined with a Biltmore stick. Basal area was measured using a 10 BAF prism with the nest tree as the center of a variable radius plot. An index of nest position relative to canopy breadth (distance of nest from tree center/nest branch length) × 100 was calculated as was the angle of the nest branch. Tree density was measured within a 0.02-ha circular plot with the nest tree at plot center. Distance to the nearest adjacent nest within each nest aggregation also was recorded.

Data among years were combined prior to analyses because of the small number of nests located. Tree preference was examined by Chi-square analysis using data on tree diversity and density collected within discrete 0.0-2ha plots. Factor analysis (FA) with the VARIMAX rotation method was used to reduce the number of structural features needed to describe nest-site characteristics.

Results.—Twenty-three nests were located in 1989 and 10 additional nests in 1990. Maps of nest locations indicated five and three loose colonies in 1989 and 1990, respectively. The three colonies located in 1990 occupied sites used in 1989. The maximum mean distance between nests comprising a colony was 74 m, whereas the minimum distance between colonies was about 350 m, providing evidence that nests were not randomly distributed. Colonies were comprised entirely of Yellow-crowned Night-Heron nests and averaged 4.6 ± 1.2 (SE) nests in 1989, 3.67 ± 0.9 nests in 1990, and 4.25 ± 0.8 nests across both years of the study. Mixed-species colonies were not detected. Four of the colonies were on the DCWMA in forested sites that are leveed and managed as greentree reservoirs. One colony was in a shallow forested drainage on MNWR. In general, areas containing Yellow-crowned Night-Heron nests were characterized as sawtimber stands with moderate to sparse understories and sparse ground cover. No nests were located in small clearcuts or thinned areas within the forested impoundments, but the area surveyed was small.

Although three of the colonies were located in both 1989 and 1990, only three trees were used as nest sites in both years. No trees were occupied by more than one pair in the same year. Nests were located in five different tree species. Thirty-two nests (97%) were in oaks; 19 (58%) in pin oak (*Quercus palustris*), five (15%) in overcup oak (*Q. lyrata*), and four

TABLE 2

CHARACTER LOADINGS ON THE FIRST THREE PRINCIPAL FACTORS AFTER VARIMAX ROTATION OF THE FACTOR MATRIX

Character	Component Stand density	 Nest position	 Stand structure
Diameter breast height (cm)	0.23	0.40	−0.46
Tree height (m)	−0.27	0.76	−0.17
Nest height (m)	0.16	0.88	0.08
Nest branch angle (°)	−0.18	0.36	0.58
Basal area (m^2/ha)	0.26	−0.15	0.81
Horizontal nest position (%)	0.31	0.70	−0.01
Sawtimber/ha	−0.16	−0.04	0.81
Poletimber/ha	0.96	0.09	−0.14
Trees/ha	0.97	0.09	−0.02
Variance explained (%)	29.5	20.9	19.8

(12%) each in shingle oak (*Q. imbricaria*) and black oak (*Q. velutina*). One nest (3%) occurred in sweetgum (*Liquidambar stryraciflua*). Other species of trees within an 8-m radius (0.02-ha) of nest sites included shagbark hickory (*Carya ovata*) and blackgum (*Nyssa sylvatica*); snags also were present. Based on the density of each tree species within 0.02-ha of nest sites, nests were constructed in oak species significantly more than expected ($\chi^2 = 16.6$, 1 df, $P < 0.005$) by chance based on their occurrence.

Three uncorrelated linear combinations of habitat variables, identified by factor analysis, accounted for 70.2% of the variation in nest-site attributes (Table 2). The first factor, or combination of variables, was denoted as stand density. The variables with the highest loadings were poletimber and total tree density. Both variables were highly variable among nest sites. Poletimber density at individual nest sites ranged from 200–2400 trees/ha ($\bar{x} = 920 \pm 98$), whereas total tree density ranged from 350–2500 trees/ha ($\bar{x} = 1059 \pm 95$) (Table 1).

The second factor was denoted as nest position because the variables with the highest loadings were nest height, horizontal position of the nest, and tree height (Table 2). The first two variables are dependent on tree form, of which tree height is a partial indicator. The height of the nest varied directly with the height of the nest tree ($r = 0.54$, $P = 0.001$), with the vertical position of the nest about 9–11 m below the maximum tree height (Table 1). Horizontally, nests were located away from the tree bole and towards the edge of the canopy. All nests were located on the outer half of the limb forming the main nest brace.

The variables with the highest loading coefficients on the third axis were basal area and sawtimber density (Table 2). This factor was termed stand structure because it partially describes the size and density of potential nest trees. Sawtimber density ranged from 50–400 trees/ha ($\bar{x} = 139 \pm 14$) at individual nest sites. Basal area, measured in variable radius plots, also indicated that several trees in the sawtimber size class were in the vicinity of the nest site.

Discussion.—The average size of colonies in our study was 4.25 ± 0.8 nests, and all nests occurred in separate trees. This provides additional support of earlier evidence that night-herons typically nest in unshared trees (Wischusen 1979, Drennen et al. 1982) and that colonies are small relative to other Ardeid colonies (Custer et al. 1980, Palmer 1962, Hancock and Kushlan 1984).

Yellow-crowned Night-Herons are known to use a variety of habitats for nesting (Watts 1989), and the influence of social and vegetation factors in nest-site selection has been documented for other heron species (McCrimmon 1978, Burger 1979, Beaver et al. 1980). An additional factor in inland freshwater systems may be the distance to reliable foraging areas during brood rearing. In coastal environments, foraging tends to be dependent on tidal fluctuations (Custer and Osborn 1978, Watts 1988), but the location of these areas is dependable. In contrast, the location of available foraging sites in Mingo Swamp is more dynamic (Laubhan et al. 1991). Water levels within leveed impoundments fluctuate seasonally as a result of planned management activities. Water may be present in an impoundment when nest sites are selected but may be dry two weeks later. As a result, foraging opportunities only are available for a short time. On DCWMA and MNWR, individual impoundments are drawn down sequentially so that foraging opportunities last longer, but the location of foraging sites changes periodically. This may influence colony location among years, but insufficient data were collected to permit testing this hypothesis.

Because wetland vegetation is primarily determined by the hydrological regime (Fredrickson and Reid 1990), the species of nest tree partially reflects the long-term hydrological cycle in the vicinity of the nest. Pin oak predominates in habitats that remain partly flooded from December to May, and surface water is rarely >20 cm deep (Heitmeyer et al. 1989). In addition to providing good nesting substrate, more nests may have occurred in pin oak because this species is adapted to sites that are indicative of favorable foraging areas that are available through the brood rearing period.

Several hypotheses have been provided to explain the position of heron nests in the tree canopy. Positioning nests low in the canopy of hardwood trees reduces the danger of excessive thermal stress during the brood period (Burger 1978, Beaver et al. 1980) and also may provide concealment from aerial predators (Burger 1978). In Virginia, Yellow-crowned Night-Herons nested low in the canopy of loblolly pines (*P. taeda*). The primary selective advantage of pines over hardwoods may have been to reduce clutch losses to crows (*Corvus brachyrhynchos* and *C. ossifragus*), even though deciduous trees provide a better thermal environment for brood rearing (Watts 1989). These results indicate that positioning nests within a specified zone of the canopy may be a mechanism to increase the recruitment of young.

In our study, both the structural features of nest trees and nest position were highly uniform. In contrast with previous studies, however, we found that nests typically were placed away from the center of the tree and in the upper reaches of the canopy. According to Watts (1989), this may increase the incidence of aerial predation. Although nest fate was not closely documented, crow nests were present in the same tree as Yellow-crowned Night-Heron nests, suggesting that clutch loss to crows may occur. However, it may also suggest that clutch loss to crows is not a principal factor influencing nest-site selection in this area.

The placement of nests in the upper portion of trees and towards the outer edge of the canopy may represent a mechanism to reduce the probability of nonavian predation. Black rat snakes (*Elaphe obsoleta*) destroyed 25% of all nests by box-nesting Wood Ducks (*Aix sponsa*) on MNWR from 1966–1970 and apparently killed two incubating female wood ducks (Hansen and Fredrickson 1990). During the same time period, raccoons (*Procyon lotor*) destroyed an additional 8% of Wood Duck nests (Hansen 1971). The position of night-heron nests observed in our study would tend to minimize the predation risk by terrestrial predators, because nests are more difficult to detect from the ground and from the main stem of the tree following leaf expansion. At the same time, some overhead cover would be provided for shading young and for protection from aerial predators. Nesting in separate trees also may help reduce the incidence of terrestrial predation by forcing predators to exploit each nest tree individually (Watts 1989).

Acknowledgments.—This is a contribution of Gaylord Memorial Laboratory (The School of Natural Resources, Univ. of Missouri–Columbia, and Missouri Dept. of Conservation cooperating), Missouri Cooperative Fish and Wildlife Research Unit, Contracts USDI 14-16-009-1556-32, and the Missouri Agricultural Experiment Station, Projects 170 and 183, Journal Series #11,331. J. Wortham assisted in nest searches and data collection. T. Custer, L. Fredrickson, M. Kaiser, J. Kelley, Jr., B. Watts, and an anonymous reviewer provided helpful comments on earlier versions of the manuscript.

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Wilson Bull., 103(3), 1991, pp. 491–493

Migration of Sharp-shinned Hawks in the Dry Tortugas, Florida.—It is a long-held notion that many species of raptors (Falconiformes) avoid crossing large bodies of water during their biannual migrations (Allen and Peterson 1936, Haugh and Cade 1966, Heintzelman 1986). Recently, however, some species have been found to make long water crossings during migration (MacRae 1985). Kerlinger (1985) suggested that species involved in over-water flights are those with high aspect ratio wings that decrease the cost of powered flight. Species that lack the desired aspect ratio for sustaining flapping flight seem reluctant to undertake long-distance water crossings (Kerlinger 1989). Indeed, one of these species, the Sharp-shinned Hawk (*Accipiter striatus*), seldom undertakes water crossings of >125 km and apparently avoided crossing water when lateral winds were strong and chances of seaward displacement were high (Kerlinger 1989). Large numbers of Sharp-shinned Hawks are observed every fall in the Florida Keys where minor water crossings are routine (e.g., Atherton and Atherton 1988). Although a northeasterly reverse migration has been described from the Keys (Darrow 1983), many birds traverse >100 km of ocean to reach the Dry Tortugas where they can be quite common (W. G. Mattox, pers. comm.). No information, however, has been gathered concerning the flight orientation of these migrants after reaching the Tortugas. Three possibilities exist: (1) they continue on a southerly or southwesterly direction across the Gulf of Mexico, (2) they reverse direction and head easterly back toward the Keys, or (3) they reorient in a northwesterly direction toward Louisiana and Texas. I undertook this study to determine the directional orientation and behavior of Sharp-shinned Hawks confronted by the open waters of the Gulf of Mexico at the Dry Tortugas.

The Dry Tortugas, 117 km west of Key West (24°38′N, 82°52′W), form the western