

## SHORT COMMUNICATIONS

*The Condor* 91:979-983  
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### NEST-SITE CHARACTERISTICS OF YELLOW-CROWNED NIGHT-HERONS IN VIRGINIA<sup>1</sup>

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*Key words:* Yellow-crowned Night-Heron; nest-site characteristics; Virginia.

Nest-site characteristics of many Ardeidae species have been quantified and discussed for several areas along the Atlantic coast (Meanley 1955, Jenni 1969, Burger 1978, McCrimmon 1978, Beaver et al. 1980). Because Yellow-crowned Night-Herons (*Nycticorax violaceus*) nest in very scattered, small colonies or as isolated pairs, they are often difficult to locate (Price 1946, French 1973, Parnell and Soots 1979). For this reason, available information on nesting sites consists largely of qualitative descriptions of a few nests (e.g., Imhoff 1962, Palmer 1962, Sutton 1967, French 1973, but see Wischusen 1979, Drennen et al. 1982). The primary objective of this study was to provide a description of the vegetative characteristics associated with coastal nest sites in Virginia.

#### METHODS

The western shore of the lower Chesapeake Bay is comprised of six major cities (Norfolk, Virginia Beach, Newport News, Hampton, Chesapeake, and Portsmouth). A road census of residential areas during the breeding seasons of 1986-1987 revealed 163 pairs of Yellow-crowned Night-Herons widely scattered over eight river drainages. Thirteen nest-site characteristics (Table 1) were quantified in 1986 for all 65 nests located in May and June of that year. Nest height, nest-tree height, and height of first major limb were all measured to the nearest 0.5 m using a hypsometer while standing a horizontal distance of 23 m from the tree base. The depth of the nest-tree canopy was measured as the distance between the lowest limb and the top of the crown. As an index of which portion of the canopy was utilized, nest position was calculated as the following percentage: [(nest height - first limb height)/canopy depth] × 100. The trunk diameter of all nest trees was measured to the nearest centimeter at breast

height (dbh = ca. 1.4 m) using a diameter tape. Trees were aged by counting the winter rings on a 0.32-cm core sample removed with a standard 41-cm increment borer. During both the 1986 and 1987 breeding seasons, the species of all nest trees as well as the number of pairs forming a colony were recorded. Pairs not nesting within 50 m of another active nest were considered to be singles, but pairs forming a cluster of two or more nests were said to be a colony. The number of pairs occupying each nest tree was also recorded.

Vegetation was examined in discrete nest plots. Each nest plot consisted of a 0.12-ha circular plot (33.9 m radius) with the nest tree at its center. The number of hardwood trees and loblolly pines (*Pinus taeda*) (>15 cm dbh) within the plot was recorded as well as the total tree number. Canopy closure over the nest plot was measured (to the nearest 10%) by visually blocking off five sections of the canopy (looking through a 7.7-cm × 7.7-cm hole in a 12.8-cm × 20.8-cm card held at arm's length) and estimating the area represented by light gaps. The value recorded for each plot was the mean of five estimates rounded to the nearest 10%. All 65 nest trees sampled were plotted as accurately as possible on 7.5-min topographic maps. The distance from the plotted tree position to the nearest tidal marsh or permanent body of water was measured to the nearest 20 m. Both factor analysis (Beaver et al. 1980) and principal component analysis (McCrimmon 1978) have been used to reduce the number of variables needed to describe nesting situations of wading birds. Because separate categories of variables (nest position, tree structure, tree stand, habitat structure) were measured and entered in the same analysis here, factor analysis is appropriate (Johnson and Wichern 1988). See Beaver et al. (1980) for a description of this technique.

#### RESULTS

In 1986 and 1987, 257 nesting attempts (some of which were likely the same pairs in both years) were documented in residential areas. The majority of these attempts (87.8%) were made on privately owned lots with occupied homes. Remaining attempts were on privately owned vacant lots (5.4%) and city owned parkland (7.8%). Yellow-crown pairs seemed to be exceedingly tolerant of humans, often nesting over areas of high human activity. Colony size varied between two

<sup>1</sup> Received 21 November 1988. Final acceptance 18 May 1989.

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TABLE 1. Nest-tree and habitat parameters measured in residential areas during 1986.

Character	n	$\bar{x}$	SD	Range
Nest tree				
Age (years)	61	57.1	18.1	28-110
Height (m)	65	23.3	2.9	17.5-28.0
First limb height (m)	65	13.6	4.1	7.0-23.0
Canopy depth (m) <sup>a</sup>	65	9.8	2.8	4.0-15.0
Diameter at breast height (cm)	65	48.4	9.4	30.5-65.0
Nest height (m)	65	15.2	3.7	7.5-23.0
Nest position (%) <sup>b</sup>	65	15.6	14.5	0-54.0
Habitat				
Tree density (tree/ha)	65	305.0	100.1	140-479
Pine density (tree/ha)	65	202.0	96.7	25-404
Canopy closure (%)	65	62.8	15.0	40-90
Subcanopy cover (%)	65	26.3	17.7	10-80
Shrub cover (%)	65	21.5	19.9	0-90
Distance to water (m)	65	307.0	329.9	20-1,100

<sup>a</sup> Calculated as tree height - first limb height.

<sup>b</sup> Calculated as nest height - first limb height/canopy depth  $\times$  100.

and 15 pairs ( $\bar{x} = 4.2 \pm 2.72$  SD) with 25.3% of pairs nesting singly. Few trees were occupied by more than one pair. Trees containing single occupants represented 82.1% of all nesting attempts while nest trees containing two and three occupants represented only 13.2% and 4.7%, respectively.

Nests were located in seven different tree species. Over 95% were found in loblolly pines with 1.5% in red oaks (*Quercus rubra*), 0.8% in black oaks (*Q. velutina*), 0.8% in hackberry (*Celtis occidentalis*), 0.4% in red maple (*Acer rubrum*), 0.4% in pignut hickory (*Carya glabra*), and 0.4% in sweet gum (*Liquidambar styraciflua*). Hardwoods accounted for only 4.3% of all trees used for nesting. Though hardwood trees were not counted on any scale larger than the sample plot, they appeared to be at least as common as pines locally. Pairs nesting in extensive hardwood stands with small, scattered pockets of loblolly pines would nest in available pines. Herons were found most frequently in stands which were 40-70 years old, and had been nesting there less than 15 years (pers. comm. with residents). Nest trees greater than 70 years old had been used longer than 15 years and were typically remnant pine pockets in tree stands dominated by hardwoods.

Factor analysis defined four vegetative components which describe Yellow-crowned Night-Heron nest sites: tree structure, stand density, nest position, and understory openness (Table 2). These four components represented 85.0% of the variation in the data. The other nine components derived were omitted from the VARIMAX rotation because the individual eigenvalues were less than 1.0 (Stevens 1986).

The first principal factor was termed tree structure because the characters with highest loadings were tree height, first limb height, nest height, and tree age. The first three of these characters seemed to describe tree form which was dependent on the last character, tree age. The second axis was termed stand density because both pine and total tree density were best correlated with this component. The axis could also have been termed concealment or canopy closure since stand den-

sity directly determined canopy cover, the remaining character which showed a high correlation coefficient. Crown depth, nest position, and first limb height loaded the highest on the third component. This component was termed nest position because nest position varied directly with first limb height and crown depth. The fourth component was termed understory openness because both subcanopy cover and shrub cover described the amount of vegetation below the canopy level.

The nest position value indicated the location of the nest within the available area of the crown. Preference for a particular zone was examined by comparing the observed vertical distribution of nests to that expected by random. The vertical crown area was divided into six equal zones by percentage. Though the expected nest distribution was not weighted according to an idealized crown geometry, it is thought that the use of equal zones provided a conservative test for vertical preference since actual limb density increased dramatically in the upper areas of the crown. The frequency of nest positions in each of the zones is shown in Figure 1. A significant difference between the observed and expected nest positions ( $P < 0.001$ ,  $G$ -test) suggested that yellow-crowns selectively nest on the lower edge of the canopy. This finding was supported by the placement of nests on lower limbs. Nests were placed on the lowest tree limb with a frequency of 26.2%, on the second lowest limb with a frequency of 40.0%, and on limbs above the second with a frequency of only 33.8%.

The progressive loss of lower limbs with tree age in loblolly pines caused a directional reduction in canopy depth. A significant negative correlation between canopy depth and tree age was evident in the nest trees sampled ( $r^2 = -0.37$ ,  $P < 0.004$ ). This pattern was coupled with a positive relationship between the nest position value and canopy depth ( $r^2 = 0.44$ ,  $P < 0.001$ ). This suggests that Yellow-crowned Night-Herons may select or reject nest sites based on a minimum canopy cover criterion. If this is the case, old pine stands may

TABLE 2. Character loadings on the first four principal factors after VARIMAX rotation of the factor matrix.

Character	Factors*			
	I	II	III	IV
Tree age	0.63	-0.23	-0.09	-0.07
Tree height	0.92	-0.11	0.14	-0.17
First limb height	0.85	0.09	-0.52	0.00
Canopy depth	-0.29	-0.24	0.88	-0.17
Diameter at breast height	0.00	-0.07	0.45	0.10
Nest height	0.90	0.24	-0.25	0.08
Nest position	-0.12	0.37	0.57	0.19
Tree density	-0.04	0.84	-0.11	-0.01
Pine density	-0.15	0.71	-0.01	-0.37
Canopy closure	0.09	0.60	-0.02	-0.01
Subcanopy cover	-0.11	-0.12	0.06	0.72
Shrub cover	0.05	0.04	0.06	0.67
Distance to water	0.46	0.30	-0.05	-0.55
Eigenvalue	3.69	2.11	1.42	1.11
Cumulative percent of total variance	37.6	59.2	73.7	85.0

\* Factors are interpreted to be tree structure (I), stand density (II), nest position (III), and understory openness (IV).

not be used because of their lack of adequate canopy cover.

#### DISCUSSION

Yellow-crowned Night-Herons in different geographic areas are known to utilize a variety of substrates for nesting. Pairs nesting on islands or in estuaries nest in available shrubs with nest height being reflective of vegetation height (McVaugh 1975, Bagley and Grau 1979). Nests described in swamp lands are often low in the understory vegetation and may overhang water (Sprunt 1954, Wischusen 1979, Drennen et al. 1982). Most nests found on upland drainages are high in pines (Wayne 1906) or hardwood trees (Price 1946, Sutton 1967). Though it is difficult to make comparisons with the few nests described, the nesting situations in this study were most consistent with those reported from upland drainages which were inland from the coast. The near exclusive use of pines had not been documented in other geographic areas and may reflect selective events which are specific to the Chesapeake Bay area.

Two previous studies have examined nest-site characteristics for other wading bird species. McCrimmon (1978) used principal component analysis to describe and compare nest-site characteristics of five waders in North Carolina (including Great Egret *Casmerodius albus*, Snowy Egret *Egretta thula*, Cattle Egret *Bubulcus ibis*, Tricolored Heron *E. tricolor*, and Little Blue Heron *E. caerulea*). He found that four components (vegetation structure, accessibility, protection, and shrub/tree-center distance) accounted for 69% of the variation. Beaver et al. (1980) used factor analysis to describe the nest sites of seven waders (including Great Egret, Snowy Egret, Cattle Egret, Tricolored Heron, Little Blue Heron, Black-crowned Night-Heron *N. nycticorax*, and Glossy Ibis *Plegadis falcinellus*) in different colonies along the Atlantic coast. They found that vegetation size and nest stability were the two factors explaining most (55.2%) of the variation in data.

Vegetation height, nest height, and vegetation over

the nest (termed nest position here) were the only characters measured in all three studies. Nest and vegetation height loaded highly on the first component in all three studies. By examining these two variables between colonies, Beaver et al. (1980) showed that the species-colony means tended to group by colony rather than by species, suggesting that these were not reliable species characteristics. The amount of vegetation over the nest or "nest openness" also loaded highly in all three studies. Though this character reflects the structure of the vegetation available, it appears to vary between species (McCrimmon 1978) and seems important in nest-site selection for Yellow-crowned Night-Herons.

Burger (1978) and Beaver et al. (1980) have suggested that vegetation over the nest serves to shade young in the summer months when direct exposure to the sun may cause severe thermal stress. This hypothesis implies that nest positions are selected based on characteristics which will be beneficial during the brooding period. The low nest position values observed

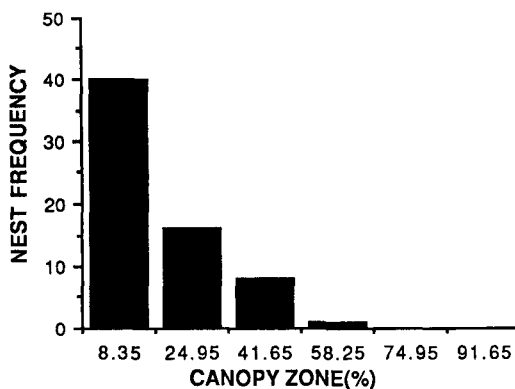


FIGURE 1. Frequency distribution of nest positions in six vertical canopy zones.

in the present study support this hypothesis, since nesting low in the canopy would provide the maximum amount of shading by the tree foliage.

Overhanging vegetation may also act as a visual screen to aerial predators (Burger 1978), making nests more difficult to locate. Crows were shown to be the only significant aerial predators of yellow-crown nests in residential areas of the lower bay, causing 75.6% of all clutch losses, but were never known to take young (Darden, unpubl. data). This suggests that the choice of nesting sites with the best screening properties would be most beneficial during the incubation period when attacks from aerial predators are most likely to occur. The low nest position values observed support this hypothesis also, since nesting low in the canopy would ensure the greatest visual obstruction to predators passing above the crown.

Yellow-crowned Night-Herons begin to return to nesting sites along the Chesapeake Bay in mid- to late March (Darden, unpubl. data). By mid- to late April most breeding pairs have complete clutches and incubation of those clutches continues until late May. During these early stages of nesting (including nest-site selection and incubation) most deciduous trees are devoid of leaves. The majority of young hatch in late May or early June and pre fledging young may be present in nests until as late as early August. By early June, leaf expansion is nearly complete in deciduous trees along the lower bay. If the principal selective advantage of nesting low in the canopy is to provide shade for young, then one would expect yellow-crowns to nest more frequently in large deciduous trees. Large deciduous trees have a complete canopy by the time the majority of young hatch and certainly before the heat of the summer arrives. Because these trees transpire a greater volume of water than pines, and give more complete shading, they would likely provide a cooler environment. However, 95.7% of all trees used for nesting between 1986 and 1987 were loblolly pines.

I suggest that the primary selective advantage for nesting in loblolly pines is the reduction of clutch losses to crows (*Corvus brachyrhynchos* and *C. ossifragus*). The timing of clutch initiation relative to the phenology of foliage indicates that pairs nesting in deciduous trees would be very susceptible to location by crows during the incubation period. Clearly, these hypotheses are not mutually exclusive. Nesting in trees with greater canopy depth surrounded by other trees would also increase shading. However, observations of pairs standing over their brood and wing shading them for hours during hot days suggests that loblollies do not provide adequate shade from the sun.

Many authors have noted that unlike most other ardeids, yellow-crowns nest in unusually small colonies (Bent 1926, Imhoff 1962, Palmer 1962, Sutton 1967, Hancock and Kushlan 1984). Others (Wischusen 1979, Drennen et al. 1982) have reported that two pairs rarely occupy the same nest tree. These observations were supported by the data presented here. Of 46 colonies observed over the 2-year period, the mean colony size was only 4.2 pairs. Also, over 82% of all nesting attempts were by pairs occupying exclusive nest trees. It seems unlikely that the use of separate nest trees reflect some minimum individual distance, since the distance between nests in adjacent trees was often times less

than what could be achieved by nesting at opposite sides of the same tree. It is possible that the use of separate trees is the result of selective pressure exerted by mammalian predators. Raccoons and opossums were responsible for 18.5% of all clutch losses and 38.0% of all young losses reported in residential areas (Darden, unpubl. data). Unlike aerial predators which may easily move from tree to tree, most mammalian predators must return to the ground to locate and exploit each nest tree individually.

I thank all of those residents who provided information and allowed free access to their property. This study was supported by the Nongame Program of the Virginia Department of Game and Inland Fisheries. Dana Bradshaw, Don McCrimmon, and Michael Gochfield provided helpful comments on earlier drafts of this manuscript.

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*The Condor* 91:983-985  
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## OVERNIGHT MASS LOSS BY WINTERING VERDINS<sup>1</sup>

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*Key words: Body mass; roosting; energetics; body composition; fat; Remizidae.*

For small birds in extreme environments, the accumulation of sufficient energy reserves for overnight survival is a primary aim of daytime activity (King 1972, Chaplin 1974, Blem 1976). During the winter when thermoregulatory demands are greatest and food resources often scarce, the survival of small passerines may depend on continuous foraging and coincidental lipid storage throughout the day (Blem and Pagels 1984). In birds weighing <40 g, stored energy often provides less than two times the estimated overnight caloric requirements (Blem 1976). This small capacity for storage provides only a very limited reserve for metabolic maintenance during periods when food is not accessible or when the weather prohibits foraging.

Circadian cycles of body mass, recorded primarily from captive birds, have been reported for several avian species (reviewed by Lehikoinen 1987). These weight changes are often correlated with daily rhythms of body fat content (Blem 1976, Blem and Pagels 1984). Estimates of energy utilization may therefore be made from mass loss of fasting birds if appropriate assumptions are made regarding body composition (Helms 1963). Errors associated with assumptions of the caloric content of lost mass may be significant, however, since body components other than fat affect the daily mass cycle (King 1972, Dolnik and Gavrilov 1979). Estimates of caloric reserve utilization from mass changes must therefore be accompanied by "tedious qualifications and uncertainties" (King 1972) such as those

in this paper. Nevertheless, the close correspondence between diurnal cycles of wintertime fat content and body mass in small insectivorous birds (Chaplin 1974, Blem and Pagels 1984) prompted the present study.

To estimate the energy cost of roosting, I measured overnight changes in body mass of free-living Verdins (*Auriparus flaviceps*) wintering in the Colorado Desert of southern California. Verdins are very small (ca. 6.5 g) and highly active insectivores; such a species might represent an extreme for daily cycles of energy storage among passerine birds.

### STUDY AREA AND METHODS

I studied Verdins between December and February 1986-1988 at the Living Desert Reserve, an arboretum and nature preserve near Palm Desert, Riverside County, California. The habitat preferred by Verdins in this area is typical of Colorado Desert alluvial washes, with coarse-grained sandy soil supporting a diverse plant community dominated by palo verde (*Cercidium floridum*), smoketree (*Dalea spinosa*), and cheesebush (*Hydrocotyle salsosa*).

Verdins were captured by hand from their winter roost nests (Buttner et al. 1987) or mist-netted as they left the roost. I caught birds just before the start of their normal active period (mean time = 06:30, range = 06:05-07:05) and about 1 hr after they entered the roost in late afternoon (mean time = 17:14, range = 16:10-18:10). Within 5 min of capture, I weighed the birds to the nearest 0.05 g using a K-Tron DS-10 portable electronic balance. Individual birds were weighed only once during the study; none had previously been disturbed. The birds were released after I banded them with unique color-band combinations to distinguish individuals. I sexed the birds by comparative intensity of the yellow head (males showed brighter, more extensive color) and by observing subsequent behavior (male singing; Taylor 1967). Dissections of Verdins killed in the course of other studies confirmed my sex determinations in 11 of 13 cases.

<sup>1</sup> Received 19 December 1988. Final acceptance 18 May 1989.

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