NONBREEDING BALD EAGLE COMMUNAL AND SOLITARY ROOSTING BEHAVIOR AND ROOST HABITAT ON THE NORTHERN CHESAPEAKE BAY

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Abstract: We studied roosting behavior and habitat use of nonbreeding bald eagles (*Haliaeetus leucocephalus*) on the northern Chesapeake Bay during 1986–89. In summer and winter, 11 and 13 communal roosts, respectively, and many solitary roosts were used simultaneously in the 3,426-km^2 study area. Radio-tagged eagles roosted solitarily with differing frequency by season (60, 21, 39, and 44% of 81 eagle nights in summer, fall, winter, and spring, respectively) ($P < 0.05$). Roost trees, predominantly oaks (*Quercus* spp.) or yellow poplars (*Liriodendron tulipifera*), were larger in diameter and provided greater canopy cover than random trees ($P < 0.05$). Roost sites had snags present more often than did random sites ($P < 0.01$). Most roosts (86%) were in woodlots >40 ha, and none were in human-developed habitat. In contrast, only 23% of random sites were in woodlots >40 ha, and 9% were in developed areas. Roosts were farther from human development than were random sites ($P < 0.05$); 57% of the roosts were found on public lands, compared to only 20% of the random sites ($P < 0.001$). Winter roost sites were protected from prevailing northerly winds more often than were summer sites ($P < 0.05$). We prescribe a 1,360-m-wide shoreline management zone that extends 1,400 m inland to encompass roost sites and provide a buffer from human disturbance.

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Communal roosting and roosting habitat of wintering bald eagles have been described in detail, and strategies for managing winter communal roosts have been developed (e.g., Stalmaster 1980, Steenhof et al. 1980, Anthony et al. 1982, Keister and Anthony 1983). In contrast, we are aware of only a single study of summer communal roosting (Chester et al. 1990). Reports of bald eagles roosting alone are anecdotal and lack detailed habitat descriptions (Southern 1963, Steenhof et al. 1980). Moreover, there are no published estimates of the relative frequency of communal versus solitary roosting.

Management strategies for wintering eagles have focused on protecting communal roost habitat (Steenhof 1978, Stalmaster 1980, Stalmaster and Gessaman 1984). Other areas of shoreline habitat on the Chesapeake Bay are being rapidly lost to development (Gray et al. 1988). If solitary roosting in winter is commonplace, then losses of shoreline habitat may limit eagle populations in some areas. The first step in determining whether solitary roosting habitat is limiting is to describe that habitat, determine the frequency with which it is used, and determine its abundance in areas eagles use.

Habitat requirements of roosting eagles also need to be described for the remainder of the year to determine whether habitat use changes seasonally and to determine if availability of roost habitat is limiting distribution in seasons other than winter. In our study, we used radio telemetry to estimate the frequency of solitary versus communal roosting by nonbreeding eagles. We tested the hypothesis that habitat characteristics differed among summer communal, winter communal, summer solitary, and winter solitary roosts. We also tested the hypothesis that roost habitat differed from habitat available at random on the northern Chesapeake Bay.

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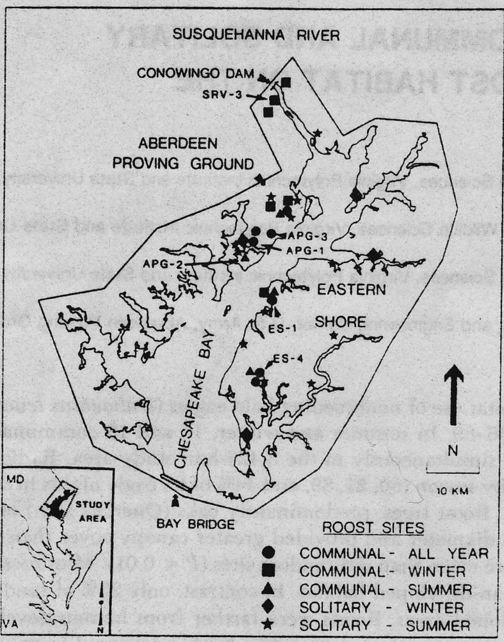

Fig. 1. Bald eagle roost sites, northern Chesapeake Bay, Maryland, 1986–89.

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STUDY AREA

The study area extended along the Chesapeake Bay from the Bay Bridge at Annapolis, Maryland to the Conowingo Dam on the Susquehanna River, encompassing 3,426 km² (Fig. 1). The area included 2,472 km of bay, river, and creek shoreline and extended inland to the head of all major tributaries except the Susquehanna and Chester rivers. It also included part of the Baltimore metropolitan area and the U.S. Army Aberdeen Proving Ground, a 350-km² military installation. Habitat on the study area included a largely urban-suburban setting near Baltimore, coastal lowland oak-gum (*Quercus* spp.–*Liquidambar styraciflua*) forests on the Aberdeen Proving Ground, agricultural fields with scattered oak-gum woodlots on the Eastern Shore, and upland and lowland oak-gum-hickory (*Carya* spp.) forests along the Susquehanna River valley.

METHODS

Eagle Roost Use

We located roost sites by following radio-tagged eagles until they roosted in the evening. We used floating noose-fish (Cain and Hodges 1989) and padded leghold traps (Young 1983) during 1984–88 to trap 34 eagles (32 immatures and 2 ad) at Aberdeen Proving Ground, Susquehanna River, and Eastern Shore trap sites. We sampled birds hatched in the northern Chesapeake region by radiotagging 39 nestlings at 8–10 weeks of age in nests dispersed throughout the study area during 1984–88.

Eagles were equipped with 65-g radio transmitters that had solar-charged nickel-cadmium batteries (Telemetry Systems, Inc., Mequon, Wis.) and an expected life of 4–5 years. We mounted radios dorsally on the eagles with a 1-cm-wide teflon ribbon harness (Bally Ribbon Mills, Bally, Pa.).

Twice weekly during the day from June 1988 to May 1989, we located all radio-tagged eagles on the study area from fixed-wing aircraft. Using a random-numbers table, we assigned random numbers to all eagles located on a particular day. We selected the eagle with the lowest random number and tracked it with a hand-held, 3-element, Yagi antenna to its roost in the evening by vehicle, boat, or on foot.

We classed each roost site as communal (>1 eagle obs roosting on at least 1 occasion) or solitary (communal roosting never obs). We classified communal roosts as communal-winter (primary use in winter) or communal-summer (primary use in summer) and solitary roosts as solitary-winter (use in Nov–Apr) or solitary-summer (use in May–Oct). These periods coincided with the major shifts in roosts used by eagles on the study area (Fig. 2).

One or 2 observers counted eagles at communal roosts during 1986–89 from parked vehicles or blinds. Counts began 2 hours before dark and ended at dark. We took panoramic photos of each roost and recorded on enlarged

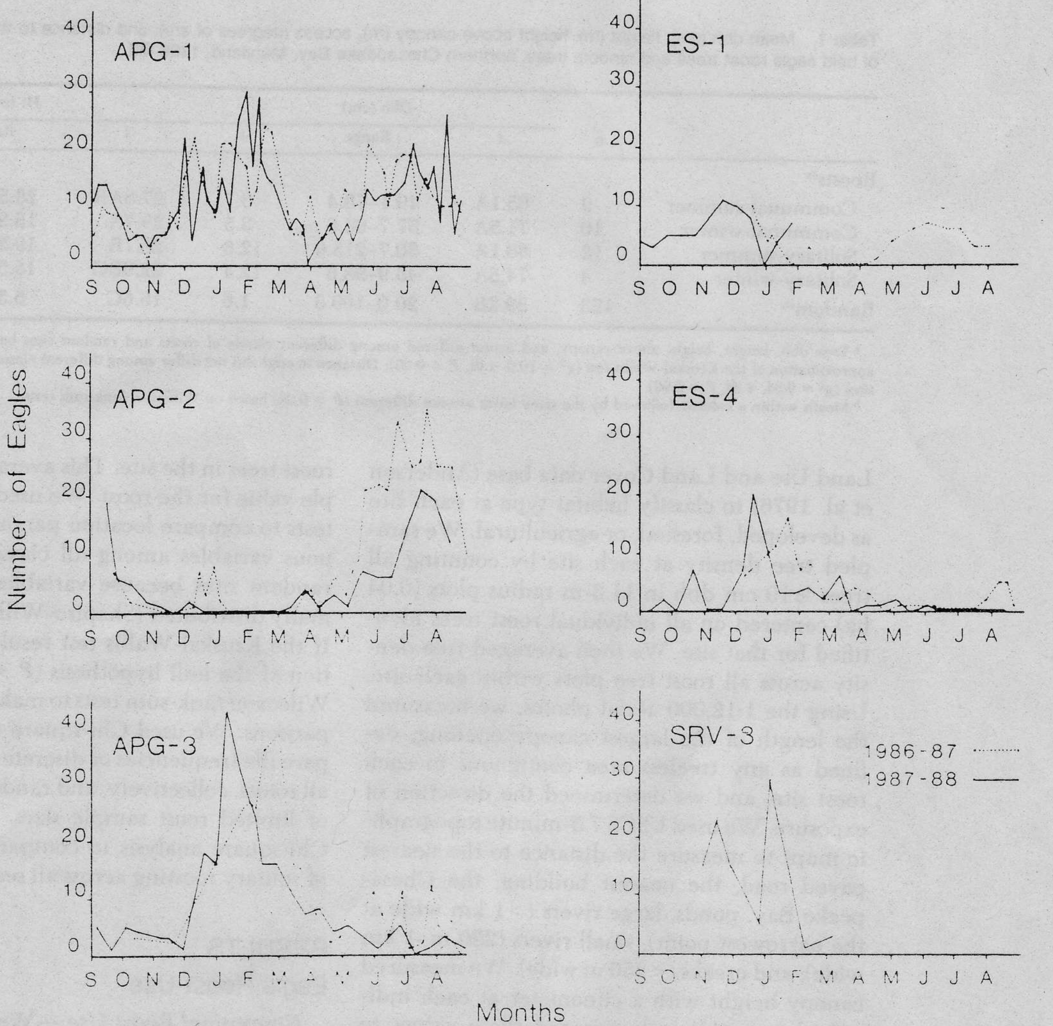

Fig. 2. Bald eagle counts at communal roosts, northern Chesapeake Bay, Maryland, 1986–89, by geographic area (APG = Aberdeen Proving Ground, ES = Eastern Shore, and SRV = Susquehanna River valley).

photos the roost tree used by each eagle. Counts were conducted twice monthly at communal sites in use, but only monthly after use during a season stopped.

Roost Tree Characteristics

For each roost tree observed, we recorded species, diameter at breast height (dbh), and height (measured by clinometer). We estimated tree accessibility as the total arc (0–360°) that was unobstructed by other tree canopies for a distance of 10 m out from the trunk and 3 m below the tree's crown. We measured percent canopy cover with a densiometer (Lemmon 1956) at 4 randomly selected points 5.6 m from the roost tree trunk. We averaged these 4 readings to get percent canopy cover for the entire tree. We classed roost trees as alive, dead, or dead topped. We measured the distance from the tree to the nearest habitat edge, defined as the intersection of forest, aquatic, human-developed, or agricultural-field habitats.

Roost Site Characteristics

To characterize roost habitat, we defined a communal roost site as the area enclosed by a minimum convex polygon formed by connecting all perimeter roost trees. We measured roost size on 1:12,000 color aerial photos taken in 1985. For solitary roosts (single trees), a site was a 0.04-ha circle centered on the roost tree.

We used the U.S. Geological Survey (USGS)

Table 1. Mean dbh (cm), height (m), height above canopy (m), access (degrees of arc), and distance to the nearest edge (m) of bald eagle roost trees and random trees, northern Chesapeake Bay, Maryland, 1986–89.

		Dbh (cm)			Ht (m)		
	n	$\bar{x}$	Range	SE	$\bar{x}$	Range	SE
Roosts[a,b]							
Communal-summer	9	65.1A	49.1–78.4	3.7	27.8AB	23.5–34.4	1.2
Communal-winter	10	71.5A	57.7–93.6	3.5	29.7A	16.8–36.9	1.7
Solitary-summer	12	83.1A	50.7–215.0	12.6	26.7B	19.2–42.1	1.7
Solitary-winter	4	74.8A	45.9–98.6	12.4	22.0BC	15.5–27.4	2.5
Random[a,b]	123	39.2B	20.0–109.3	1.6	16.6C	5.5–29.3	0.5

[a] Tree dbh, height, height above canopy, and access differed among different classes of roosts and random sites based on the Chi-square approximation of the Kruskal-Wallis test ($\chi^2 > 10.0$, 4 df, $P < 0.05$). Distance to edge did not differ among different classes of roosts and random sites ($\chi^2 = 0.34$, 4 df, $P = 0.99$).

[b] Means within a column followed by the same letter are not different ($P > 0.05$) based on Wilcoxon rank-sum tests.

Land Use and Land Cover data base (Anderson et al. 1976) to classify habitat type at each site as developed, forested, or agricultural. We sampled tree density at each site by counting all trees ≥10 cm dbh in 11.3-m radius plots (0.04 ha) centered on all individual roost trees identified for that site. We then averaged tree density across all roost tree plots within each site. Using the 1:12,000 aerial photos, we measured the length of the largest canopy opening, defined as any treeless area contiguous to each roost site, and we determined the direction of exposure. We used USGS 7.5-minute topographic maps to measure the distance to the nearest paved road, the nearest building, the Chesapeake Bay, ponds, large rivers (>1 km wide at the narrowest point), small rivers (250 m–1 km wide), and creeks (<250 m wide). We measured canopy height with a clinometer at each individual tree plot and averaged these values to estimate canopy height of the entire site.

We overlayed a 1- × 1-m grid on the study area and developed a coordinate system along north–south (x) and east–west (y) axes of the grid. Using a random-numbers table, we selected 200 x and y coordinate combinations to locate random points, 123 of which fell in non-aquatic habitat. We used these points for comparison with roost trees and roost sites. We chose the tree ≥20 cm dbh closest to each random point and measured the same characteristics that we measured on roost trees. Within a 0.04-ha circle centered on the random tree, we also measured the same characteristics measured at each roost site.

We considered each roost a sampling unit because we did not consider individual trees within a roost site to be independent. We averaged continuous roost tree variables for all roost trees in the site. This average was the sample value for the roost. We used Kruskal-Wallis tests to compare location parameters of continuous variables among all classes of roosts and random sites because variables were not normally distributed (Shapiro-Wilk test, $P < 0.05$). If the Kruskal-Wallis test resulted in the rejection of the null hypothesis ($P < 0.05$), we used Wilcoxon rank-sum tests to make pair-wise comparisons. We used Chi-square analyses to compare the frequencies of discrete variables among all roosts, collectively, and random sites, because of limited roost sample sizes. We also used a Chi-square analysis to compare the frequency of solitary roosting across all seasons of the year.

RESULTS

Eagle Roost Use

Communal Roost Use.—We located 11 communal-summer roosts, 13 communal-winter roosts, and 16 solitary roosts during 1986–89. Communal-summer and communal-winter roosts were clumped in 3 general locations: Aberdeen Proving Ground (n = 12), the Eastern Shore (n = 9), and the Susquehanna River valley below the Conowingo Dam (n = 3) (Fig. 1). Seven communal roosts were used during winter and summer, 6 were used solely in winter, and 4 solely in summer.

We tallied 3,481 eagles at 17 communal sites during 444 observations ($\bar{x}$ = 7.84 eagles/count, range = 0–43 eagles/count) and recorded eagle age in 3,149 cases. Counts included 843 adults (26.8%), 144 subadults (4.6%), and 2,162 immatures and juveniles (68.7%).

Roost APG-1 was used all year and served more eagles than any other roost ($\bar{x}$ = 12.3 eagles/count, n = 132, range = 0–30) (Fig. 2).

Table 1. Extended.

Ht above canopy (m)			Access (degrees)			Distance to edge (m)		
$\bar{x}$	Range	SE	$\bar{x}$	Range	SE	$\bar{x}$	Range	SE
5.7A	−0.6–9.1	1.0	294A	208–360	17.7	31	0–130	16
0.5B	−7.0–7.3	1.3	232B	135–360	22.4	13	0–50	6
7.1A	0.0–26.8	2.2	298A	150–360	20.5	23	0–100	10
3.3AB	0.9–7.6	1.5	258AB	160–350	50.7	13	0–30	8
1.2B	−15.8–28.3	0.5	194B	0–360	12.2	33	0–680	7

Roost ES-1 also was used about equally in winter and summer. Eight roosts were used primarily during winter, and 4 roosts were used primarily in summer. All 3 roosts in the Susquehanna River valley were most used in fall and winter (Fig. 2).

Roost use peaked in winter coincident with the presence of northern migrants and again in summer coincident with the presence of southern migrants and most of the northern Chesapeake resident eagles (Fig. 2) (Buehler et al. 1991*a*). Roost use in the Susquehanna River valley coincided with peaks in eagle use below Conowingo Dam in the late fall and early winter.

Solitary Roost Use.—Radio-tracked eagles roosted alone on 15 of 25 nights (60.0%) in the summer, only 5 of 24 nights (20.8%) in the fall, 9 of 23 nights (39.1%) in the winter, and 4 of 9 nights (44.4%) in the spring (n = 81, χ^2 = 7.86, 3 df, $P < 0.05$). In general, solitary sites were more widely dispersed than communal sites, especially on the Eastern Shore (Fig. 1).

Roost Tree Characteristics

We identified 117 roost trees at communal roosts: 44 trees were used only in the summer, 57 were used only in the winter, and 16 were used during both seasons. No roost trees were identified where communal roosting occurred infrequently (2 communal-summer and 3 communal-winter sites). We identified 16 solitary roost trees, including 12 used during the summer period and 4 in the winter period.

All roost tree classes (communal-summer, communal-winter, solitary-summer, solitary-winter) were much larger in dbh than were random trees, and roost trees in communal-summer, communal-winter, and solitary-summer roosts were taller than random trees ($P < 0.01$ and $P < 0.001$, respectively) (Table 1). Communal-summer and solitary-summer roost trees were more accessible in terms of height above canopy and access arc than were communal-winter trees and random trees ($P \leq 0.05$) (Table 1). Only 1 of 123 random trees (0.8%) surpassed the minimum measurements of communal-summer roost trees, and only 2 of 123 random trees (1.6%) surpassed the minima for the communal-winter trees.

Roost Site Characteristics

Communal-winter roosts were found in stands with greater canopy heights than were communal-summer roosts ($P < 0.05$) (Table 2), and both were found in stands with greater canopy heights than were random sites ($P < 0.001$ and $P < 0.05$, respectively). All classes of roost trees had more canopy cover than did random trees ($P < 0.05$). Snags occurred more often at roost sites than at random sites ($P < 0.01$) (Table 2). Oaks and yellow poplars were used most frequently at 23 of 35 roost sites (65.7%) but occurred most frequently at only 15.5% of random sites (χ^2 = 37.04, 2 df, $P < 0.001$).

Communal-winter, solitary-summer, and solitary-winter roosts were closer to water than were random sites ($P < 0.01$), whereas communal-summer roosts were closer to the Chesapeake Bay than were random sites ($P < 0.001$) (Table 3, Fig. 3). There were no differences among sites in the distance to large and small rivers, creeks, and ponds. All roost classes were farther from paved roads and buildings than were random sites ($P < 0.05$). Building density was much greater within 500 m of random sites than within 500 m of roosts ($P < 0.01$). Of the roosts in our study, 95% were within 720 m of the water, and 50% were at least 680 m from the nearest building.

Eagles selected forested sites for roosting in almost all cases, far more than availability as

Table 2. Mean canopy height (m), canopy cover (%), tree density (trees/ha), and presence of snags (% of sites) of bald eagle roost sites and random sites on the northern Chesapeake Bay, Maryland, 1986–89.

		Canopy ht (m)			Canopy cover (%)		
	n	$\bar{x}$	Range	SE	$\bar{x}$	Range	SE
Roosts[a,b]							
Communal-summer	9	22.2A	14.6–35.1	2.1	61.3A	26.9–100.0	6.5
Communal-winter	10	29.3B	23.8–36.6	1.4	68.4A	34.6–96.2	5.5
Solitary-summer	12	19.7AC	9.1–29.0	1.6	69.3A	5.8–98.3	9.0
Solitary-winter	4	18.7AC	7.9–25.9	3.9	73.9A	48.3–90.1	9.0
Random	123	15.4C	0.0–29.0	0.7	37.5B	0.0–100.0	3.0

[a] Canopy height, canopy cover, and snags present differed among different classes of roosts and random sites based on the Chi-square approximation of the Kruskal-Wallis test ($\chi^2 > 21.5$, 4 df, $P < 0.001$). Trees per ha did not differ among different classes of roosts and random sites ($\chi^2 = 8.21$, 4 df, $P = 0.08$).

[b] Means within columns followed by the same letter are not different ($P > 0.05$) based on Wilcoxon rank-sum tests.

measured by random sites ($\chi^2 = 25.74$, 2 df, $P < 0.001$). Eagles never selected sites associated with human-developed habitats, whereas 8.9% of random sites were developed based on the USGS classification. All but 3 solitary roosts occurred in woodlots ≥43 ha ($\bar{x}$ = 800 ha), and all but 2 communal sites were in woodlots ≥110 ha ($\bar{x}$ = 1,543 ha) (Fig. 4), whereas 48% of all woodlots on the study area were <43 ha in size. All Aberdeen Proving Ground roosts, except APG-2, occurred in the same 5,068-ha forest; the second largest forest on the study area. Of 35 roost sites, 20 (57.1%) were on public land whereas only 25 of 123 random sites (20.3%) were on public land ($\chi^2 = 18.13$, 1 df, $P < 0.001$). Six of 15 remaining roosts (40%) occurred on private land on 2 large corporate farms, one (Remington Farms) that is managed specifically for wildlife.

Communal-summer and communal-winter roosts had smaller openings adjacent to the site than did solitary-summer and solitary-winter sites ($\bar{x}$ = 660, 681, 3,509, and 4,758 m, respectively, $P < 0.01$). Thirteen of 14 winter roosts (communal and solitary, 92.9%) were protected from prevailing northerly winds, whereas only 12 of 21 summer sites (communal and solitary, 57.1%) were protected from northerly winds ($\chi^2 = 5.25$, 1 df, $P = 0.02$). Winter roosts did not differ from summer roosts with respect to exposure to prevailing southerly winds ($P = 0.78$). Communal-summer and communal-winter sites averaged 1.00 and 0.39 ha, respectively ($P = 0.65$).

DISCUSSION

The primary differences between summer and winter roost trees were that summer trees had greater access and protruded above the canopy. The key difference between summer and winter roost sites was that summer sites were exposed in the northerly direction. These differences might be related to selection in winter for more wind protection. Buehler et al. (1991*b*) reported

Table 3. Mean distances (km) from bald eagle roost sites and random sites to aquatic and human features, northern Chesapeake Bay, Maryland, 1986–89.

		Closest water		Distance to bay		Distance to large river		Distance to small river	
	n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Roosts[a,b]									
Communal-summer	9	0.33AB	0.09	2.13A	0.30	7.21	1.29	2.82	0.49
Communal-winter	10	0.16A	0.07	5.34AB	1.67	5.71	1.32	6.01	1.77
Solitary-summer	12	0.19A	0.08	5.30AB	1.31	6.25	1.36	2.00	0.50
Solitary-winter	4	0.04A	0.04	3.98AB	1.82	1.22	0.22	1.18	0.62
Random[a,b]	123	0.59B	0.06	8.22B	0.52	4.83	0.40	2.79	0.20

[a] The closest water, distance to bay, distance to road, distance to building, and buildings within 500 m differed among different classes of roosts and random sites based on the Chi-square approximation of the Kruskal-Wallis test ($\chi^2 > 17.2$, 4 df, $P < 0.001$). The distance to large and small rivers, creeks, and ponds are not different among different classes of roosts and random sites (χ^2 = 8.9, 8.3, 3.7, 8.7; 4 df; P = 0.06, 0.08, 0.45, 0.07, respectively).

[b] Means within columns followed by the same letter are not different ($P > 0.05$) based on Wilcoxon rank-sum tests.

Table 2. Extended.

Trees/ha			Snags present (%)		
$\bar{x}$	Range	SE	$\bar{x}$	Range	SE
406	192–1,033	92.8	24.4A	11.4–75.0	6.5
307	156–513	34.0	13.3AB	0.0–30.0	2.8
460	156–1,625	113.0	10.2B	0.0–50.0	4.0
444	325–650	73.9	29.5AB	0.0–57.0	12.0
613	25–3,750	50.1	3.6C	0.0–67.0	0.8

that during winter a communal-summer site had significantly greater wind speeds than a communal-winter site, which is consistent with this interpretation.

Trees used for roosting were larger in diameter, taller, and more accessible than other trees available on the study area. These results are consistent with other studies on eagle nesting, roosting, and perching habitat (e.g., McEwan and Hirth 1979, Stalmaster and Newman 1979, Steenhof et al. 1980, Keister and Anthony 1983, Anthony and Isaacs 1989, Chester et al. 1990). Large trees may be selected because they aid in territorial advertising and defense, they can hold large nests, they are aerodynamically advantageous, or they allow exposure to wind which might reduce insect infestations (Fraser 1981). However, hypotheses to explain selection of large trees that apply only to 1 type of behavior (e.g., the importance of large trees for holding nests) are inadequate. Perhaps the most parsimonious explanation is that there are more suitable perching limbs in large trees, or that because of the large size and flight characteristics of eagles, they can only comfortably enter and exit trees with an open canopy structure (Herrick 1924, Gerrard et al. 1975, McEwan and Hirth 1979).

MANAGEMENT IMPLICATIONS

On >40% of eagle tracking nights, nonbreeding eagles roosted by themselves. Moreover, communal roosting occurred year-round, but only 41% of the sites were used in both summer and winter. Thus, if efforts to protect eagle roosting habitat are limited to protecting winter communal roosts, most roost sites will go unprotected.

Because roosts were near water and far from buildings, roost habitat could be preserved by protecting undeveloped shoreline forest stands that extend at least 1,400 m inland from the water's edge and encompass at least 1,360 m of shoreline edge (680-m buffers on both sides and inland from the site). This size (190 ha) slightly exceeds the minimum size of the forest stands that contained communal roosts (110 ha). Forest management within these stands should protect existing tall, large diameter trees and promote their growth in stands where they are lacking.

Table 3. Extended.

Distance to creek		Distance to pond		Distance to road		Distance to building		Buildings within 500 m	
$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
1.26	0.38	0.67	0.11	0.76A	0.18	1.21A	0.19	0.00A	0.00
0.98	0.34	0.61	0.12	0.74A	0.18	0.84AB	0.18	1.10AB	0.69
1.19	0.36	0.86	0.20	0.64A	0.14	0.70B	0.20	3.50B	2.07
0.63	0.37	0.53	0.27	0.60A	0.13	0.55B	0.12	0.50AB	0.50
1.38	0.11	1.34	0.10	0.27B	0.03	0.35C	0.04	16.7C	2.57

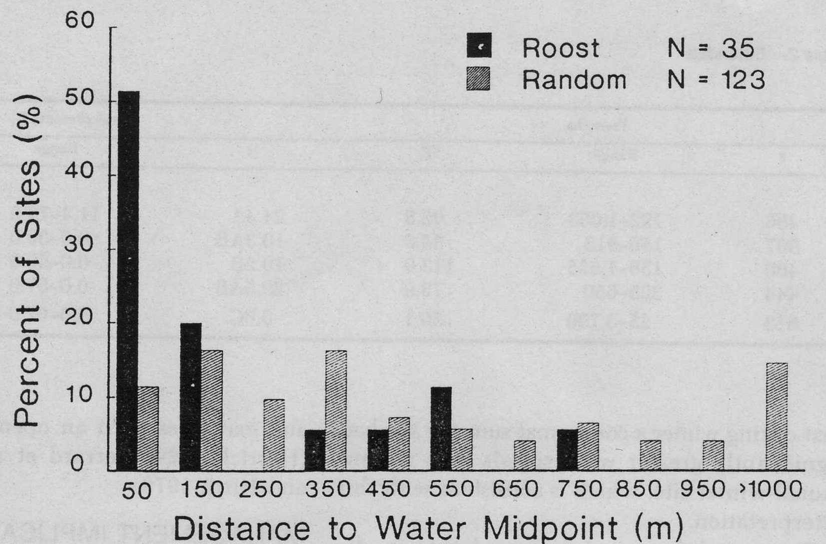

Fig. 3. Distance (m) to water (Chesapeake Bay, large rivers, small rivers, creeks, or ponds) from roost sites and random points, northern Chesapeake Bay, Maryland, 1986–89.

In addition to providing roosting habitat, such preserves could provide foraging, loafing, and nesting habitat.

We did not estimate the total number of suitable roost trees or roost sites on the northern Chesapeake, or the number of sites required to support a particular number of eagles. Consequently, we do not know whether roost habitat is limiting eagle distribution. However, fewer than 2% of the random trees met the minimum habitat values of roost trees, indicating that suitable roost trees are scarce relative to other trees. This relative scarcity suggests that if shoreline forest is removed indiscriminately, roost habitat could become limiting to the bald eagle population in the future.

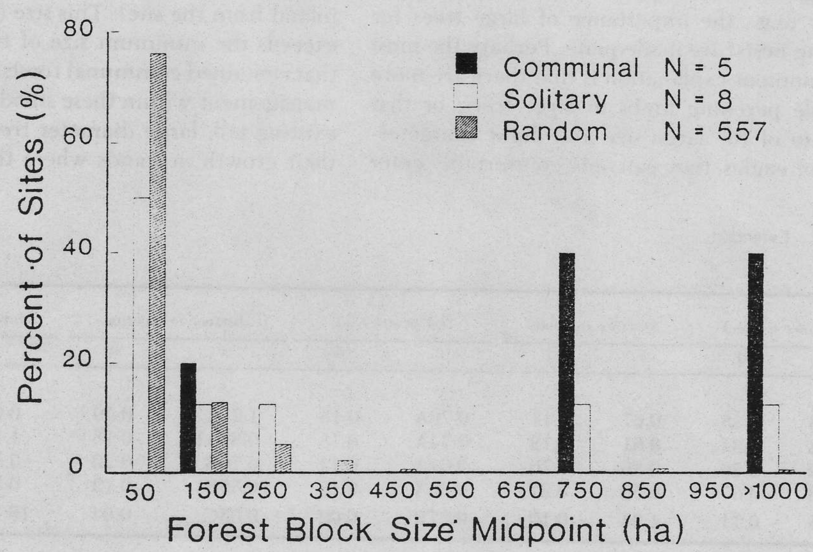

Fig. 4. Size (ha) of forest blocks in which communal roosts and solitary roosts were found, and forest block size of the northern Chesapeake Bay, Maryland 1986–89.

A substantial portion of the northern Chesapeake shoreline is already developed (Buehler et al. 1991*c*), and development pressure on the remaining shoreline is expected to be great (Gray et al. 1988). We recommend, therefore, that the adequacy and sustainability of the current roost habitat need to be evaluated.

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