BALD EAGLE HABITAT USE ON B. EVERETT JORDAN LAKE AND FALLS LAKE, NORTH CAROLINA

by

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(ABSTRACT)

I examined the roosting and perching habitat preferences of a nonbreeding population of bald eagles in North Carolina during 1986 and 1987. I characterized roosting habitat at 2 scales; those of forest stands and individual roost trees. Eagles chose roost areas that were less dense, had less canopy cover, were closer to forest edges, and had larger trees than random forest areas ($P < 0.05$). Within roost areas eagles choose trees that were larger (height and dbh) than random trees. Additionally, eagles roosting at the Morgan Creek roost preferred dead hardwoods close to the forest edge and eagles at the Mason Point roost preferred trees farther from a frequently used dirt road within the roost.

Suitable perch trees were the most important attribute of perching habitat. Eagles preferred loblolly pines and trees with leafless crowns ($P < 0.05$), which relates to their accessible crown structures. Perch trees were larger (height and dbh, $P < 0.05$) than adjacent trees along the shore. Eagles utilized the bottom of tree crowns during summer but used tree tops during fall and winter. I found no evidence that eagles selected perches in relation to forest stand characteristics within 20 m of perch trees, forest cover types in 1 ha blocks surrounding perches, or habitat disturbances.

Management recommendations include techniques to enhance bald eagle habitat on the study area. Primary emphasis should be toward managing for roosting habitat because of its apparent scarcity. Perch trees are plentiful but long term management is desirable. Future nesting seems likely and management techniques for potential nesting habitat are suggested.

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INTRODUCTION

The bald eagle (*Haliaeetus leucocephalus*) is the only fish eagle native to North America. Historically, bald eagles occurred throughout North America wherever suitable habitat was available. However, by the early 1900's human disturbance in the form of habitat destruction and persecution caused noticeable population declines (Maxon 1903, Cameron 1907, Sage et al. 1913, Roberts 1932, Howell 1937, 1941). Furthermore, Broley (1958) reported a decrease in bald eagle productivity that began during the 1940's. This low productivity was determined to be a result of environmental contaminants, particularly DDE, a metabolite of the organochlorine pesticide DDT ([dichlorodiphenyltrichloroethane] Hickey and Anderson 1968, Krantz et al. 1970, Grier 1982, Wiemeyer et al. 1984). Other contaminants thought to have impacts on bald eagle populations include the organochlorine insecticides endrin and dieldrin, mercury, and PCB's (polychlorinated biphenyl's), which are used as plasticizers and dielectric fluids (Green 1985).

Declines in many wildlife species related to human persecution during the late 1800's and early 1900's precipitated the emergence of the environmental movement, which in turn led to the passage of several important conservation laws that have enhanced the recovery of the bald eagle. These legislative actions include the Bald Eagle Protection Act, the Migratory Bird Conservation Act, and the Endangered Species Act (Bean 1983). The Bald Eagle Protection Act was passed in 1940 in response to population declines of the bald eagle and its unique status as the nation's symbol. This act made it illegal to take or possess bald eagles or any part, egg, or nest thereof (Bean 1983). In 1972 the Migratory Bird Treaty Act was amended to include bald eagles and other raptors. Also in 1972, the Environmental Protection Agency banned the use of DDT (E.P.A. 1975). In 1978, under the Endangered Species Act, bald eagles were declared endangered in 43 states and threatened in 5 states. In addition to protecting eagles from direct harm, endangered species designation provided for the protection of critical habitat and, under Section 7 of the Act, stipulated that federal agencies refrain from any action that would jeopardize the existence of a listed species (Bean 1983).

In recent years, bald eagle populations seem to be stabilizing or improving. Increased reproductive success since the ban of DDT is probably a primary factor (Fraser 1981, Grier 1982, Wiemeyer et al. 1984). Still, bald eagles remain listed as endangered or threatened in all of the conterminous states. Although human persecution may be reduced, shooting, trapping, electrocution, and poisoning by pesticides and lead shot still cause direct eagle mortality (Fraser 1985). Habitat loss to human encroachment through cutting of nest trees, perch trees, and roost sites remains a serious concern (Stalmaster 1976, Stalmaster and Newman 1979, Hansen et al. 1980, Nash et al. 1980).

Bald Eagles in North Carolina

The National Wildlife Federation reported 20, 3, and 27 eagles observed in 1985, 1986, and 1987 respectively, during midwinter counts for North Carolina. The wide variation was a result of variable survey efforts. An active nest was found in 1984 for the first time in 10 years (Welton 1984), and there were 3 active nests found in 1988 (Tom Henson, pers. comm.). Efforts to increase bald eagle numbers in North Carolina include a reintroduction project at Lake Mattamuskeet National Wildlife Refuge (Welton 1984).

Since the summer of 1985, large numbers of bald eagles have been observed on B. Everett Jordan Lake and Falls Lake in central North Carolina. These eagles represent a significant increase in the state bald eagle population. The bald eagle population at Jordan Lake and Falls Lake is unique in that it is primarily a transient summer population of immature eagles. To date, very little is known or published about communal summer roosts and summer habitat use of bald eagles anywhere within their range. Research emphasis has been on communal winter roosting and nesting habitat use. Identification of summer habitat requirements is necessary to provide a basis for management activities aimed at recovery of bald eagles in accordance with the objectives of the Endangered Species Act. Thus, the objectives of this study were to:

1. Assemble, synthesize, and interpret existing information on the status and management of summer bald eagle roosts;
2. Quantitatively describe the vegetative characteristics of roosts, roost trees, perch sites, and perch trees in relation to available habitat;
3. Relate bald eagle distribution on B. Everett Jordan Lake and Falls Lake to habitat types, emphasizing roost sites and foraging areas.
4. Develop management recommendations and guidelines for the eagle population on the reservoirs;
5. Determine local bald eagle food habits on an opportunistic basis.

LITERATURE REVIEW

Life History

Bald eagles occur throughout North America, but generally are found in association with large bodies of water. In much of its range the bald eagle is a permanent resident (Bent 1937). However, during the winter, bald eagles from northern Alaska and Canada migrate south to find open water and food (Brown and Amadon 1968). Some Florida bald eagles, which breed in the winter, migrate north during the summer (Broley 1947).

Bald eagles are among North America's largest birds with a wingspan of 1.8 - 2.4 m and weight of 3.6 - 6.4 kg (Imler and Kalmbach 1955, Brown and Amadon 1968). Typically two subspecies are recognized with the northern subspecies being larger than the southern subspecies. However, sizes between the subspecies are not distinctly different and thus, the differences probably represent clinal variation in accordance with Bergmann's Rule (body size tends to be larger in cooler climates and smaller in warmer climates; Amadon 1983). As is true with many raptors, females are larger than males. Also, bald eagles have superb eyesight and thus, vision is the primary sense for food and danger detection.

Bald eagles are long-lived with a known age in captivity of up to 36 yr (Newton 1979). Data are lacking on longevity in the wild. Bald eagles are believed to mate for life (Bent 1937), and although the age of sexual maturity and first breeding are not well established, Bent (1937) states that "...almost always both birds of a breeding pair are white-headed adults." This indicates a minimum age of approximately 5 years. A pair may use the same nesting territory in successive years, either rebuilding the old nest or constructing a new nest within the territory (Herrick 1934, Bent 1937, Brown and Amadon 1968). As a result, bald eagle nests may reach sizes up to 3 - 4 m in height and 3 m in diameter (Herrick 1934, Bent 1937).

The breeding season may begin as early as November in Florida (Broley 1947) and progress through May in the northern-most areas of its range (Brown and Amadon 1968). The female usually lays 2 eggs but may lay from 1 to 4 (Bent 1937). Incubation lasts about 35 days and fledging generally occurs 10-12 weeks after hatching (Herrick 1934, Fraser 1981).

Bald eagles go through several plumage phases before reaching the final adult phase. The exact ages of changes in plumage phases has not been determined and it is likely that there is considerable variation among individuals. Regardless, the general pattern seems to be that first year birds (juveniles) are uniformly dark brown; immatures (approximately 2 to 4 year-olds) are mostly brown with white mottling, especially on the back, chest, and belly. By the fourth year (subadults) they begin to assume adult plumage: dark brown bodies with white head and tail, although usually with some brown mottling in the head and tail. By age 5 or 6 they attain full adult plumage without brown mottling (Bent 1937, Brown and Amadon 1968).

Habitat

Several factors have been identified as important to habitat selection by bald eagles, including proximity to a food source, vegetative structure, microclimate, and human disturbance (McEwan and Hirth 1979, Stalmaster and Newman 1979, Steenhof et al. 1980, Andrew and Mosher 1982, Anthony et al. 1982, Keister and Anthony 1983, Keister et al. 1987). Within these general constraints bald eagles are quite adaptable as to the particular food items, vegetative species, and proximity to humans of the habitats they will utilize.

Most studies on bald eagle roosting habitat have been done on winter roosts in the west (Edwards 1969, Stalmaster and Newman 1979, Steenhof et al. 1980, Anthony et al. 1982, Keister and Anthony 1983). Winter roost areas are often associated with open water due to the availability of associated prey items such as fish and waterfowl. Steenhof et al. (1980) reported that, from among similar forest stands, eagles chose the stand closest to an important foraging area on the Missouri River. Keister and Anthony (1983) found that bald eagles chose winter roost sites as close as possible to food sources while meeting minimum vegetation requirements. This was indicated because eagles flew up to 20 km to find suitable roost habitat in the Klamath Basin of Oregon and California (Keister and Anthony 1983). In Utah, Edwards (1969) reported that eagles flew 19 - 24 km to roost.

Suitable vegetation for bald eagles relates to their physical characteristics (large size, visual orientation). Bald eagles select winter roost sites based on vegetation structure that allows easy access and good visibility of the surrounding area. Roost sites have a more open canopy and lower tree density than surrounding forest stands (Keister and Anthony 1983). Steenhof et al. (1980) considered edge important for both visibility and access. Individual roost trees are taller, more open in structure and larger in diameter at breast height (dbh) when compared with surrounding forest trees (Steenhof et al. 1980, Anthony et al. 1982, Keister and Anthony 1983). Keister and Anthony (1983) suggested that eagles select Douglas fir (*Pseudotsuga menziesii*) due to its open, strong-limbed structure. Eagles may also select large tree limbs because they fit their feet comfortably. Snags, spike-topped conifers and large deciduous trees are particularly preferred but actual tree species vary regionally (Anthony et al. 1982, Keister and Anthony 1983). Selection of particular roost sites and trees may provide favorable microclimates that should enhance bald eagle energy balance and thus, survival and reproductive fitness.

During severe winter weather, roost sites with warmer microclimates are used. Steenhof et al. (1980) related roost site selection in South Dakota to wind protection. In Washington, Stalmaster (1981) showed that roosting in conifers yielded a net energy advantage due to reduced energy loss to wind and rain and protection from radiative heat loss. Presumably eagles select favorable microclimates at other times of the year, but no literature is available to confirm this. Eagles would be expected to select sites with cooler microclimates during hot summer temperatures.

Literature on summer roosts is nonexistent. Communal summer roosts are known to occur in the Chesapeake Bay area and the Chippewa National Forest in Minnesota (J. Fraser pers. comm.); however, no study results have been published to date. It seems likely that eagles used communal summer roosts in the past, at least prior to the population declines earlier in this century. However, summer roosts have only recently been documented.

A possible scenario is that recent population expansions have allowed reestablishment of communal summer roosts. Increased productivity following the population declines of the DDT era may have produced a large cohort of immature eagles. Therefore, the lack of communal summer roosts in the recent past may have been a result of the low numbers of nonbreeding eagles. Reestablishment of summer roosts may be indicative of an expanding population. Nonbreeding eagles may be more likely to form large congregations than breeding eagles because breeding eagles establish territories and therefore are more dispersed. Other factors contributing to large communal summer roosts may be concentrated food sources and a lack of suitable habitat. As less habitat is available, eagles must concentrate in the remaining sites.

Habitat requirements for summer roosts that should be similar to those for winter roosts are proximity to a food source, vegetative structure allowing access and long sighting distances, and human disturbance factors. An abundant food source may be the prime attractant to an area. Eagles should select for tall, open structured trees in less dense stands as suggested by Steenhof et al. (1980) and Anthony et al. (1982). There are no studies indicating whether or not eagles react differently to human disturbance according to season. Considerations for microclimate are likely to be different. Bald eagles would be expected to select habitats with microclimates cooler than ambient temperatures on hot summer days as compared to warmer microclimates during cold winter weather.

Diurnal perch sites share some common features with roost sites. Probably the most important characteristic of perch sites is proximity to a food source (Stalmaster and Newman 1979, Steenhof et al. 1980), which usually is quantified as the distance to water. Steenhof et al. (1980) found 94% of diurnal perches in South Dakota within 30 m of the Missouri River and Stalmaster and Newman (1979) found "virtually all" perches within 50 m of the Nooksack River in Washington.

Once eagles have found an area with abundant food, perch site selection centers on characteristics that provide access, long sighting distances, and a stable perch. Trees that are relatively tall, close to open areas, and have an open crown structure with stout horizontal limbs are preferred (Stalmaster and Newman 1979, Steenhof et al. 1980). Stalmaster and Newman (1979) also found that eagles wintering in Washington perched as high as possible on a given tree and have a strong preference for dead trees. However, eagles perched on lower limbs in dense tree crowns are hard to see and may have been underrepresented in their sample. Particular tree species may be heavily utilized in a given area but the species used vary with vegetation type and region, crown structure appears to be the dominant characteristic.

Human disturbance can affect eagles' selection of perch sites. Stalmaster and Newman (1978) reported that the distance at which eagles flushed from human disturbances was shortest when eagles were perched in areas with a vegetative canopy. Thus, in areas of heavy human use eagles may choose areas with denser vegetation.

As with roost and diurnal perch habitat, bald eagles choose nesting sites based on the proximity to food, vegetation structure, and human disturbance factors. Bald eagles typically select nesting habitat within 1.5 km of water (Whitfield et al. 1974, McEwan and Hirth 1979, Todd 1979, Grubb 1980, Fraser 1981, Andrew and Mosher 1982). This nesting preference relates to their reliance on fish and other aquatic oriented food items. In Arizona, Haywood and Ohmart (1986) found that eagles selected nest habitat in relation to physical characteristics of the river. Nests occurred near deep pools with contiguous shallow areas and riffles, apparently to optimize eagle foraging.

Vegetation structure plays an important role in nesting habitat selection. Bald eagles usually locate nests in dominant or co-dominant trees of low density forest stands or along forest edges to allow unobstructed access to the nest tree (McEwan and Hirth 1979, Todd 1979, Fraser 1981, Andrew and Mosher 1982, Anthony et al. 1982). Nest tree species vary geographically and by forest types, suggesting that eagles choose nest trees based on structural attributes of tree crowns that provide strong support for the nest.

The effect of human disturbance on nest site selection has not been fully determined. Andrew and Mosher (1982) and Fraser et al. (1985) stated that eagles appeared to avoid human activity by nesting at a greater distance from activity and selecting nest sites buffered from disturbance by stands of vegetation. Several studies (Hensel and Troyer 1964, Grubb 1980, Nash et al. 1980) have suggested that human activity has negative effects on productivity while others shown no relationship between human activity and bald eagle productivity (McEwan and Hirth 1979, Fraser et al. 1985). These differences probably result from different definitions of human disturbance and problems in quantifying disturbance. Therefore, more definitive studies are needed.

In summary, bald eagle habitat selection can be related to the species' life history and physical characteristics. Their preference for fish and other aquatic oriented prey creates a need to be near large bodies of water. Their large size results in a need for vegetation structure that allows easy access. Their nest building habits, longevity, and nest site fidelity require strong structural support for the nest. Also, bald eagles seek habitats that create favorable microclimates. Their widespread distribution in North America reinforces the idea that they are adaptable with respect to individual species and probably select for structural attributes of the vegetation.

Food Habits

Bald eagles are opportunistic foragers, utilizing what is available and concentrating on what is abundant. Although bald eagles prefer fish (Wright 1953, Griffin et al. 1982), all vertebrate classes as well as a few invertebrates have been represented in studies of prey remains. In Maine, Todd et al. (1982) found remains of 64 vertebrate and 2 invertebrate species and in Florida, McEwan and Hirth (1980) found remains of 34 vertebrate species of prey items in nests and beneath nest trees.

In general, fish are the primary food for bald eagles, both by weight and biomass. Catfish (*Ictalurus* sp.), carp (*Cyprinus carpio*) and suckers (Catastomidae) comprise the bulk of breeding bald eagles diets (Dunstan and Harper 1975, McEwan and Hirth 1980, Todd et al. 1982, Haywood and Ohmart 1986). Evidently bottom feeding fish foraging in shallow water are easy prey (Haywood and Ohmart 1986). However, most studies only record prey remains and thus may give biased estimates toward species with indigestible parts (Mersmann et al. 1987). American coots (*Fulica americana*) and other waterfowl are the most common bird prey items, while rabbits (*Sylvilagus* spp.), hares (*Lepus* spp.) and large mammalian carrion comprise the major mammalian food items (McEwan and Hirth 1980, Griffin et al. 1982, Todd et al. 1982, Haywood and Ohmart 1986). Amphibians, reptiles and invertebrates are only minor food items (Dunstan and Harper 1975, McEwan and Hirth 1980, Clark 1982, Grubb and Coffey 1982, Todd et al. 1982, Haywood and Ohmart 1986).

Bald eagle food habits change seasonally and regionally to take advantage of available food sources. Todd et al. (1982) found that inland and inshore coastal nesting eagles in Maine relied primarily on fish in summer and avian and mammalian prey in winter. Offshore eagles relied on colonial seabirds all year. Griffin et al. (1982) report that eagles fed heavily on dead and crippled waterfowl during winter in Missouri, but winter-killed fish were preferred when available. Eagles concentrate in areas of the Northwestern U.S. in winter to feed on spawned-out salmon (Stalmaster et al. 1979, McClelland et al. 1981). Thus, even though bald eagles are quite adaptable in their food habits, most prey items are closely associated with water or at least can be found near it.

Management

Present bald eagle management plans typically are specific to individual use sites, such as nests, roosts, and feeding sites. Common management recommendations include inventory of actual and potential use areas, restriction of human activities and protection of important habitat and food sources (Mathisen et al. 1977, Steenhof 1978, Anthony et al. 1982, Anderson 1985).

Inventories are conducted to identify actual and potential nesting, roosting and foraging sites. Once sites are identified, concentric zones limiting human activities are established based on site characteristics and eagle behavior (Mathisen et al. 1977, Anderson 1985). Specific management actions include complete protection from all human activity in core areas, habitat protection from development and forest harvest, and restriction of human activities during critical times of the year (such as nesting or winter roost periods). Stalmaster and Newman (1979) suggest using vegetation strips as buffers against human disturbances.

Stalmaster (1983) developed an energetics model to help make management decisions. By computing available food biomass, energy consumption and activity costs, the model estimates carrying capacity, eagle population energy demands and food use. Resultant management recommendations include increasing food availability and reducing energy drains. Habitat management to reduce flight distance and produce favorable microclimates was suggested.

Andrew and Mosher (1982) suggested managing entire habitats as well as protecting specific eagle use sites. To provide for the expansion of the bald eagle population, identification and protection of potential habitat is needed. Anderson (1985) concluded that carefully planned silviculture can be used to create and maintain eagle habitat.

STUDY AREA

The study area consisted of B. Everett Jordan Lake, Falls Lake and the surrounding lands. These areas are managed primarily by the U.S. Army Corps of Engineers (COE). The lakes are adjacent to the Raleigh-Durham metropolitan areas in central North Carolina (Fig. 1). The study area is in the Piedmont Plateau physiographic province and the southeastern mixed forest ecoregion (Bailey 1978).

Both lakes are COE impoundments established for flood control, water supply, water quality control, recreation, and fish and wildlife conservation. Construction of Jordan Lake was begun in 1967 by the COE and was completed in 1973. Permanent impoundment was completed in October 1982. The project encompasses 18,927 ha of which 5,625 ha are permanently flooded. At normal pool stage Jordan Lake is approximately 27.4 km long with 241 km of shoreline (Corps of Engineers 1983a). The Falls Lake project was begun in 1978 by the COE and the impoundment was completed in 1982. The project encompasses 15,378 ha of which 5,055 ha are permanently flooded. The lake is approximately 35.4 km long with 370 km of shoreline (Corps of Engineers 1983b).

Management plans for both lakes call for extensive recreational use and developments, such as boat launching areas, picnic and camping areas, and beaches (Stephen Brown, U.S. Army Corps of Engineers, Falls Lake, North Carolina, pers. comm.). Some of these developments currently are in use, others are in various stages of planning and construction.

METHODS

Roosting Habitat

I quantified roost habitat at two scales. The first scale included characteristics of individual roost trees and randomly selected trees within the boundaries of roosts (Table 1). I chose random trees by establishing two perpendicular axes so that X and Y coordinates could be randomly selected within roosts. I then generated random coordinates and measured the tree ≥20 cm in diameter at breast height (dbh, 1.4 m) closest to each random coordinate. Known roost trees were not included as random trees. I measured tree diameters with a diameter tape and tree heights, bole heights, and crown lengths with a clinometer. Distances from trees to forest edges were measured with a meter tape or from an aerial photograph. The amount of crown unobstructed by neighboring trees (crown accessibility) was measured in degrees with a sighting compass. I considered a tree crown obstructed where neighboring tree crowns were within 2 m. I tested the hypothesis that trees used by eagles were similar to random trees using t-tests or Wilcoxon rank sum tests, depending on data normality.

The second scale of roost habitat measurement described entire roosts. Measurements within roosts were taken from points on transects crossing roosts perpendicular to the base axes. The base axis for the Morgan Creek roost was defined by a linear forest edge on the eastern edge of the roost and oriented approximately north to south. The base axis for the Mason Point roost consisted of state route 1728, which ran north to south along the eastern edge of roost.

I randomly chose the distance to the starting point on the base axis for the first transect and spaced the remaining transects evenly across roosts. The distance on the transect to the first sampling point also was chosen randomly, and sampling points were established at 50 m intervals from that point. To determine how roost characteristics differed from characteristics of adjacent forest stands, I established 8 500 m transects within 6 km of the midpoint between roosts, and sampled at 50 m intervals along these transects. I discarded three sampling points that fell in open fields. In these instances, I continued along the transect at 50 m intervals until I crossed the open field.

I sampled roost areas using the point-centered-quarter procedure (Brower and Zar 1977). In each quadrant, I measured the nearest tree to the sampling point that was greater than 20 cm dbh. The dbh, height, tree species, and the distance from the sampling point to the tree were recorded. Tree density was estimated using formulae in Brower and Zar (1977:83). I compared roosts to each other and to random transects using Kruskal-Wallis tests, Wilcoxon rank sum tests, and principal components analysis.

Perching Habitat

I evaluated bald eagle perching habitat at 3 levels. The first level analyzed individual perch trees, by observed eagle use patterns determined during shoreline surveys and by measured characteristics of the perch trees. At the second level, perch sites, I compared the forest stand within 20 m of perch trees to randomly located sites within 200 m. Finally, I compared the forest composition of 1 ha areas surrounding perches and random points.

Perch Tree Use

I collected data on bald eagle use of perch trees in association with aerial and weekday/weekend boat shoreline surveys conducted primarily to determine bald eagle distribution and abundance and human disturbance factors for a concurrent study by Timothy J. Smith (Smith 1988).

We surveyed shorelines at Jordan Lake, Falls Lake, and portions of associated streams using Cessna 152, Cessna 172, and Piper Supercub fixed-wing aircraft. These surveys were conducted approximately 30 m above the water and 15-30 m from the shoreline trees, at air speeds between 110-150 km/hr (60-80 knots), consistent with safety and FAA regulations.

We flew aerial surveys from July 1986 through December 1987. We attempted to survey both lakes twice weekly during spring and summer, twice monthly during fall, and monthly during winter. Effort was based on the number of eagles present. Unavailability of pilots or aircraft and inclement weather (visibility < 5 km, ceiling < 305 m [1000 ft], wind > 50 km/hr) reduced the number of surveys we could conduct. When possible, canceled flights were rescheduled.

When feasible, both lakes were surveyed on the same day. We alternated the order in which the lakes were surveyed to minimize temporal biases. We usually began surveys during early morning hours, but some afternoon surveys were flown for comparison with morning flights.

We conducted paired weekday and weekend (weekday-weekend) boat surveys on selected sections of Jordan Lake with high densities of eagle use. We traveled 50 - 200 m from the shoreline (depending on water depth) and used binoculars to scan for eagles. Weekday-weekend surveys were conducted between 1100 and 1600 EST to encompass times of maximum human use. We conducted weekday-weekend surveys only on Jordan Lake because few eagles used Falls Lake.

For each bald eagle observed during aerial and boat shoreline surveys we recorded the position in the perch tree crown (top, middle, or bottom), the perch tree type (hardwood or conifer), and the perch tree crown type. I classified perch tree crown types based on the distribution of leafless limbs: no leafless limbs; leafless bottom limbs only; leafless top limbs only; all leafless limbs (including stubs); and interspersed leafless limbs.

I used chi-square analyses to test for differences in perch use in relation to survey mode, season, time of day, and to compare perch use versus availability. Weekday-weekend boat surveys were conducted only after 1100 EST from May through October, thus all comparisons involving aerial and boat surveys included data from aerial surveys conducted only during these times. I defined seasons as leaf-on (April - October) and leaf-off (November - March) based on the phenology of hardwoods. Only aerial survey data were used for seasonal analyses. Data for availability of tree types and crown types was obtained from trees $\geq$ 20 cm dbh within density plots at paired random perch sites (see Perch Sites).

Perch Tree Characteristics

I identified 120 bald eagle perch trees on Jordan Lake and 14 on Falls Lake during shoreline surveys conducted from boats. We conducted weekly surveys of the entire shoreline of Jordan Lake using 2 power boats beginning at approximately 0730 EST and ending at approximately 1700 EST. The starting point was alternated between the Farrington boat launch in the north end of the lake and the Ebeneezer boat launch near the south end to reduce temporal data biases. Survey boats traveled in opposite directions around the lake; the survey was completed when the 2 boats met approximately 9.5 hrs later. Shoreline surveys on Falls Lake were conducted twice weekly using one boat and only encompassed the shoreline north of the state route 50 bridge because very few eagles were ever seen below the bridge. I alternated the starting point between the Ledge Creek and Hickory Hill boat launches. When an eagle was located we marked the perch tree with a color coded sign and the location was recorded on a topographic map. We noted the direction that the eagle flushed and where it landed to prevent flushing the same bird repeatedly.

Additionally, we marked trees during weekday-weekend surveys on Jordan Lake. To avoid disturbing eagles, we photographed the perch trees and returned on another day to mark them.

I compared characteristics of marked eagle perch trees to those of the 2 nearest trees within 10 m that were ≥20 cm in diameter at breast height (dbh, 1.4 m). The lower limit of 20 cm for random trees was based on a pilot sample of 20 perch trees located during boat surveys; the smallest dbh in this sample was 20 cm. For each tree we recorded species, crown type, number of accessible perch limbs, dbh, total height, bole height, distance to the forest edge, and crown accessibility (Table 1). I categorized tree species as loblolly pine (*Pinus taeda*), snags, oaks (*Quercus* spp.), sweetgum (*Liquidambar styraciflua*), and others. A limb was considered an accessible perch limb if it was ≥5 cm in diameter, was ≤15 degrees from horizontal, and had at least 1 m of open space above and below. I measured dbh with a diameter tape, distance to forest edge with a tape measure, and total height and bole height with a clinometer. I subtracted bole height from total height to obtain crown length. I defined forest edges as the planes between the trunks of the outermost trees ≥20 cm. I measured crown accessibility as described for roost trees.

I tested the hypothesis that perch trees and paired trees had similar characteristics. For continuous variables, I tested the mean values of the 2 paired trees against perch tree values using paired t-tests for normally distributed data and signed rank tests for nonnormally distributed data (Kolmogorov-D test, SAS 1985). I used chi-square tests for categorical variables.

Perch Sites

Perch site measurements sampled small blocks (20 m × 20 m) of habitat at marked perch trees and at paired control trees. I chose control trees by pacing a random distance (20 - 200 m) and direction along the forest edge and choosing the nearest tree ≥20 cm dbh approximately the same distance from the forest edge as the corresponding perch tree.

Foliage volume and accessible limbs

I estimated foliage volume and the number of potential perch limbs at perch sites and control sites by creating 3-dimensional profiles along four 20 m transects (Fig. 2). I aligned the front transect parallel to the shore and centered it on the perch or random tree. The middle transect was perpendicular to the shore, started at the forest edge, and included the perch or control tree. The left and right transects were parallel to the middle transect, and started at the forest edge at the ends of the front transect (Fig. 2).

Along each transect, I established five 2 m x 4 m quadrats. I estimated foliage volume in 7 rectangular parallelepipeds above each quadrat (Fig. 3). Thus, there were 35 rectangular parallelepipeds over each of the 4 transects. The tops of parallelepipeds were 2, 5, 10, 15, 20, 25, and 35 m above the ground for height classes 1-7, respectively. I categorically estimated the foliage volume (0%, 1 - 5%, 6 - 25%, 26 - 50%, 51 - 75%, 76 - 95%, 96 - 100%) for all parallelepipeds (Fig. 3). For height classes 4 - 7 I categorically estimated the number of potentially accessible perch limbs (0, 1 - 2, $\geq$3).

To help estimate foliage volume within parallelepipeds, I used a clear acetate template with various sized boxes calibrated to approximate the sizes of parallelepipeds when viewed at fixed distances from observers' eyes. I stood 4 m to one side of the transects to facilitate viewing of the upper layers and to reduce overlap among adjacent parallelepipeds. I attached strings to the template and held them with my teeth to maintain the proper distance between the template and my eyes.

Other site characteristics

I determined slope by sighting at eye level from one end of the middle transect to the other (20 m) using a clinometer. I measured the angle of open forest edge by standing where the middle transect met the forest edge and sighting along the edge for approximately 20 m in each direction

(Fig. 4). I determined the aspect of the forest edge by taking the vector representing half the angle of open forest edge (Fig. 4) and categorized the values into eight directions: North, Northeast, East, Southeast, South, Southwest, West, and Northwest. I estimated large tree density by counting the number of trees of each species ≥20 cm dbh within the area bounded by the front transect, the left and right transects and extending 5 m back from the front transect (approximately 100 m^2, Fig. 4). I recorded the crown type for each tree counted in the density estimates at the random sites to provide an estimate of crown type availability for comparison with observed eagle use of crown types during shoreline surveys. I measured the distance from the perch or random tree to the shore at normal pool level. During low water levels I estimated this point using vegetation and shore erosion clues. I measured a water depth index from 7.5′ topographic maps with an electronic planimeter. The water depth index was the distance (meters) from the point on the shore (216′ contour line on Jordan Lake, 250′ contour on Falls Lake) nearest the perch or random tree to the closest point on the next contour line (210′ contour on Jordan Lake, 240′ contour on Falls Lake). Because of the different contour interval this variable was not compared between lakes.

Statistical comparisons

I tested the hypothesis that habitat characteristics of perch sites and paired random sites did not differ. I compared mean foliage volume and the number of accessible limbs at perch and random sites for front transects and all transects combined. I compared the crowns of perch trees to paired random trees by defining a core area consisting of the middle 12 m of the front transect and the first 8 m of the middle transect (Fig. 5). I controlled for height differences by comparing only the top 3 levels containing foliage (representing the tree crown). I compared eagle use sites and paired random sites with respect to slope, aspect of forest edge, water depth index, distance to shore, forest edge angle, large tree density, and species density.

I tested the homogeneity of vegetation within eagle use sites. The rationale behind this analysis was that important vegetation characteristics may have been clumped near perch trees. If so, comparing entire perch sites to entire control sites could have masked important differences in vegetation resulting from the nature of vegetation very close to perch trees. Thus, I compared front transects to middle transects and the middle transects to side transects (average of left and right transects).

I tested for differences in means using paired t-tests for normally distributed data and signed rank tests for nonnormally distributed data, as determined by a Kolmogorov-D test (SAS 1985). For categorical data, I used chi-square tests.

Perch Areas

I defined perch areas as 1 ha square areas with the lakeshore side centered on perch trees. I measured perch area characteristics from 1:1320 scale aerial photographs provided by the U. S. Army Corps of Engineers. These perch area measurements characterized forest composition within the 1 ha blocks at marked perch trees and at random points along lakeshores. To determine if the habitat of perch areas differed from the habitat generally available on the lakes, I compared perch areas with randomly selected areas on Jordan Lake (n = 120) and on Falls Lake (n = 20). Random areas on which eagles were seen during aerial surveys were included with perch areas for analysis.

I plotted perch tree and random points on 7.5′ topographic maps and transferred them to aerial photographs. Jordan Lake aerial photographs were taken 19 May 1985 and Falls Lake photographs were taken 24 June 1983. On a clear acetate template I outlined a 1 ha square divided into 9 square cells. I aligned the front of the 1 ha square parallel to the lakeshore; the middle cell of the front row was centered on eagle perch trees or the centers of randomly selected points. I recorded the dominant cover type (pine, hardwood, open, flooded timber, water) within each cell. A cell represented 11.1% of the site total, so I determined the percent composition of each cover type for each area by summing the number of cells dominated by each cover type and multiplying by 11.1. For example, the percent composition of an area with 5, 3, and 2 cells dominated by hardwoods, conifers, and fields respectively would be 55.5% hardwood, 33.3% conifer, and 22.2% field.

I tested the null hypotheses that 1) cover types did not differ between lakes, 2) cover types at eagle use areas did not differ between lakes, and 3) cover types did not differ between eagle use areas and randomly selected areas at each lake. I tested the distribution of the data for normality using a Kolmogorov - D test (SAS 1985). I analyzed normally distributed data using t-tests and nonnormally distributed data using Wilcoxon rank sum tests.

Habitat Disturbances

I used 7.5′ topographic maps (revised 1981) to determine the distance to habitat disturbances from eagle perch trees and random points. I verified the existence of habitat disturbances with 1:1320 scale aerial photographs. I used an electronic planimeter to measure distances to occupied houses, dirt roads, paved roads, fields, forest harvest areas, major powerlines, and campgrounds. Forest harvest areas contained forest regrowth but the trees had not reached the height of the surrounding forest. I used a minimum size for fields and forest cuts of 0.6 ha and 0.15 ha, respectively.

I tested the null hypothesis that the distance to habitat disturbances from eagle use sites and random sites was not not different between lakes, and that habitat disturbances were equidistant from eagle use sites and random sites at each lake. I used t-tests for normally distributed data, and Wilcoxon rank sum tests for nonnormally distributed data as determined by a Kolmogorov-D test (sample size $>$ 50) or a Shapiro-Wilk test (sample size $\leq$51; SAS 1985).

Food Habits

Prey remains and castings (regurgitated pellets of undigestable food items) were collected from beneath known eagle perch and roost trees as time allowed. I identified prey from bones, scales, hair and feathers by comparing these to reference materials.

RESULTS AND DISCUSSION

Roosting Habitat

Roost Areas

The Mason point roost was in the 1983 seed tree cut conducted by North Carolina State University at the south end of state route 1728 (Fig. 6). I observed eagles flying throughout most of the 18.1 ha opening but actual roosting was concentrated in 2 smaller areas of approximately 2 and 3 ha. Eagles roosted in some of the remaining seed trees and in trees along the edge of the harvest area and the surrounding closed canopy forest. The Morgan Creek roost was located in the northwest corner of the Morgan Creek arm of Jordan Lake (Fig. 6) and was associated with a 3.5 ha open area; defined by the closed canopy forest to the east, north, and west, and open to Jordan Lake on the south. Roosting was concentrated in a 1.3 ha area of dead hardwoods along the eastern edge of the opening. The distances from roosts to Jordan Lake were 0.47 and 0 km for the Mason Point and Morgan Creek roosts, respectively. Communal roost sites ranging in size from 0.32 ha to 254 ha (Steenhof 1976, Griffin 1978, Hansen et al. 1980, Keister and Anthony 1983), and from

0.25 km to 24 km away from food sources (Edwards 1969, Stalmaster et al. 1979, Hansen et al. 1980, Keister and Anthony 1983) have been reported for winter roosting bald eagles. Steenhof et al. (1980) and Keister and Anthony (1983) suggested that bald eagles roosted in forest stands as close as possible to feeding areas, provided that the stands met minimum vegetative requirements: low densities of large trees with open crown structures and stout, horizontal perching limbs.

The Mason Point and Morgan Creek roost sites had lower tree densities, larger trees, less canopy cover, more ground vegetation, and were closer to forest edges than random forest areas nearby ($P < 0.001$ for all variables, Table 2). Eagles may prefer these areas because of the ease of access to perching limbs and/or microclimate conditions. The species compositions of roosts and random points differed (Fig. 7), but these differences were not consistent for the two roosts.

To further describe the characteristics of roost sites in relation to random sites, I conducted a principal components analysis (PCA), which allows the consideration of several variables simultaneously. I first subjected the 106 habitat samples to PCA and derived 2 "components" representing habitat gradients (Table 3). The first component represented a gradient from sites with high canopy cover, small trees at high density a long distance to a forest edge, to sites with low canopy cover, large trees at low density close to the forest edge (Table 3). This component accounted for 57% of the variation in the data set. The second component, representing 15% of the variation in the data, described a gradient of tree height and distance to forest edge. Plotting the data on 2 axes demonstrated that the 2 roost sites were similar to each other structurally, but differed substantially from random sites (Fig. 8). This lack of similarity between roosts and random points suggests that potential roosting habitat is scarce in the vicinity of the Morgan Creek and Mason Point roosts.

The vegetation structure of the Morgan Creek and Mason Point roosts is similar to that described for winter roosts in other parts of the U. S. (Steenhof 1976, Griffin 1978, Steenhof et al. 1980, Anthony et al. 1982, Keister and Anthony 1983). The Jordan Lake roosts also are similar in structure to summer eagle roosts on the Chesapeake Bay (Buehler, Fraser, Mersmann, and Chase, unpublished data).

Roost Trees

Roost trees in the Morgan Creek roost had larger diameters and greater crown accessibility than randomly selected trees. Furthermore, roost trees were more often dead hardwoods and were closer to the forest edge than randomly selected trees ($P < 0.001$ for all tests, Table 4). At Mason Point, roost trees were taller, had longer boles, and were farther from the road than random trees ($P = 0.008$, $P = 0.008$, $P = 0.016$ respectively). Nearly all trees within the seed tree cut on Mason Point were loblolly pines, making inferences about species selection difficult at that roost (Table 4). The high use of the Mason Point roost suggested that large loblolly pines provided quality roost trees. Size appeared to be the most important criterion used by eagles when choosing roost trees. Large dead hardwoods, such as those dominating the Morgan Creek Roost, and live loblolly pines have relatively open crowns with large branches. These crown characteristics provide easy access and stable perches. Other researchers (Steenhof 1976, Anthony et al. 1982, Keister and Anthony 1983) also have shown that eagles choose the larger more open crowned trees that are available in roost stands.

The frequent use of the Mason Point roost road by people may prevent eagles from using trees close to the road. Restricting human disturbances near the roost by closing this road and monitoring eagle behavior would provide more conclusive evidence.

Perching Habitat

Perch Trees

Analysis of summer eagle observations during aerial and boat surveys showed that eagles used hardwoods less and pines more than expected based on availability ($P < 0.001$ and $P = 0.002$ for aerial and boat observations, respectively; Fig. 9). The species composition of perch trees marked on boat surveys confirmed these results; eagles used loblolly pines more than expected and sweetgums less than expected based on the availability of trees adjacent to perch trees ($P = 0.056$; Fig. 10). During aerial surveys we observed a predominant use of pines during seasons when hardwoods had leaves (leaf-on) and a predominant use of hardwoods during seasons when hardwoods were leafless (leaf-off, $P < 0.001$, Fig. 11). Because eagles are more easily detected in leafless trees, this apparent switch may be explained, in part, by survey biases. During leaf-on, eagles used pines more after 1100 than at or before 1100 ($P = 0.041$).

Although most eagles observed during summer aerial and boat shoreline surveys were perched in tree crowns with no leafless limbs (complete crowns), entirely leafless trees were used more than expected based on availability ($P < 0.001$ for aerial and boat surveys, Fig. 12). Aerial surveys showed that this selection for leafless crowns persisted throughout the winter (Fig. 13). This is consistent with the observed switch from predominant use of pines in summer to predominant use of hardwoods in winter. During the leaf-on period, eagles used leafless crowns and complete crowns equally before 1100, but used complete crowns more than leafless crowns after 1100. During the leaf-off period, eagles used leafless crowns more than complete crowns at all times (Fig. 13). Eagle perch trees had more accessible perch limbs within their crowns than neighboring trees (Fig. 14). Thus, eagles seemed to select crowns that allowed easy access to large, horizontal limbs.

During aerial surveys we observed eagles perched in the bottom of tree crowns more often during the summer than in fall, winter, and spring ($P < 0.001$, Fig. 15) even though eagles should be more easily detected in the tops of tree crowns in summer. During summer, eagles perched in the bottom of tree crowns more often after 1100 than they did before 1100 ($P = 0.015$, df = 2, $\chi^2 = 8.45$).

Marked perch trees were significantly taller, had longer boles, longer crowns, and larger diameters than neighboring trees ($P < 0.001$, $P < 0.001$, $P = 0.032$, $P < 0.001$ respectively, Table 5). Perch trees were closer to forest edges ($P = 0.002$) and had larger angles of accessibility ($P < 0.001$) than neighboring trees (Table 5). The minimum tree diameter used by eagles during this study was 20 cm, and this was used as the minimum size for comparison trees. However, eagles used trees 20 cm - 30 cm dbh much less frequently than expected and trees > 40 cm dbh much more frequently than expected based on the sizes of available (adjacent) trees ($\chi^2 = 27.51$, df = 2, $P < 0.005$). I used the percentage of trees adjacent to perch trees that had both a dbh ≥30 cm and ≥3 accessible limbs (39.7%) to estimate the availability of suitable bald eagle perch trees. I multiplied this percentage by the average density at paired random sites to estimate that a suitable perch tree within 5 m of the forest edge should be available, on average, every 15.5 m. This is probably an overestimate of the number of available trees, because perch sites differed somewhat from random sites (see below), but suggests that there are many suitable trees on the lakes.

Perch Sites

My data from sampling plots centered on perch trees indicated that perch sites had significantly more foliage above 20 m than paired control sites ($P < 0.01$) when analyzed for all transects (Table 6, Fig. 16) and for front transects only (Table 7, Fig. 17). Perch sites had significantly more accessible limbs at all heights for all transects ($P < 0.05$, Fig. 18) and all heights except the top for front transects only ($P < 0.01$, Fig. 19).

I compared foliage volumes within parallelepipeds at the core (Fig. 5) of perch sites and paired random sites. This analysis compared the crowns of perch trees and random trees and controlled for differences in heights of these trees by comparing only the top 3 layers containing foliage. I found no differences in foliage volume between perch tree and random tree crowns (Table 8, Fig. 20). However, perch trees contained significantly more accessible limbs in all levels of the crown (Fig. 21).

Front transects had significantly more foliage below 2 m than middle transects ($P < 0.046$). The middle transects had significantly more foliage between 10 - 15 m ($P = 0.022$) and marginally more between 5 - 10 m ($P = 0.051$, Table 9, Fig. 22). The dense vegetation below 2 m on the front transects is a result of the increased sunlight available along the forest edge. The denser vegetation along the middle transect at the upper levels indicates the denser canopy cover of the forest compared to the edge. There were no significant differences in the number of accessible limbs between the front and middle transects (Fig. 23).

I found no differences in foliage volume between the middle transect and side transects (Table 10, Fig. 24), indicating that forest stands at perch sites were relatively homogeneous. The middle transect had significantly more accessible limbs than the side transects in the 10 - 15 m, 15 - 20 m, and 20 - 25 m height classes ($P = 0.003$, $P < 0.001$, $P = 0.052$, respectively; Fig. 25). However, this reflects the presence of the perch tree on the middle transect because these differences were no longer significant ($P > 0.20$ for all 4 heights) after I removed from the analysis the first column of parallelepipeds on the middle transect (representing the perch tree).

Perch sites had a higher density of pines than control sites (Table 11) suggesting that eagles prefer pine stands. I used slope and aspect of forest edge as indirect measures of microclimate, forest edge angle and large tree density as indicators of eagle accessibility, and water depth index and distance to shore as indices of food availability. I found no significant differences between perch sites and paired sites for slope, aspect of forest edge, angle of forest edge, large tree density, water depth index, and distance to shore (Table 11). Thus, eagles apparently do not select perch sites based on these variables.

The key differences between perch sites and control sites (more foliage in the upper layers, more accessible limbs) appear to be a function of the eagles' choice of large, open-crowned perch trees. This is consistent with my analyses of individual perch trees, suggesting that good perch trees are the most important characteristic of forest stands for bald eagles.

Perch Areas

To determine if availability of cover types differed between lakes I compared the random segments of each lake. The percentage of water was significantly different between lakes (Table 12), so I compared eagle use areas to random areas for each lake separately. Eagle use areas did not differ between lakes (Table 13) and were similar to random areas for all variables (Table 14, Table 15). Thus, eagles did not seem to select perching areas based on the proportions of different cover types near perch trees.

Habitat Disturbances

Random shoreline sites were closer to houses, fields, and powerlines at Falls Lake than at Jordan Lake (Table 16). Correspondingly, houses, fields, powerlines, and campgrounds under construction were all closer to eagle use sites on Falls Lake than Jordan Lake (Table 17). On Jordan Lake the eagles were concentrated north of the Farrington bridge and the nearest campground under construction was Poplar Point, whereas on Falls Lake the main eagle use areas were close to the Rollingview Recreation Area.

On Jordan Lake, eagle use sites were closer to houses and powerlines and farther from paved roads and campgrounds (in use and under construction) than were random sites (Table 18). No houses were directly on the lakeshore and thus all were buffered from eagle view by vegetation. Vegetation buffers may decrease the effect of human disturbance (Stalmaster and Newman 1978). One major powerline crossed the north end of New Hope Creek which is a high eagle use area. On Falls Lake eagle use sites were closer to powerlines and campgrounds under construction than random sites (Table 19).

The mean distances to habitat disturbances seem quite long compared to flush distances ($\bar{x}$ = 137 m, this study; $\bar{x}$ = 131 m, Stalmaster and Newman 1978; $\bar{x}$ = 152 m, Knight and Knight

1984; $\bar{x}$ = 476 m, Fraser et al. 1985) but there are no studies indicating how far eagles would go to avoid consistent human disturbance areas. Andrew and Mosher (1982) measured the distance from nest sites and randomly located points to habitat alterations and found that eagle nests were closer to unpaved roads and farther from paved roads, occupied and unoccupied structures, and agricultural fields than were the random points. McEwan and Hirth (1979) reported that production of young was independent of habitat alteration and amount of road use within 1.5 km of nests. Fraser et al. (1985) reported that eagle nests were farther from clusters of houses but not single houses than expected at random. Andrew and Mosher (1982) and Fraser et al. (1985) suggested that bald eagles avoid human disturbance when selecting new nest sites.

The rather long distances between eagle use sites and habitat disturbances, and the inconsistent results between the two lakes suggests that habitat disturbances did not have a major impact on eagle distributions. The significant differences I observed between eagle use sites and random sites were probably an artifact of the clumped distributions of eagles and habitat disturbances.

Factors Affecting Perch Site Selection

Eagles selected perch trees that were larger and more accessible than neighboring trees. They preferred loblolly pines and leafless trees with open crown structures and stout horizontal limbs. These crown characteristics may improve with tree age (Keen 1943). Correspondingly, eagles used trees in stands that were taller and contained more pines than stands at random sites. Several researchers have reported that eagles prefer large, open crowned trees (McEwan and Hirth 1979, Stalmaster and Newman 1979, Steenhof et al. 1980, Andrew and Mosher 1982, Keister and Anthony 1983). These characteristics may be selected for because they provide easy ingress and egress and good visibility of the surrounding area.

Bald eagle perch selection varied with season and time of day. During hot seasons or times of day, eagles selected portions of crowns that provided shade. Stalmaster and Gessaman (1984) found that wintering bald eagles in Washington effectively conserved energy by seeking protected microclimates. Seeking shade in the summer may be an equivalent energy conservation mechanism. Leafless hardwoods and snags may be more attractive to eagles during colder seasons and on cool mornings because they provide eagles a less obstructed flight path, the greatest range of vision, and possible thermoregulatory advantage by exposing birds to solar radiation.

Bald eagles may normally seek the highest perch possible unless conditions dictate use of a lower perch. Stalmaster and Newman (1979) reported that wintering bald eagles in Washington perched at the highest point at which branches would support them. Gerrard et al. (1980) reported that high perches were used as lookouts while low perches were used for eating and roosting. High perches may be favored because they afford easy take-offs and landings.

Effects of Habitat on Bald Eagle Distribution and Abundance

The high density of eagle use on Jordan Lake north of the Farrington bridge (Smith 1988) suggested that there may have been more suitable habitat there. Therefore, I compared the habitat characteristics of Jordan Lake north of the Farrington bridge with those of Jordan Lake south of the Farrington bridge and of Falls Lake. I found no differences in the availability of tree crown types (classes of leafless limb distribution) between the areas on Jordan Lake north of the Farrington bridge and south of the Farrington bridge ($\chi^2 = 4.54$, df = 3, P = 0.209) based on trees ≥20 cm dbh at paired random sites. Falls Lake had a higher percentage of trees with leafless crowns and a lower percentage of trees with leafless bottom limbs than Jordan Lake north of the Farrington bridge ($\chi^2 = 11.62$, df = 3, P = 0.009) which suggested that Falls Lake may have a higher density of suitable perch trees than northern Jordan Lake. I also found no differences in characteristics (dbh, total height, bole length, crown length, distance to edge, crown accessibility, species, accessible limbs, and crown types) of perch tree nearest neighbors between Jordan Lake north of the Farrington bridge and the 2 other areas.

I found no difference in large tree density between random sites north of the Farrington bridge and south of the Farrington bridge on Jordan Lake or between random sites north of Farrington bridge and Falls Lake. The density of large pines, oaks, snags, sweetgums, and others also was not different between these areas.

Finally, I compared the forest composition of random forest blocks (1 ha) between the areas. The area of Jordan Lake south of Farrington bridge had a higher percentage of conifers ($P = 0.031$, Wilcoxon signed rank test, $Z = 2.15$) and lower percentage of flooded timber ($P = 0.035$, Wilcoxon signed rank test, $Z = 2.11$) than Jordan Lake north of Farrington bridge. This may indicate better habitat south of Farrington bridge because eagles preferred pines but did not use flooded timber very often. There were no differences between north of Farrington bridge and Falls Lake in forest composition. Overall, the relatively low eagle densities on Jordan Lake south of Farrington bridge and on Falls Lake were apparently not attributable to lack of suitable perches and must be attributable to other factors.

I did not estimate the amount of suitable roosting habitat south of the Farrington bridge on Jordan Lake or on Falls Lake. I suspect that such habitat exists, but more study of this would be useful.

Falls Lake Nest Site

We found a nest during the 30 July 1986 aerial survey of Falls Lake. During December 1986 we climbed into the nest and examined it. The large size of the nest, its shape, branches used for construction, prey remains in the nest, and its location in areas used by eagles (Fig. 26) indicated that it probably was constructed by eagles. It had been recently refurbished with green plant materials and we observed eagles perched near and in the nest. We found a pair of great-horned owls (*Bubo virginianus*) using the nest in early February 1987. It is not unusual for great-horned owls to use eagle nests (Broley 1947, Fraser 1981).

The nest was located in a sparse group of dominant loblolly pines. The crowns of these pines extended well above the hardwood canopy below. The nest tree was located near two forest edges: one was the lakeshore, and the other was a corn field during the study period.

Food Habits

I identified 87 prey items from remains under 22 perch trees and 4 roost trees; I identified 12 prey items from 3 castings including 1 casting from the nest. Catfish (family Ictaluridae) were the most commonly identified prey items (Fig. 27), followed by carp (*Cyprinus carpio*), bass and sunfish (family Centrarchidae), shad (family Clupeidae), bowfin (*Amia calva*), unknown fish, turtles (*Chrysemys* spp.), unknown mammals, and birds (Family Rallidae). These data probably do not accurately represent the relative importance of different fish species in the diet because of heterogeneous recovery rates (Mersmann et al. 1987). Catfish and carp are overrepresented due to low digestibility of large bones and spines and slow decomposition rates. The importance of fishes such as shad and centrarchids is underestimated.

These results indicate that fish are the primary food source for eagles on Jordan Lake and Falls Lake. Also, the coot (*Fulica americana*) remains were found in the casting taken from the nest in December 1986. Although American coots are common prey items, eagles apparently prefer fish when available (Wright 1953, Griffin 1978, McEwan and Hirth 1980, Griffin et al. 1982). Gill net data from Jordan Lake (R. L. Noble and J. R. Jackson, North Carolina State University, unpubl. data) indicate that fish are less abundant during the winter. Thus the lack of available fish during the winter may be partly responsible for the low numbers of wintering eagles on these lakes.

However, further research on local prey availability and eagle food habits is needed to confirm this hypothesis.

CONCLUSIONS

1. Bald eagles chose roost stands with a consistent vegetation structure that allowed unobstructed flight within the roost. This was accomplished by roosting along the edge of an open area (Morgan Creek) and in a low density, open canopy forest stand (Mason Point). The need for open vegetation structure relates to the large size of bald eagles which makes maneuvering through dense vegetation difficult.

2. Forest stands with structural characteristics similar to those of the measured communal eagle roosts were rare. Principal components analysis showed little overlap in vegetation characteristics between roosts and random transects. Roost sites had low densities of large, open crowned trees and were associated with the edges of relatively large openings in the forest. The Mason Point roost was created by a seed tree cut in 1983 and the Morgan Creek roost was created by clearing the lake bottom for Jordan Lake. These results suggest that eagles would benefit from management directed at creating more potential roosting habitat. This can be accomplished through carefully planned silvicultural practices conducted during winter when eagle numbers are lowest.

3. Eagles selected perch and roost trees that, on average, were larger and had more open crowns than available trees within the roost. Open crown structures that provide access to stout,

horizontal limbs are the primary characteristic of eagle perch and roost trees. Taller trees also provide a greater dropping distance for eagles to gain flight speed when taking off.

4. Tree structure was more important to eagles than particular tree species. Eagles made extensive use of the abundant loblolly pines and used dead or leafless trees in a proportion greater than their availability. Similar results throughout the U.S. by other researchers suggest that eagles may use any tree that meets minimum structural requirements. Some species, such as loblolly pines on this study area, generally have a better structure than other tree species for perching and roosting eagles.

5. Eagles used different tree types, crown types and locations in the crown at different times of day and in different seasons. This was probably due to behavioral and microclimate considerations. Eagles preferred to perch in the bottom of live tree crowns (predominantly pines) during the summer after 1100. This provides a cool, shady environment for loafing eagles. At other times, eagles preferred to perch in the tops of dead or leafless trees (predominantly hardwoods). Higher perches have several advantages for eagles: easier take-offs and landings, longer range of vision, and exposure to solar radiation for warmth during cooler seasons and times of day. Range of vision and accessibility are particularly important to eagles during early morning foraging activities.

6. Suitable perch trees are the most important vegetation characteristic of perching habitat. I found no evidence that characteristics at the site (20 m × 20 m) or area (1 ha) levels influenced habitat selection. Evidently perching habitat is selected based on the presence of suitable perch trees in areas otherwise acceptable to eagles (eg. abundant prey, lack of human disturbance) and vegetation characteristics at the other scales measured have no meaning to eagles.

7. Potentially suitable perch trees were relatively abundant on the shores of both lakes. I estimated that approximately 40% of trees along the lakeshores are suitable (≥30 cm dbh, ≥3 accessible limbs) for eagle use. This is equivalent to an average of 1 suitable perch tree within

5 m of the forest edge every 15.5 m of forested shoreline. This is probably an overestimate of the percentage of suitable trees because it is based on data from eagle use sites which were slightly different from random sites. However, the estimate of the number of suitable trees along the shoreline may be an underestimate because eagles may perch farther into the forest than 5 m from the edge.

8. Habitat disturbances were either too far away or not disturbing to bald eagles on this study area. Habitat disturbances such as fields and forest cuts, while removing suitable habitat, may not in themselves be disturbing to eagles, ie. eagles may perch near them. Shoreline developments such as campgrounds may retain some suitable perch trees yet the presence of humans may be the disturbing factor. The long average distances to habitat disturbances from perch sites and the inconsistent results between Jordan Lake and Falls Lake suggest that habitat disturbances did not affect bald eagle distribution significantly. Significant differences between eagle use sites and random sites probably reflect the clumped distributions of eagles and habitat disturbances.

9. Fish are the primary food source for bald eagles at Jordan Lake and Falls Lake, but our data are insufficient to determine species importance. Food habits studies based on prey remains are biased toward species with heavy bones and indigestible parts such as fur and feathers. There is some indication that eagles utilized birds in the winter when fish were less available. Thus, food availability could be a limiting factor for eagles in the winter.

MANAGEMENT RECOMMENDATIONS

Jordan Lake and Falls Lake clearly provide important habitat for migrating and summering bald eagles. In addition, the nest found on Falls Lake and the presence of eagles throughout the year suggests that these lakes may be capable of supporting a population of resident breeding eagles.

Presence of this endangered species places clear responsibilities on the Corps of Engineers under the U.S. Endangered Species Act. The Act states (section 7) that "All...federal agencies shall...utilize their authorities in furtherance of the purposes of this act, by carrying out programs for the conservation of endangered species..." and that "Each federal agency shall...insure that any action authorized, funded, or carried out by such agency...is not likely to jeopardize the continued existence of any endangered species..."

In addition to legislated responsibility, the Corps of Engineers and cooperating agencies have an exciting opportunity and management challenge. Considering that the eagles were drawn to the area because of man-made habitat, ie. the reservoirs and the seed tree regeneration harvest that serves as the main roost, there is a real opportunity to further enhance the Projects for bald eagles through habitat manipulation. Recognizing that eagle management goals and objectives must be coordinated with other land management goals and objectives on the Projects, I offer the following suggestions as techniques that can be used to enhance bald eagle habitat and management.

Roost Habitat Management

My data suggests that roosting habitat is in short supply on Jordan Lake and Falls Lake. Thus, roost sites should be a top priority for eagle habitat management on the Projects. Additional communal roost sites that are discovered should be protected and maintained. Roost habitat can be created and maintained in appropriate stands of trees using silvicultural techniques, such as seed tree regeneration harvests. Based on data from the Mason Point and Morgan Creek Roosts, these sites should:

1. be associated with openings ≥3.5 ha in size;
2. be within 3 km of high eagle use shoreline;
3. have a density of between 25 - 100 stems/ha;

   Densities in the upper range include roosts along edges while lower densities should be created in opened forest stands.
4. consist of open crowned trees ≥40 cm dbh, such as mature and overmature loblolly pines;
5. optimally, trees should be spaced to maximize crown accessibility, but not at the expense of removing very large (≥50 cm dbh) mature trees.

Long term management for roost areas can be effected by releasing selected dominant trees in stands approximately 20 - 25 yrs old. All trees within the drip line of the dominant trees should be removed at this early release. A density of approximately 50 dominant trees per ha could be produced at this early stage to allow for future mortality. Further releases could be conducted at 35 and 50 years. At 50 yrs only 25 - 30 dominant trees per ha should be retained and all other trees ≥10 cm dbh should be removed. This schedule would improve wind firmness in the selected trees. Planted stands of loblolly pines would be ideal for this management scheme.

Perch Tree Management

Suitable perch trees along the shore appear to be plentiful at present. Thus, conservation of large trees along the shore may be all that is needed for now. All trees $\geq$50 cm dbh should be conserved as they are highly preferred by eagles but are quite rare. Mature loblolly pines and snags are the preferred tree types. However, active management can ensure the presence of perch trees in the future and enhance sites presently lacking suitable perch trees.

Perch trees could be created or improved by releasing dominant trees along the shore to improve tree height, crown structure, and eagle accessibility. Perch limb accessibility could be improved by pruning, ie. removing small limbs within tree crowns. Additionally, maintain vegetative buffer zones of forested shorelines, preferably 50 m or wider, such that a minimum of one tree per 250 meters of shoreline is $\geq$40 cm dbh, is accessible, and contains suitable perching limbs. Buffer zones are particularly important near high human use areas such as boat ramps and campgrounds.

Nest Site Management

It seems likely that eagles will nest on Jordan and/or Falls Lakes in the future. Therefore, creation of suitable nesting habitat may enhance this prospect or increase the density of bald eagle nesting once it occurs. Bald eagle pairs commonly maintain several nests within each breeding area (Mathisen 1983), so 5-6 potential nest trees should be maintained for each breeding territory. Based on characteristics of bald eagle nest trees in Florida (McEwan and Hirth 1979) and Maryland (Andrew and Mosher 1982), potential nest territories should:

1. contain dominant loblolly pines $\geq$40 cm dbh;
2. be within 1.5 km of good foraging areas;

3. have a low density (< 25 stems/ha) of large trees (> 30 cm dbh) within 50 m of nest trees, or be near a forest edge. The intent is to provide flight corridors into nest trees.

Nesting habitat can be created using techniques similar to those for roosting and perching habitat. Potential nesting territories should be located in areas as isolated from humans as possible. Any additional nest sites that are discovered should be protected and maintained.

Bald Eagle Habitat Management Areas

The Mason Point area is the key habitat parcel on Jordan Lake. It contains the only two known communal roosts, the highest density of eagle use, and the lowest density of human use on Jordan Lake (Smith 1988). Thus, Mason Point should be the primary candidate location for the first attempt to create new roost habitat near Jordan Lake. If suitable habitat could be created there, it would provide a refugia from the human disturbance at the current roost site. A detailed search of the area for the best stand of large trees should precede site selection, but if trees are available, an area adjacent to the small pond on Mason Point might be a good choice. Eagles sometimes forage in such ponds or loaf in their vicinity (J. Fraser pers. comm.). Large trees (especially loblolly pines), with crowns made accessible by roost creation would also be excellent candidates for nest construction.

Several other smaller zones were used frequently by eagles on Jordan and Falls Lakes; eagles would benefit from providing quality perching, nesting, and roosting habitat. Zones that should be considered in this category are the upper reaches of: Big Beaver Creek, Little Beaver Creek, White Oak Creek, and the Haw River on Jordan Lake and the upper reaches of Big Lick Creek, Little Lick Creek, Ledge Creek, Ellerbe Creek, and Knapp of Reeds Creek on Falls Lake.

Prey Base

The current eagle population is good evidence that the current prey base is adequate for existing eagle use, although it could be limiting during the winter. Fish populations in reservoirs usually peak and then fall and stabilize within 5-10 years of the beginning of basin filling (Kimmel and Groeger 1986). Additionally, anthropogenic factors may also have a large impact on reservoir aging (Kimmel and Groeger 1986). Long term maintenance of the eagle populations at Jordan Lake and Falls Lake will require a better understanding of the prey species used by eagles in these areas, likely changes in populations and/or distribution of these species, and management techniques to prevent undesirable changes in prey availability.

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TABLES

Table 1. Descriptions of variables used to describe habitat used by bald eagles on B. Everett Jordan Lake and Falls Lake, North Carolina, 1986-87.

Variable (Units)	Data Sets[a]	Description
Tree Diameter (dbh in cm)	Perch Roost	Diameter of trees measured at breast height (1.4 m from ground).
Tree Height (m)	Perch Roost	Height from ground to tallest point on tree.
Bole Length (m)	Perch Roost	Height from the ground to the bottom of the tree crown.
Crown Length (m)	Perch Roost	Tree height minus bole height.
Foliage Volume (%)	Perch Roost	Ocular estimate of the percentage of a parallelepiped filled with vegetation.
Canopy Cover (%)	Roost	The percent of area above 2 m covered by vegetation.
Large Tree Density (trees/ha)	Perch Roost	Density of trees greater than 20 cm diameter at breast height.
Distance to Forest Edge (m)	Perch Roost	Distance from tree or sampling point to the nearest boundary between closed canopy forest and open habitat types.
Distance to Road (m)	Roost	Distance from tree or sampling point to the nearest road.
Distance to Shore (m)	Perch	Distance from tree to the nearest point on the shore.
Water Depth Index (m)	Perch	Distance from tree or sampling point to a specified elevation contour.
Slope (%)	Perch	Slope of land relative to horizontal.
Crown Accessibility (Deg)[b]	Perch Roost	The arc of an imaginary circle centered on the middle of a tree crown that is unobstructed by neighboring trees.
Aspect of Forest Edge (Deg)	Perch	Direction from sample point or tree to open water. Perpendicular to forest edge direction.
Angle of Forest Edge (Deg)	Perch	Arc formed by sighting down a forest edge from a fixed point and rotating until the forest edge is encountered again.

Table 1. Continued.

Variable (Units)	Data Sets[a]	Description
Crown Type (Cat)[c]	Perch Roost	Describes the condition of a tree crown based on the distribution of leafless limbs.
Perch Location (Cat)	Perch	Position of perched eagles in tree crown (top, middle, bottom).
Accessible Limbs (Cat)	Perch Roost	Number of suitable perch limbs on a tree or within a sample area (0, 1-2, > 2). Suitable perch limbs include those sloping less than 30 degrees from horizontal, greater than 5 cm diameter at base, and ≥ 1 m from limbs above and below.

[a] Perch = habitat characteristic of perch trees or sites. Roost = habitat characteristic of roost trees or areas.
[b] Degrees.
[c] Categorical variables.

Table 2. Habitat characteristics of the Morgan Creek (n = 6 points) and Mason Point (n = 20 points) communal bald eagle roosts and random points (n = 80 points) at B. Everett Jordan Lake, North Carolina, 1987.

Variable	P^a	$\bar{x}$	SE
Large Tree Density (trees/ha)	< 0.001		
Morgan Creek		115 A[b]	--
Mason Point		27 B	--
Random Points		345 C	--
Dbh (cm)	< 0.001		
Morgan Creek		42.4 A	0.3
Mason Point		43.3 A	0.5
Random Points		28.7 B	1.1
Tree Height (m)	< 0.001		
Morgan Creek		21.1 A	0.9
Mason Point		24.8 B	0.5
Random Points		19.2 A	0.3
Distance to Forest Edge (m)	< 0.001		
Morgan Creek		23 A	10
Mason Point		53 B	7
Random Points		124 C	11
Foliage Volume < 2 m (%)	< 0.001		
Morgan Creek		43 A	10
Mason Point		45 A	4
Random Points		17 B	1
Canopy Cover (%)	< 0.001		
Morgan Creek		42 A	15
Mason Point		16 A	16
Random Points		93 B	2

[a] Kruskal-Wallis test (Conover 1971) of the null hypothesis that the means for roosts and random points are equal.
[b] Column means with different letters are significantly different (Wilcoxon rank sum test, maximum experimentwise error rate for each variable controlled at 0.05 by setting the comparisonwise error rate at $\alpha = 0.0167$ (SAS 1985:472)).

Table 3. Pearson's correlations of bald eagle roost characteristics on the first two principal components derived using data from roosts and random points (n = 106) at B. Everett Jordan Lake, North Carolina, 1987.

Variable	Principal Component One	Principal Component Two
Large Tree Density (trees ≥20 cm dbh/ha)	-0.49	0.33
Tree Diameter (cm)	0.89	0.27
Tree Height (m)	0.73	0.56
Distance to Forest Edge (m)	-0.55	0.60
Foliage Volume < 2 m (%)	0.67	-0.20
Canopy Cover (%)	-0.90	0.02
Variation Accounted For (%)	52	15
Cumulative Variation Accounted For (%)	52	67

Table 4. Characteristics of bald eagle roost trees and randomly selected trees within Morgan Creek and Mason Point communal roosts at B. Everett Jordan Lake, North Carolina, 1987.

		Roost Trees			Random Trees		
Variable	P	n	$\bar{x}$	SE	n	$\bar{x}$	SE
Dbh (cm)							
Morgan Creek	< 0.001[a]	24	56.3	2.5	30	33.2	1.9
Mason Point	0.576[b]	12	44.5	1.3	31	45.7	1.2
Tree Height (m)							
Morgan Creek	0.376[b]	24	24.4	1.2	30	22.9	1.1
Mason Point	0.008[a]	12	28.0	0.5	31	25.5	0.6
Bole Length (m)							
Morgan Creek	0.177[b]	24	11.0	0.5	30	9.9	0.7
Mason Point	0.008[b]	12	16.1	0.9	31	13.7	0.4
Crown Length (m)							
Morgan Creek	0.834[b]	24	13.4	1.0	30	13.1	1.0
Mason Point	0.850[a]	12	11.9	1.0	31	11.8	0.5
Crown Accessibility (degrees)							
Morgan Creek	< 0.001[a]	24	328	11	30	184	26
Mason Point	0.144[a]	12	299	33	31	352	5
Distance to Forest Edge (m)							
Morgan Creek	< 0.001[a]	24	12.4	3.7	30	28.4	3.4
Mason Point	0.191[b]	12	45.7	12.8	31	65.2	7.6
Distance to Road (m)							
Morgan Creek	--	--	--	--	--	--	--
Mason Point	0.016[b]	12	193.5	25.4	31	134.2	11.1
Dead Hardwoods (%)							
Morgan Creek	< 0.001[c]	24	79.2	--	30	20.0	--
Mason Point	--	12	0.0	--	31	0.0	--
Loblolly Pines (%)							
Morgan Creek	--	24	0.0	--	30	0.0	--
Mason Point	0.675[c]	12	91.7	--	31	87.1	--

[a] Wilcoxon rank sum test of the null hypothesis that there was no difference between roost trees and random trees within each roost.
[b] T-test of the null hypothesis that there was no difference between roost trees and random trees within each roost.
[c] Chi-square test of the null hypothesis that there was no difference in proportions of tree species.

Table 5. Characteristics of bald eagle perch trees and paired trees at B. Everett Jordan Lake (n = 53 pairs) and Falls Lake (n = 14 pairs), North Carolina, 1986-87. We chose the two trees closest to the perch trees and ≥20 cm as paired trees.

Variable	P	$\bar{x}$	SE
Dbh (cm)	< 0.0001[a]		
Perch Trees		41.5	1.5
Paired Trees[b]		32.0	1.0
Tree Height (m)	< 0.0001[c]		
Perch Trees		22.9	0.6
Paired trees		19.8	0.7
Bole Height (m)	< 0.0001[a]		
Perch trees		11.8	0.5
Paired trees		10.1	0.4
Crown Length (m)	0.032[a]		
Perch trees		11.2	0.4
Paired trees		10.2	0.4
Distance to Forest Edge (m)	0.002[c]		
Perch trees		6.9	3.6
Paired trees		7.6	3.3
Crown Accessibility (Degrees open)	< 0.0001[a]		
Perch trees		238	12
Paired trees		147	13

[a] Paired t-test of the null hypothesis that there was no difference between perch trees and paired trees.
[b] When possible, we measured two paired trees per perch tree and used the mean values for analyses.
[c] Signed rank test of the null hypothesis that there was no difference between perch trees and paired trees.

Table 6. Foliage volume (%) for all 4 transects sampled at bald eagle perch sites and paired random sites (n = 64 pairs) at B. Everett Jordan Lake and Falls Lake, North Carolina, 1986-87.

Height (m)	P	$\bar{x}$	SE
0 - 2	0.8315[a]		
Perch sites		24.3	1.4
Random sites		24.1	1.4
2 - 5	0.9045[a]		
Perch sites		22.7	1.4
Random sites		22.8	1.5
5 - 10	0.6136[a]		
Perch sites		26.6	1.6
Random sites		27.5	1.5
10 - 15	0.1387[a]		
Perch sites		30.9	1.7
Random sites		33.7	1.9
15 - 20	0.1444[a]		
Perch sites		36.5	2.2
Random sites		33.3	2.4
20 - 25	0.0032[b]		
Perch sites		23.8	2.2
Random sites		17.9	2.0
25 - 35	0.0014[b]		
Perch sites		2.9	0.8
Random sites		1.0	0.4

[a] Paired t-test of the null hypothesis that there was no difference in vegetation volume between perch sites and random sites.
[b] Signed rank test of the null hypothesis that there was no difference in vegetation volume between perch sites and random sites.

Table 7. Foliage volume (%) for front transects sampled at bald eagle perch sites and paired random sites (n = 64 pairs) at B. Everett Jordan Lake and Falls Lake, North Carolina, 1986-87.

Height (m)	P	$\bar{x}$	SE
0 - 2	0.7154[a]		
Perch sites		27.9	2.1
Random sites		29.2	2.2
2 - 5	0.8045[b]		
Perch sites		22.7	1.4
Random sites		22.8	1.5
5 - 10	0.1428[b]		
Perch sites		22.0	1.8
Random sites		25.6	2.0
10 - 15	0.0929[b]		
Perch sites		26.9	2.1
Random sites		31.7	2.5
15 - 20	0.1854[b]		
Perch sites		34.7	2.6
Random sites		30.4	2.8
20 - 25	0.0038[b]		
Perch sites		22.7	2.7
Random sites		13.3	2.0
25 - 35	0.0053[a]		
Perch sites		2.9	1.0
Random sites		0.8	0.4

[a] Signed rank test of the null hypothesis that there was no difference in vegetation volume between perch sites and random sites.
[b] Paired t-test of the null hypothesis that there was no difference in vegetation volume between perch sites and random sites.

Table 8. Foliage volume (%) of the crowns of bald eagle perch trees and paired random trees (n = 64 pairs) at B. Everett Jordan Lake and Falls Lake, North Carolina, 1986-87.

Height	P[a]	$\bar{x}$	SE
Top	0.5609		
Perch trees		20.1	1.9
Random trees		18.6	2.1
Middle	0.4581		
Perch trees		42.2	2.6
Random trees		39.9	2.3
Bottom	0.8604		
Perch trees		36.0	2.5
Random trees		36.6	2.2

[a] Paired t-test of the null hypothesis that there was no difference in vegetation volume between perch sites and random sites.

Table 9. Foliage volume (%) of front and middle transects within bald eagle perch sites (n = 67) at B. Everett Jordan Lake and Falls Lake, North Carolina, 1986-87.

Height (m)	P	$\bar{x}$	SE
0 - 2	0.0458[a]		
Front		26.9	2.1
Middle		22.3	1.8
2 - 5	0.4166[a]		
Front		22.3	1.9
Middle		20.9	1.8
5 - 10	0.0511[a]		
Front		21.2	1.8
Middle		25.1	1.9
10 - 15	0.0222[a]		
Front		25.8	2.1
Middle		31.2	2.3
15 - 20	0.0809[b]		
Front		33.2	2.6
Middle		37.8	2.6
20 - 25	0.0905[b]		
Front		21.7	2.7
Middle		25.8	2.8
25 - 35	0.7507[b]		
Front		2.8	0.9
Middle		3.0	0.9

[a] Paired t-test of the null hypothesis that there was no difference in vegetation volume between transects.
[b] Signed rank test of the null hypothesis that there was no difference in vegetation volume between transects.

Table 10. Foliage volume (%) of middle and side transects within bald eagle perch sites (n = 67) at B. Everett Jordan Lake and Falls Lake, North Carolina, 1986-87.

Height (m)	P	$\bar{x}$	SE
0 - 2	0.9532[a]		
Middle		23.3	1.8
Sides		22.4	1.6
2 - 5	0.1060[b]		
Middle		20.9	1.8
Sides		22.0	1.4
5 - 10	0.0800[a]		
Middle		25.1	1.9
Sides		27.9	1.9
10 - 15	0.7378[a]		
Middle		31.2	2.3
Sides		30.6	2.0
15 - 20	0.0833[a]		
Middle		37.8	2.6
Sides		34.2	2.5
20 - 25	0.0905[b]		
Middle		25.8	2.8
Sides		21.7	2.4
25 - 35	0.1658[b]		
Middle		3.0	0.9
Sides		2.6	0.8

[a] Paired t-test of the null hypothesis that there was no difference in vegetation volume between transects.

[b] Signed rank test of the null hypothesis that there was no difference in vegetation volume between transects.

Table 11. Habitat characteristics at bald eagle perch sites and paired random sites (n = 64 pairs) at B. Everett Jordan Lake and Falls Lake, North Carolina, 1986-87.

Variable	P	$\bar{x}$	SE
Slope (degrees)	0.9418[a]		
Perch sites		7.8	1.0
Random sites		8.3	1.0
Angle of Open Forest Edge (degrees)	0.1280[b]		
Perch sites		191	4
Random sites		183	3
Water Depth Index (m)	0.3551[a]		
Perch sites		106	21
Random sites		101	19
Distance to Shore (m)	0.4692[a]		
Perch sites		12.4	3.5
Random sites		10.5	2.7
Aspect of Forest Edge (direction)	0.581[c]		
Perch sites		--	--
Random sites		--	--
Large Tree Density (trees ≥20 cm dbh/ha)	0.0818[a]		
Perch sites		355	19
Random sites		325	22
Species Density (trees ≥20 cm dbh/ha)			
pines	0.0060[a]		
Perch sites		197	22
Random sites		137	23
oaks	0.1857[a]		
Perch sites		52	10
Random sites		78	15
snags	0.7711[a]		
Perch sites		44	12
Random sites		31	9
sweetgum	0.8820[a]		
Perch sites		43	12
Random sites		44	11
others	0.1493[a]		
Perch sites		16	6
Random sites		31	8

[a] Signed rank test of the null hypothesis that there was no difference between perch sites and paired random sites.
[b] Paired t-test of the null hypothesis that there was no difference between perch sites and random sites.
[c] Chi-square test of the null hypothesis that there was no difference between perch sites and random sites.

Table 12. Forest composition (%) of 1 ha blocks centered on random sites at B. Everett Jordan Lake (n = 75) and Falls Lake (n = 16), North Carolina, 1986-87[a].

Cover Class	P[b]	$\bar{x}$	SE
Pine	0.8087		
Jordan Lake		31.6	3.8
Falls Lake		29.1	8.4
Hardwood	0.9874		
Jordan Lake		43.6	4.1
Falls Lake		43.1	8.8
Open	0.1408		
Jordan Lake		11.1	2.7
Falls Lake		25.1	8.1
Flooded Timber	0.3552		
Jordan Lake		3.9	2.1
Falls Lake		0.0	0.0
Water	0.0140		
Jordan Lake		9.9	1.5
Falls Lake		2.8	2.1

[a] Data were taken from 1:1320 scale aerial photographs taken 19 May 1985 for Jordan Lake and 24 June 1983 for Falls Lake.
[b] Wilcoxon rank sum tests of the null hypothesis that there were no differences between lakes.

Table 13. Forest composition (%) of 1 ha blocks centered on bald eagle use sites at B. Everett Jordan Lake (n = 165) and Falls Lake (n = 16), North Carolina, 1986-87[a].

Cover Class	P[b]	$\bar{x}$	SE
Pine	0.5336		
Jordan Lake		32.4	2.8
Falls Lake		36.2	8.8
Hardwood	0.2222		
Jordan Lake		47.4	2.7
Falls Lake		36.1	8.3
Open	0.3779		
Jordan Lake		5.7	0.9
Falls Lake		9.0	3.7
Flooded Timber	0.1552		
Jordan Lake		5.9	1.8
Falls Lake		10.4	6.6
Water	0.1617		
Jordan Lake		8.7	1.2
Falls Lake		8.4	5.7

[a] Data were taken from 1:1320 scale aerial photographs taken 19 May 1985 for Jordan Lake and 24 June 1983 for Falls Lake.
[b] Wilcoxon rank sum tests of the null hypothesis that there were no differences between lakes.

Table 14. Forest composition (%) of 1 ha blocks centered on bald eagle use sites (n = 165) and random sites (n = 75) at B. Everett Jordan Lake, North Carolina, 1986-87[a].

Cover Class	P[b]	$\bar{x}$	SE
Pine	0.9061		
Use sites		32.4	2.8
Random sites		31.6	3.8
Hardwood	0.4277		
Use sites		47.4	2.7
Random sites		43.6	4.1
Open	0.1837		
Use sites		5.7	0.9
Random sites		11.1	2.7
Flooded Timber	0.4732		
Use sites		5.9	1.8
Random sites		3.9	2.1
Water	0.1617		
Use sites		8.7	1.2
Random sites		9.9	1.5

[a] Data were taken from 1:1320 scale aerial photographs taken 19 May 1985.
[b] Wilcoxon rank sum tests of the null hypothesis that there were no difference between eagle use sites and random sites.

Table 15. Forest composition (%) of 1 ha blocks centered on bald eagle use sites (n = 16) and random sites (n = 16) at Falls Lake, North Carolina, 1986-87[a].

Cover Class	P[b]	$\bar{x}$	SE
Pine	0.6294		
Use sites		36.2	8.8
Random sites		29.1	8.4
Hardwood	0.5636[c]		
Use sites		36.1	8.3
Random sites		43.1	8.8
Open	0.1932		
Use sites		9.0	3.7
Random sites		25.1	8.1
Flooded Timber	0.0798		
Use sites		10.4	6.6
Random sites		0.0	0.0
Water	0.9216		
Use sites		8.4	5.7
Random sites		2.8	2.1

[a] Data were taken from 1:1320 scale aerial photographs taken 24 June 1983.
[b] Wilcoxon rank sum tests of the null hypothesis that there were no differences between bald eagle use sites and random sites.
[c] T-test of the null hypothesis that there was no difference between bald eagle use sites and random sites.

Table 16. Distance (m) to habitat disturbances from random sites at B. Everett Jordan Lake (n = 75) and Falls Lake (n = 18), North Carolina, 1986-87[a].

Disturbance	P	$\bar{x}$	SE
House	0.0353[b]		
Jordan Lake		1139	78
Falls Lake		801	69
Dirt Road	0.6353[c]		
Jordan Lake		765	50
Falls Lake		713	85
Paved Road	0.2826[b]		
Jordan Lake		957	63
Falls Lake		802	107
Field[d]	0.0114[b]		
Jordan Lake		600	53
Falls Lake		316	73
Forest cut[e]	0.2010[b]		
Jordan Lake		950	104
Falls Lake		1005	146
Powerline	0.0001[c]		
Jordan Lake		6307	276
Falls Lake		2993	471
Campground (under construction)	0.7336[b]		
Jordan Lake		4723	343
Falls Lake		5342	903

[a] Data were obtained from 7.5′ topographic maps (revised 1981) and verified using 1:1320 scale aerial photographs taken 19 May 1985 for Jordan Lake and 24 June 1983 for Falls Lake.
[b] Wilcoxon rank sum test of the null hypothesis that there was no difference between lakes.
[c] T-test of the null hypothesis that there was no difference between lakes.
[d] Minimum size of 0.6 ha.
[e] Forest cuts were at least 0.15 ha and contained tree regrowth that had not attained the height of the surrounding forest.

Table 17. Distance (m) to habitat disturbances from bald eagle use sites at B. Everett Jordan Lake (n = 165) and Falls Lake (n = 16), North Carolina, 1986-87[a].

Disturbance	P	$\bar{x}$	SE
House	0.0114[b]		
Jordan Lake		964	43
Falls Lake		612	80
Dirt Road	0.0931[b]		
Jordan Lake		852	32
Falls Lake		686	101
Paved Road	0.4068[b]		
Jordan Lake		1133	41
Falls Lake		1026	112
Field[c]	0.0369[b]		
Jordan Lake		510	29
Falls Lake		309	54
Forest cut[d]	0.7041[b]		
Jordan Lake		770	42
Falls Lake		776	150
Powerline	0.0001[e]		
Jordan Lake		5138	208
Falls Lake		1326	141
Campground (under construction)	$<$ 0.0001[b]		
Jordan Lake		7134	288
Falls Lake		1874	561

[a] Data were obtained from 7.5′ topographic maps (revised 1981) and verified using 1:1320 scale aerial photographs taken 19 May 1985 for Jordan Lake and 24 June 1983 for Falls Lake.
[b] Wilcoxon rank sum test of the null hypothesis that there was no difference between lakes.
[c] Minimum size of 0.6 ha.
[d] Forest cuts were at least 0.15 ha and contained tree regrowth that had not attained the height of the surrounding forest.
[e] T-test of the null hypothesis that there was no difference between lakes.

Table 18. Distance (m) to habitat disturbances from bald eagle use sites and random sites (n = 75) at B. Everett Jordan Lake (n = 165), North Carolina, 1986-87[a].

Disturbance	P	$\bar{x}$	SE
House	0.0303[b]		
Use sites		964	43
Random sites		1139	78
Dirt Road	0.1591[b]		
Use sites		852	32
Random sites		765	50
Paved Road	0.0152[b]		
Use sites		1133	41
Random sites		957	63
Field[c]	0.2394[b]		
Use sites		510	29
Random sites		600	53
Forest cut[d]	0.8168[b]		
Use sites		770	42
Random sites		950	104
Powerline	0.0014[e]		
Use sites		5138	208
Random sites		6307	276
Campground (in use)	< 0.0001[b]		
Use sites		6004	262
Random sites		3359	321
Campground (under construction)	< 0.0001[b]		
Use sites		7134	288
Random sites		4723	343

[a] Data were obtained from 7.5′ topographic maps (revised 1981) and verified using 1:1320 scale aerial photographs taken 19 May 1985.
[b] Wilcoxon rank sum test of the null hypothesis that there was no difference between bald eagle use sites and random sites.
[c] Minimum size of 0.6 ha.
[d] Forest cuts were at least 0.15 ha and contained tree regrowth that had not attained the height of the surrounding forest.
[e] T-test of the null hypothesis that there was no difference between bald eagle use sites and random sites.

Table 19. Distance (m) to habitat disturbances from bald eagle use sites (n = 16) and random sites (n = 18) at Falls Lake (n = 16), North Carolina, 1986-87[a].

Disturbance	P	$\bar{x}$	SE
House	0.0808[b]		
Use sites		612	80
Random sites		801	69
Dirt Road	0.8354[b]		
Use sites		686	101
Random sites		713	85
Paved Road	0.1334[c]		
Use sites		1026	112
Random sites		802	107
Field[d]	0.7427[c]		
Use sites		309	54
Random sites		316	73
Forest cut[e]	0.1623[c]		
Use sites		776	150
Random sites		1005	146
Powerline	0.0029[b]		
Use sites		1326	141
Random sites		2993	471
Campground (under construction)	0.0005[c]		
Use sites		1874	561
Random sites		5342	903

[a] Data were obtained from 7.5′ topographic maps (revised 1981) and verified using 1:1320 scale aerial photographs taken 24 June 1983.
[b] T-test of the null hypothesis that there was no difference between bald eagle use sites and random sites.
[c] Wilcoxon rank sum test of the null hypothesis that there was no difference between bald eagle use sites and random sites.
[d] Minimum size of 0.6 ha.
[e] Forest cuts were at least 0.15 ha and contained tree regrowth that had not attained the height of the surrounding forest.

FIGURES

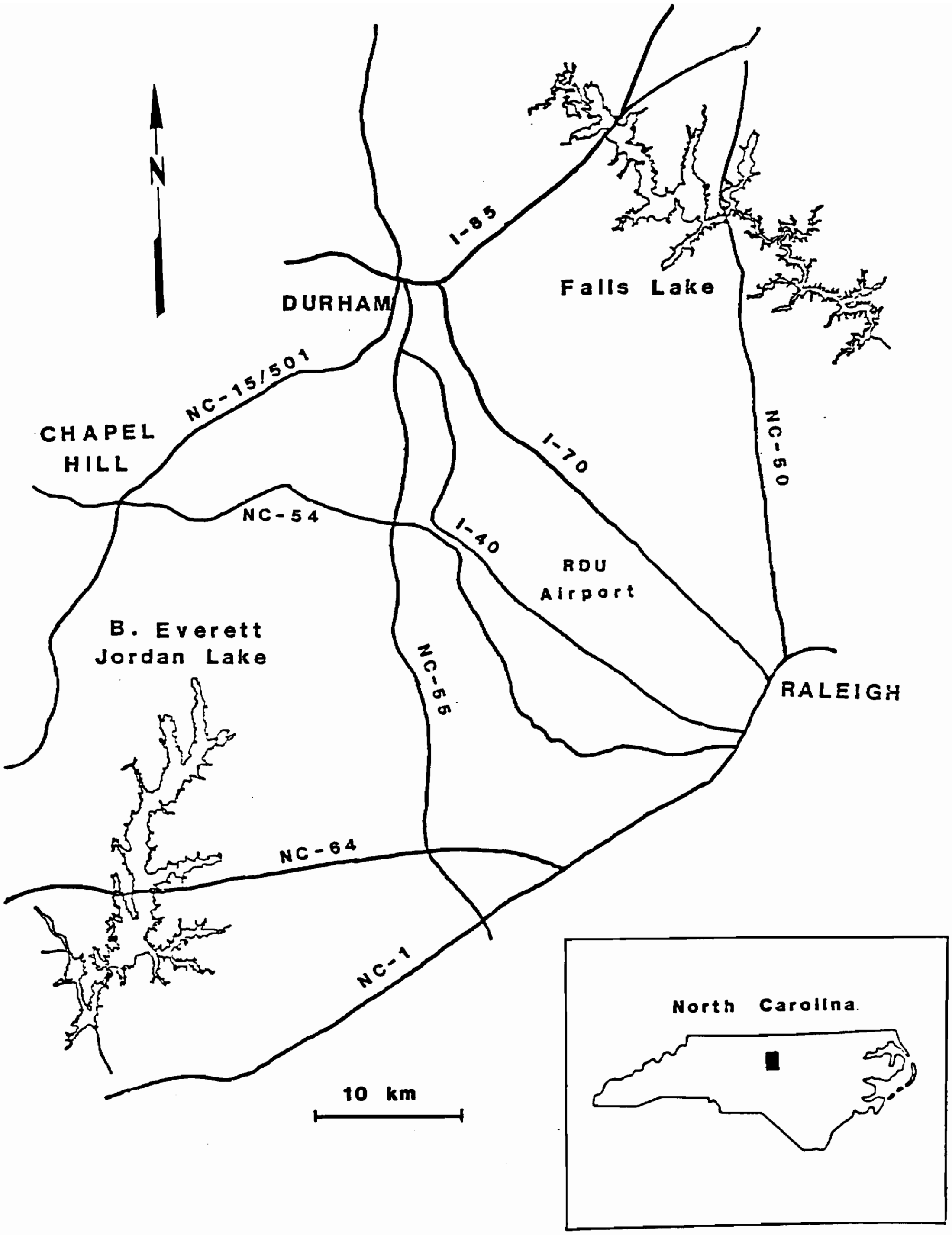

Figure 1. Locations of B. Everett Jordan Lake and Falls Lake, North Carolina.

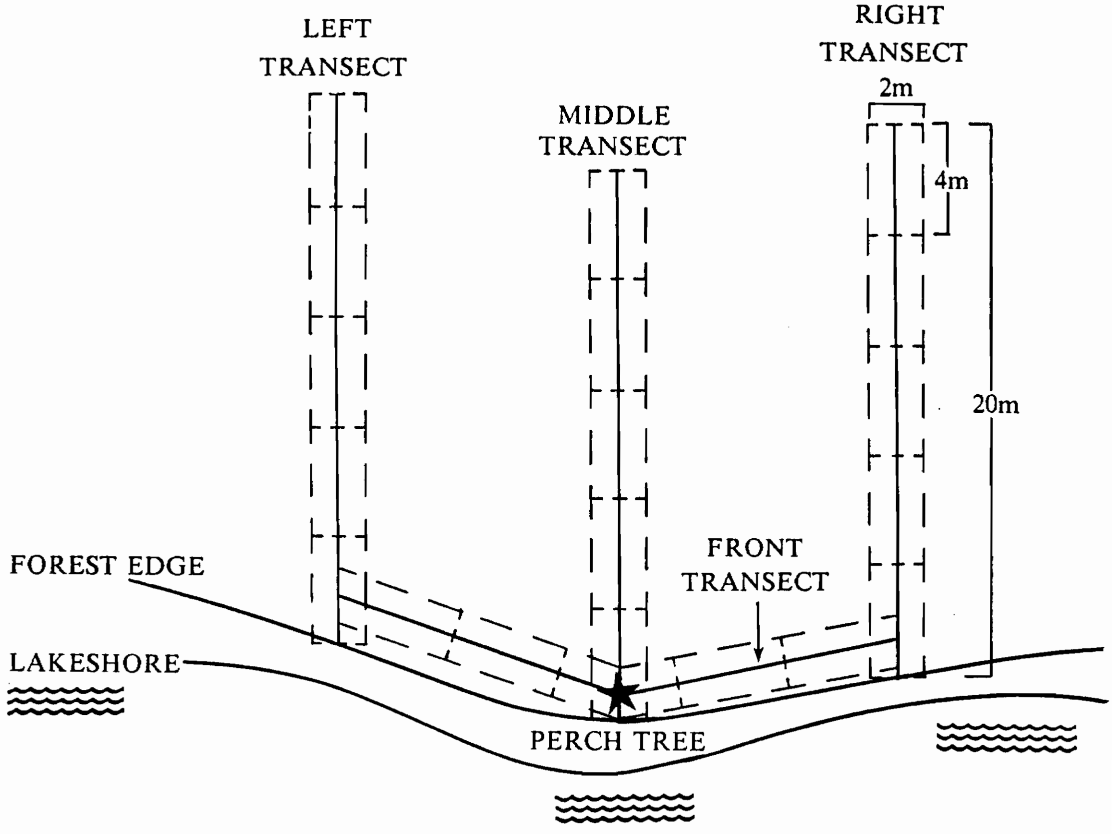

Figure 2. Overhead view of the sampling scheme used to estimate foliage volume and accessible limbs at bald eagle perch sites and paired random sites, B. Everett Jordan Lake and Falls Lake, North Carolina.

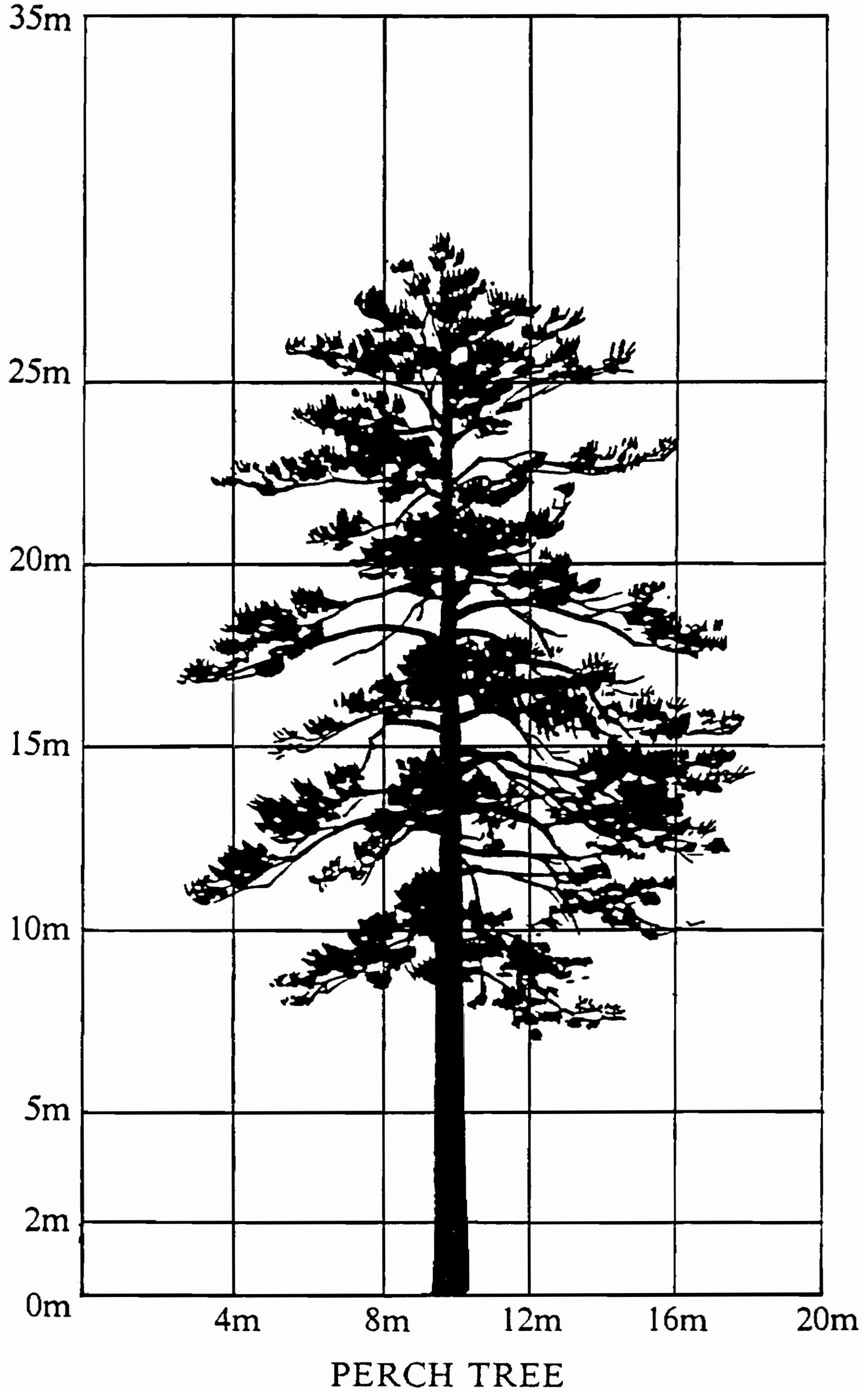

Figure 3. Front view of the sampling scheme used to estimate foliage volume and accessible limbs at bald eagle perch sites and paired random sites, B. Everett Jordan Lake and Falls Lake, North Carolina.

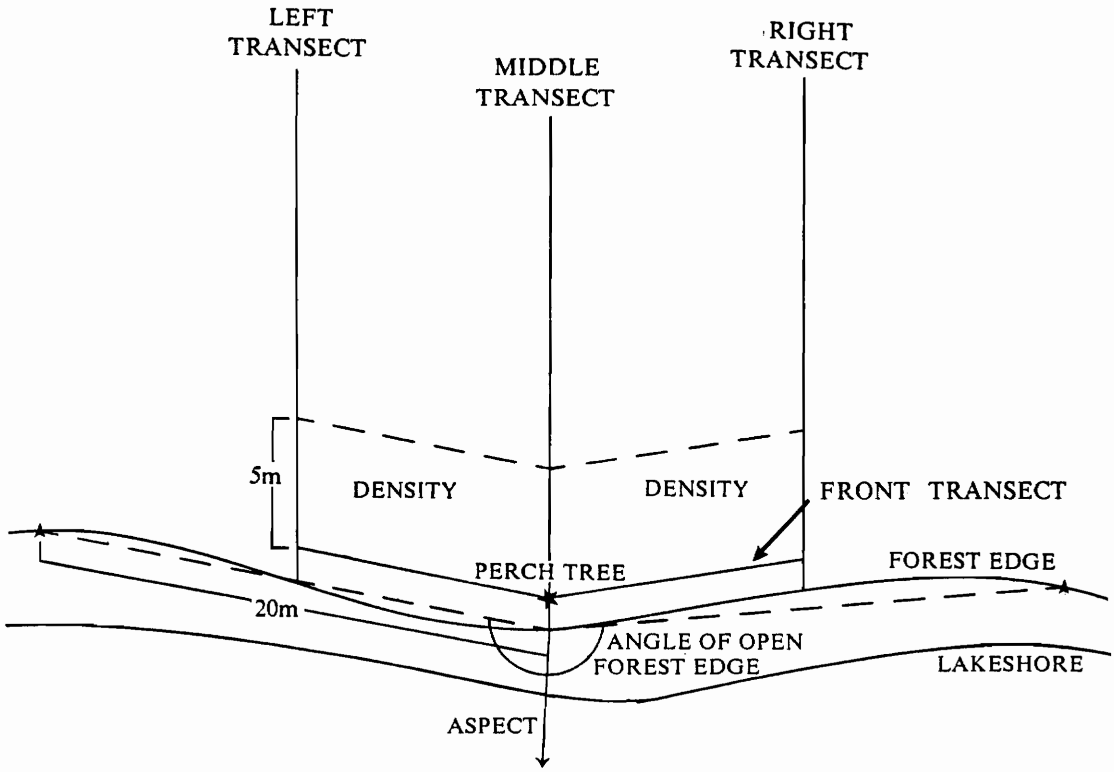

Figure 4. Sampling scheme for edge angle, aspect of forest edge, and large tree density at bald eagle perch sites and paired random sites, B. Everett Jordan Lake and Falls Lake, North Carolina.

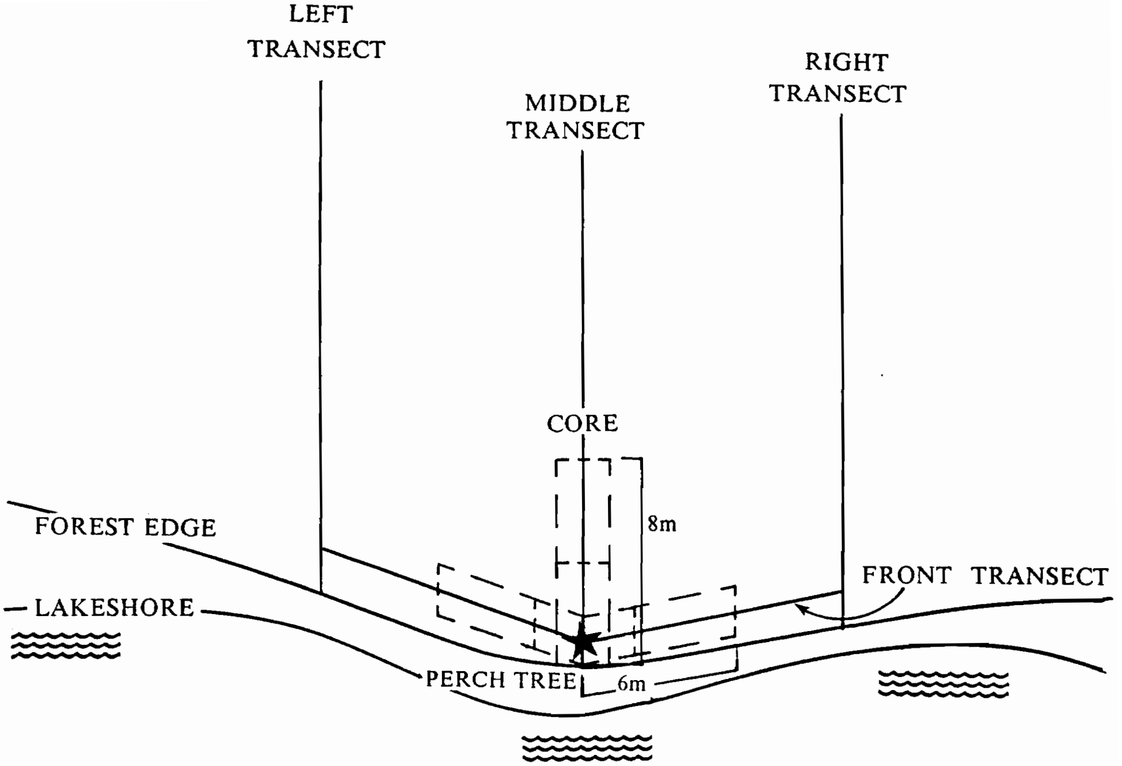

Figure 5. Overhead view of the core area used to compare bald eagle perch trees and paired random trees, B. Everett Jordan Lake and Falls Lake, North Carolina.

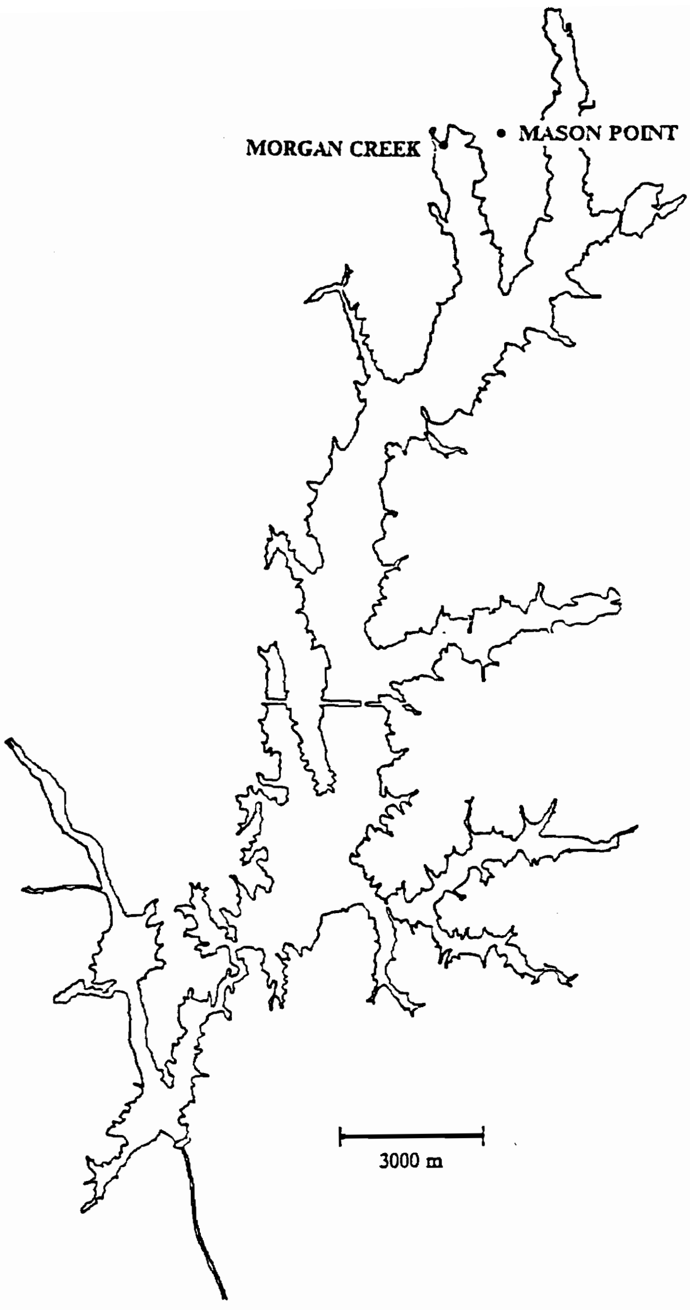

Figure 6. Locations of the Morgan Creek and Mason Point bald eagle roosts, B. Everett Jordan Lake, North Carolina.

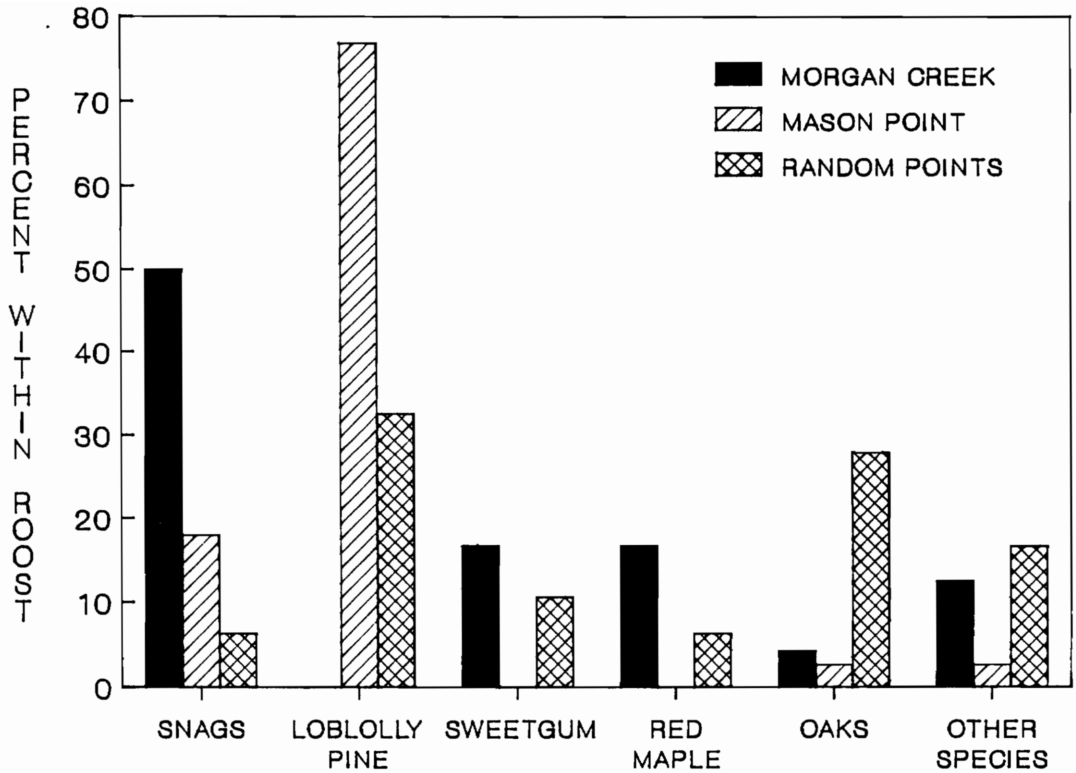

Figure 7. Tree species composition of the Morgan Creek bald eagle roost (n = 24 trees) and the Mason Point (n = 78 trees) bald eagle roost and at points along randomly located transects within 6 km of the midpoint between the roosts (n = 320 trees) at B. Everett Jordan Lake, North Carolina, 1987.

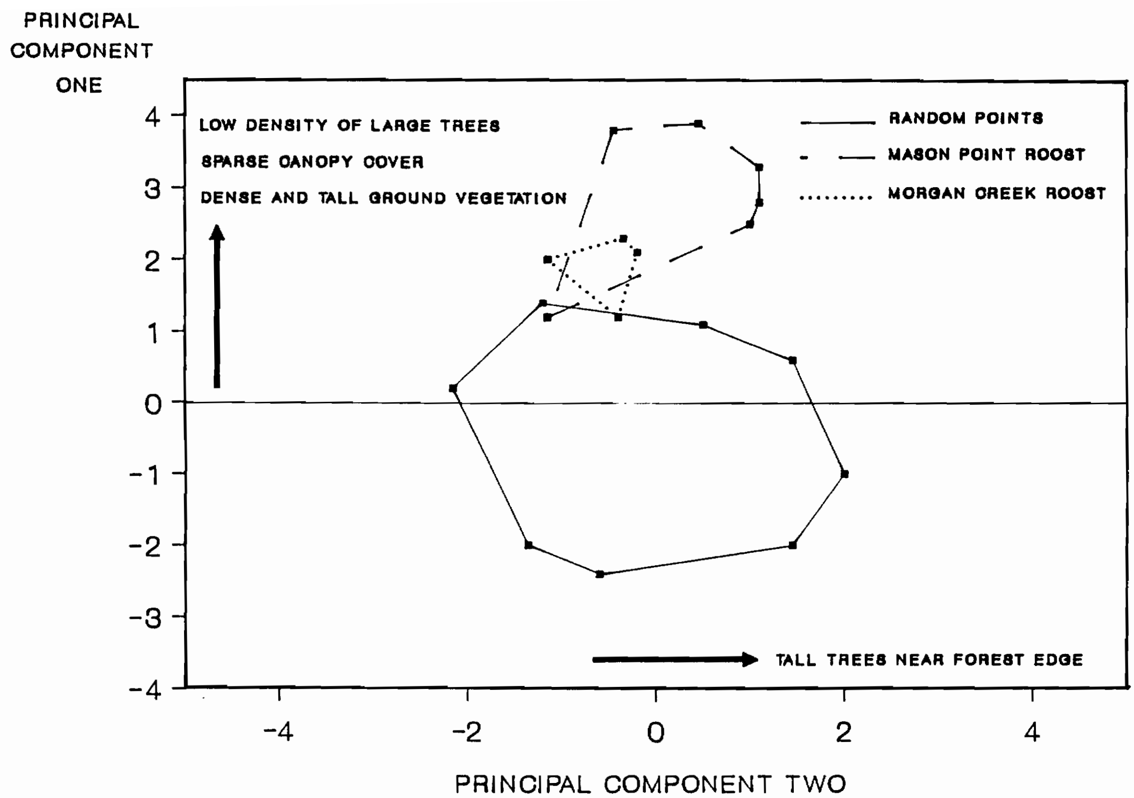

Figure 8. Distribution of habitat samples from the Morgan Creek bald eagle roost (n = 6) and the Mason Point bald eagle roost (n = 20) and random points (n = 80) along 2 habitat axes defined by a principal components analysis of random data from B. Everett Jordan Lake, North Carolina, 1987. Principal component one explains 52% and principal component two explains 15% of the variation in the data. Lines connect the outermost observations of each roost and the random points.

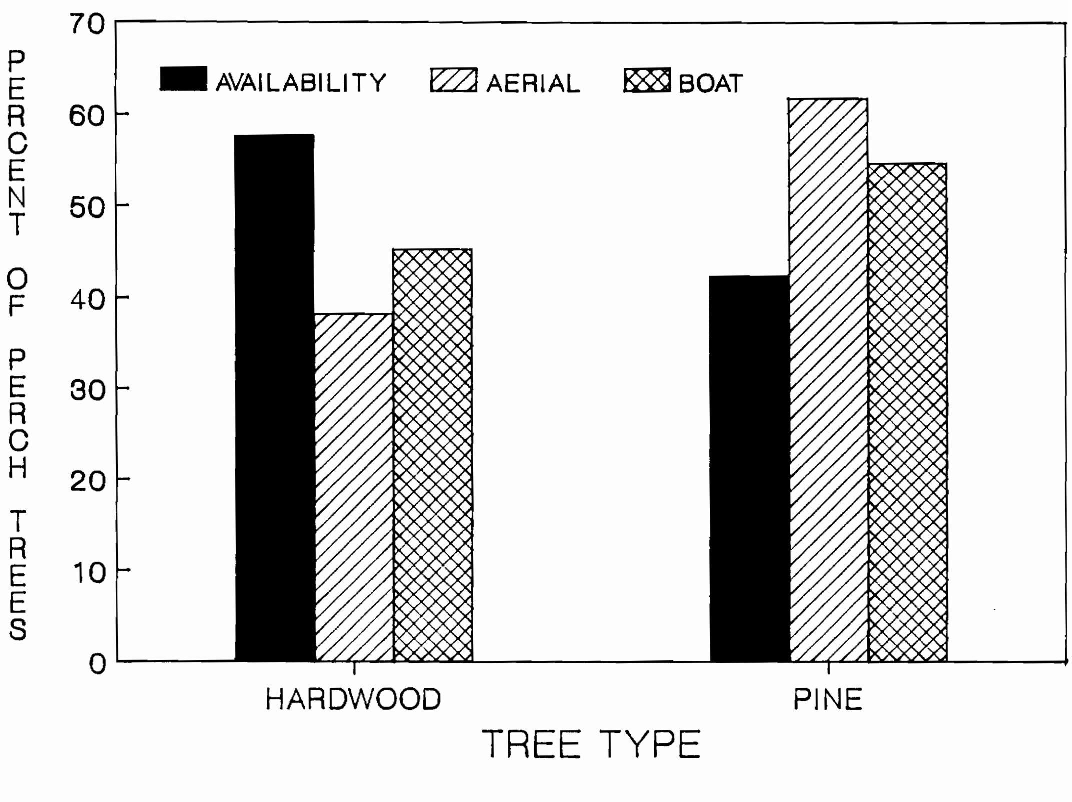

Figure 9. Observed use of tree types (n = 727) by bald eagles during aerial and boat surveys conducted after 1100 during May through September on B. Everett Jordan Lake and Falls Lake, North Carolina, 1986-87. Eagles used tree types in different proportions than they were available ($P < 0.001$, df $= 1$, $\chi^2 = 12.9$; $P = 0.002$, df $= 1$, $\chi^2 = 9.5$, for aerial and boat surveys, respectively).

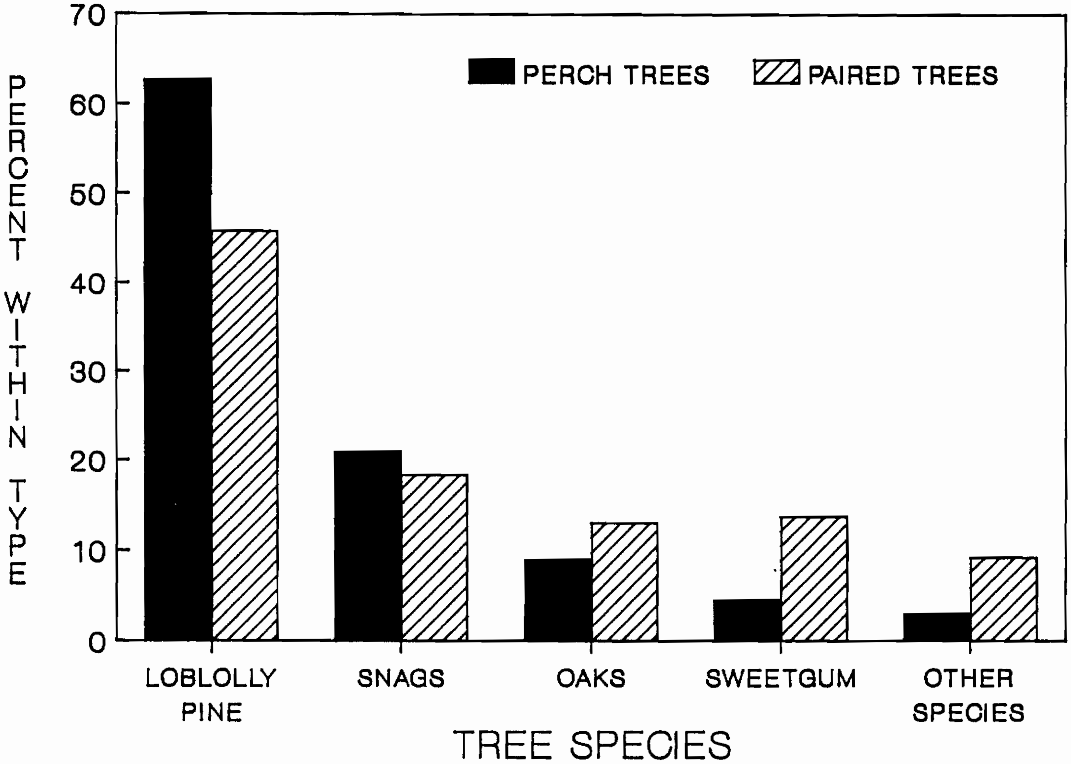

Figure 10. Species composition of bald eagle perch trees (n = 67) and adjacent trees (n = 131), B. Everett Jordan Lake and Falls Lake, North Carolina, 1987 ($P = 0.056$, df = 4, $\chi^2 = 9.2$).

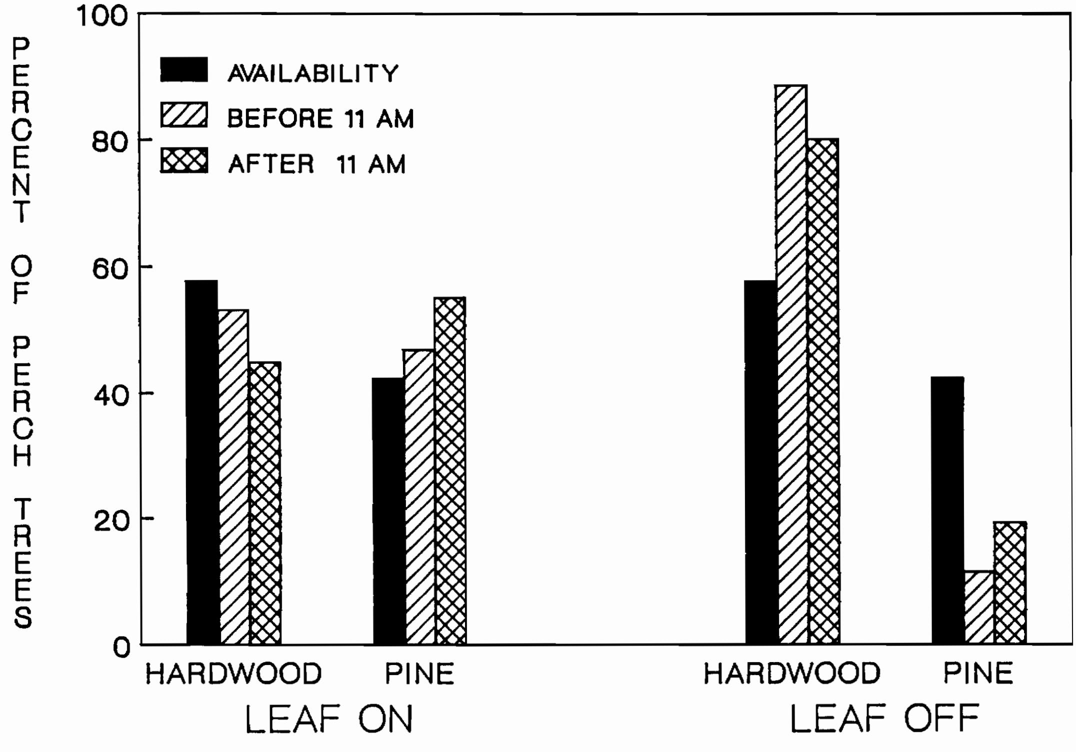

Figure 11. Observed use of tree types (n = 401) by bald eagles by time of day and season during aerial surveys of B. Everett Jordan Lake and Falls Lake, North Carolina, 1986-87. Eagles used different tree types between seasons (χ^2 = 42.2, df = 1, P < 0.001) and times of day during leaf-on (χ^2 = 4.2, df = 1, P = 0.041) but not by time of day during leaf-off (χ^2 = 0.7, df = 1, P = 0.395). Eagle use of tree types was not significantly different from availability before 1100 during leaf-on (χ^2 = 0.8, df = 1, P = 0.363) but was different during all other periods (χ^2 = 10.7, df = 1, P = 0.001; χ^2 = 12.1, df = 1, P < 0.001; χ^2 = 5.1, df = 1, P = 0.023 for leaf-on after 1100, leaf-off before 1100, and leaf-off after 1100 respectively).

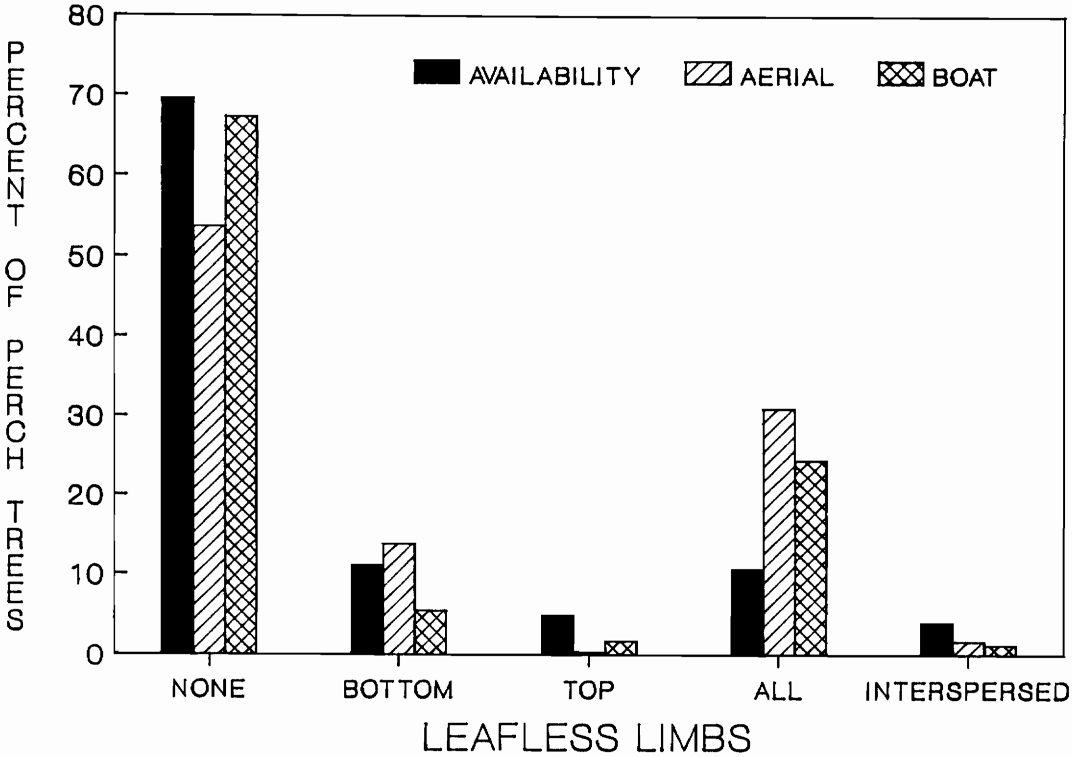

Figure 12. Observed use of perch tree crown types (n = 710) by bald eagles during aerial and boat surveys of B. Everett Jordan Lake and Falls Lake, North Carolina. Data are for surveys conducted after 1100, May through September 1986-87. Use differed from availability for both survey types (χ^2 = 28.2, df = 4, P < 0.001, aerial surveys; χ^2 = 32.8, df = 4, P < 0.001 boat surveys).

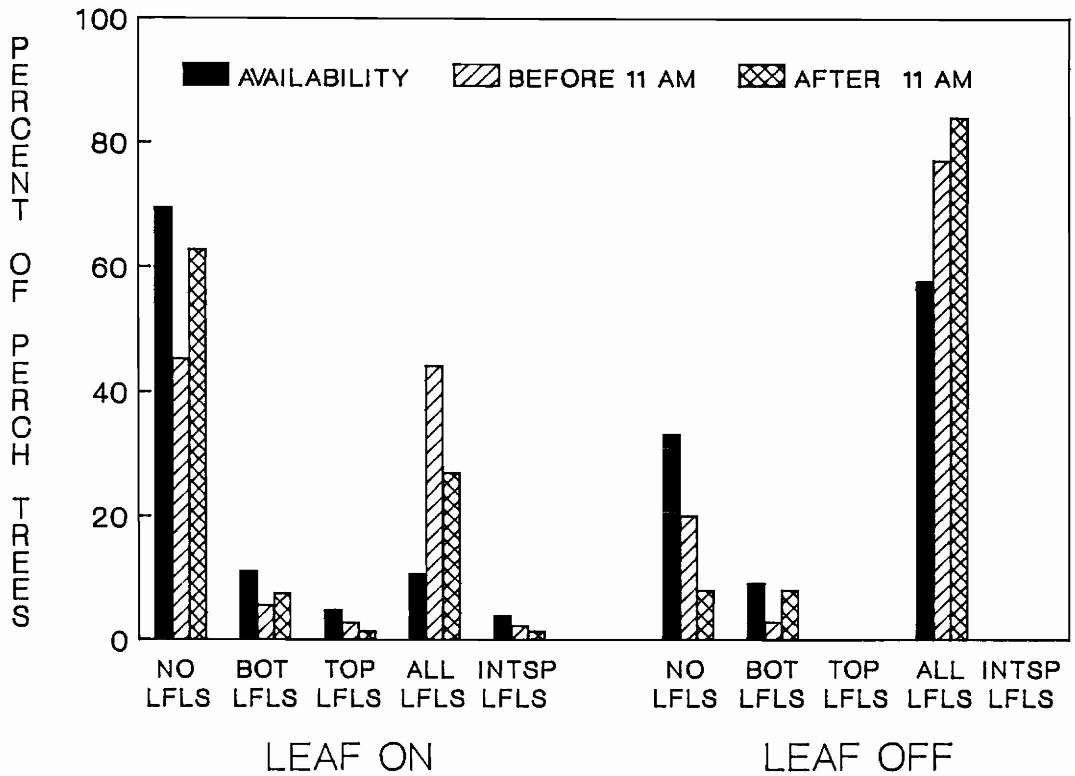

Figure 13. Observed use of perch tree crown types (n = 974) by time of day and season during aerial surveys of B. Everett Jordan Lake and Falls Lake, North Carolina, 1986-87. Crown types refer to the distribution of leafless (LFLS) limbs (INTSP = interspersed). Eagles used different crown types between seasons (χ^2 = 63.2, df = 3, P < 0.001) and times of day during leaf-on (χ^2 = 24.8, df = 4, P < 0.001) but not by time of day during leaf-off (χ^2 = 2.3, df = 2, P = 0.323). Eagle use differed from availability before and after 1100 during leaf-on (χ^2 = 56.2, df = 4, P < 0.001, before 1100; χ^2 = 36.6, df = 4, P < 0.001, after 1100) but differed from availability only after 1100 during leaf-off (χ^2 = 5.0, df = 2, P = 0.083, before 1100; χ^2 = 7.2, df = 2, P = 0.027, after 1100).

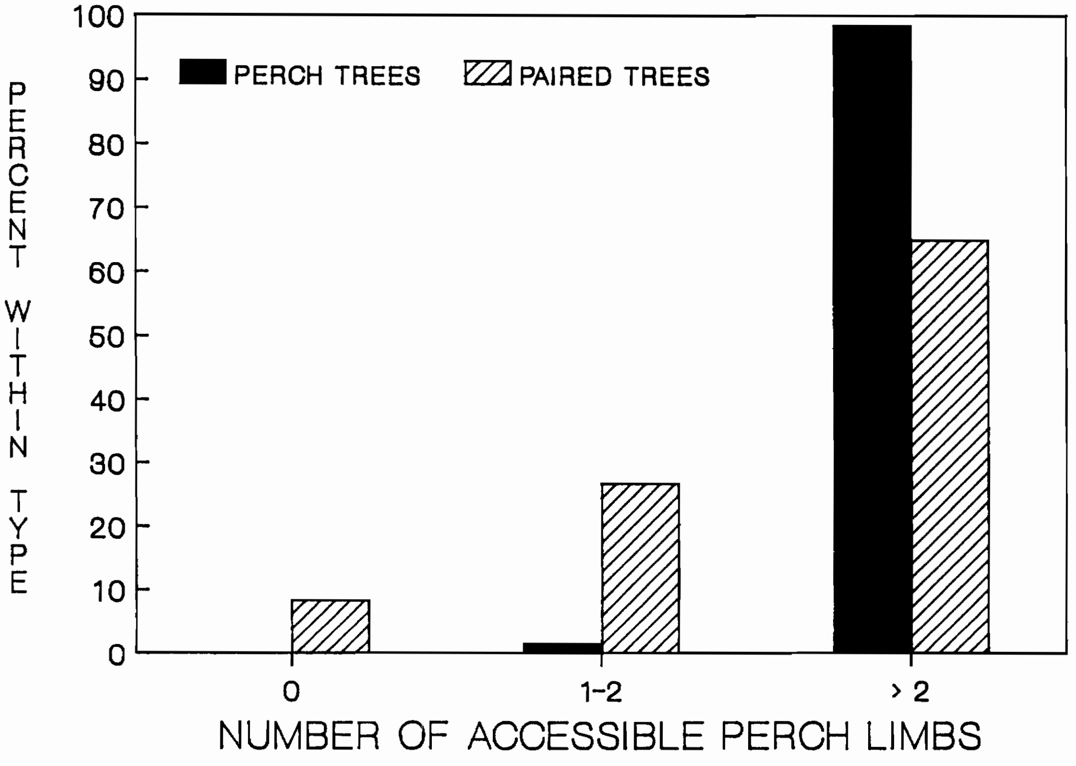

Figure 14. Accessible limbs in bald eagle perch trees (n = 67) and paired neighbor trees (n = 131), B. Everett Jordan Lake and Falls Lake, North Carolina, 1986-87 (χ^2 = 27.7, df = 2, P < 0.001).

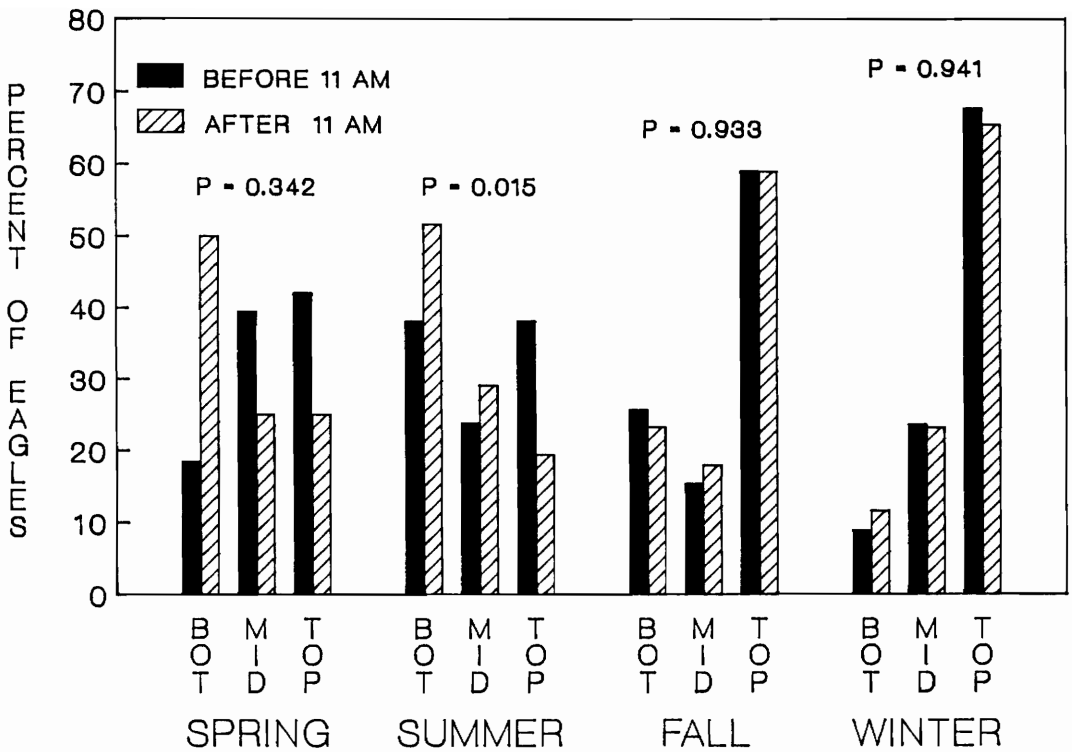

Figure 15. **Locations of bald eagles perched in tree crowns by season and time of day observed (n = 395) during aerial surveys of B. Everett Jordan Lake and Falls Lake, North Carolina, 1986-87. Significance values are for chi-square tests comparing time of day within season. Changes between seasons also were significant (χ^2 = 49.6, df = 6, P < 0.001).**

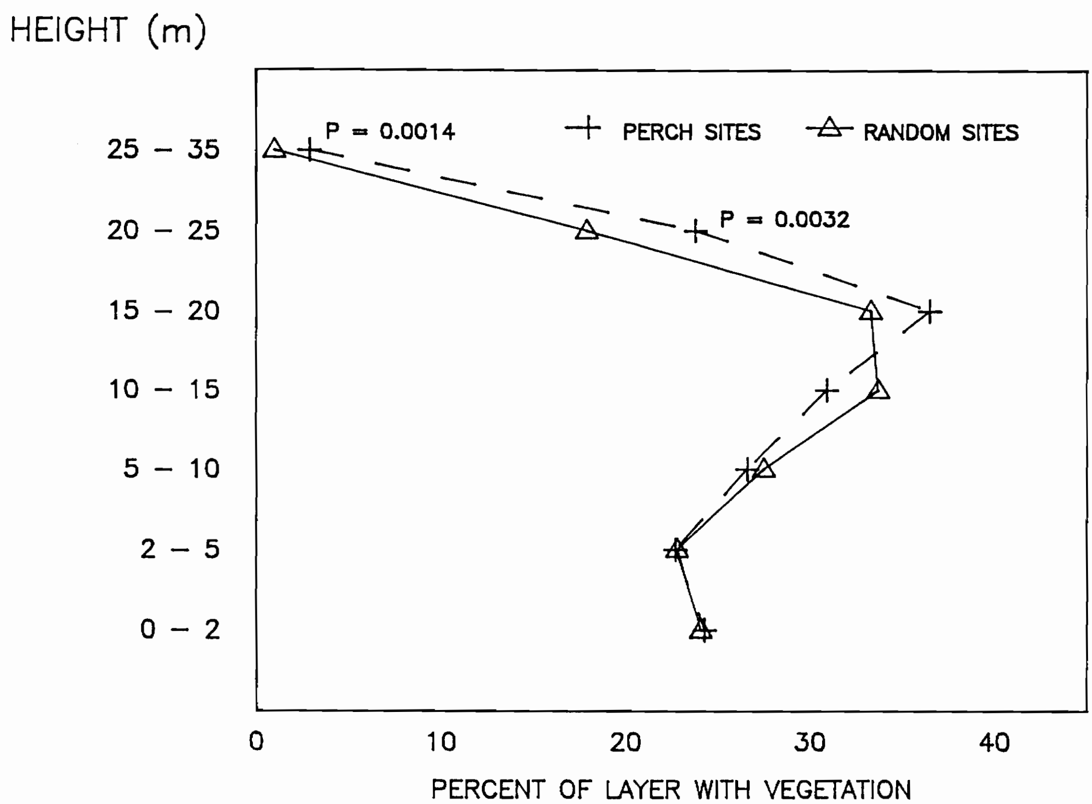

Figure 16. Foliage volume (%) within height classes for all transects sampled at bald eagle perch sites and paired random sites (n = 64 pairs), B. Everett Jordan Lake and Falls Lake, North Carolina, 1986-87. Significance values are for paired t-tests (normally distributed data) or signed rank tests (nonnormally distributed data) within levels.

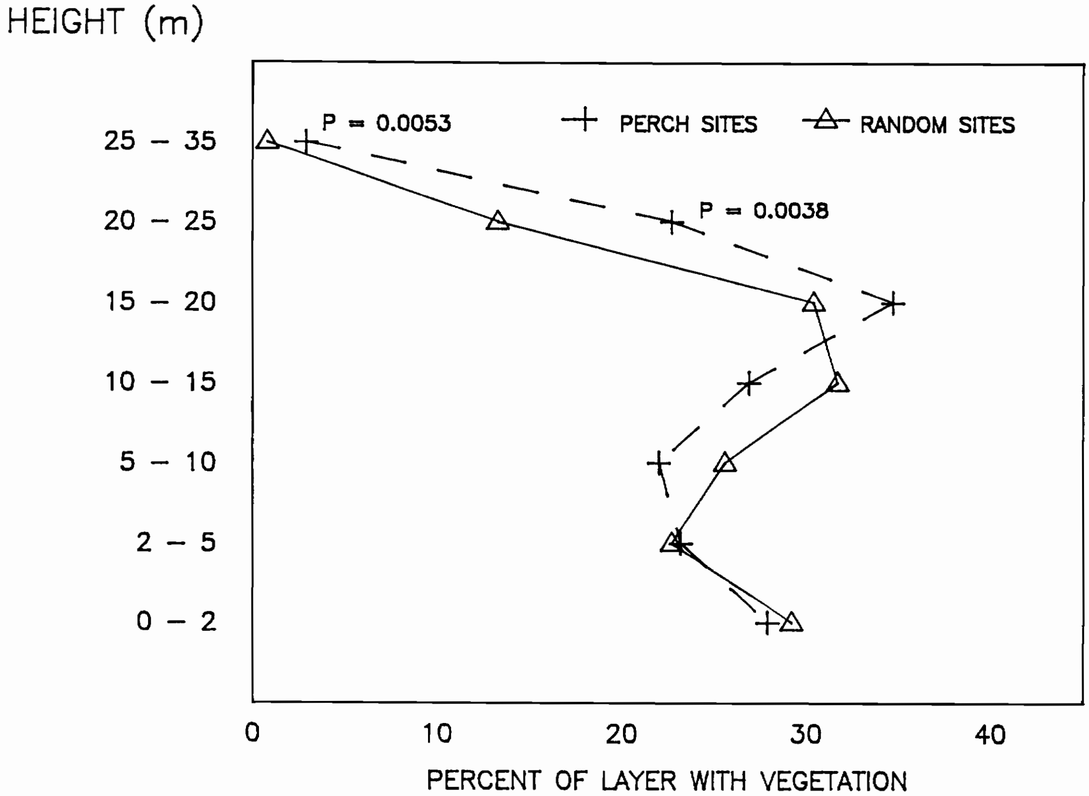

Figure 17. Foliage volume (%) within height classes for front transects sampled at bald eagle perch sites and paired random sites (n = 64 pairs), B. Everett Jordan Lake and Falls Lake, North Carolina, 1986-87. Significance values are for paired t-tests (normally distributed data) or signed rank tests (nonnormally distributed data) within levels.

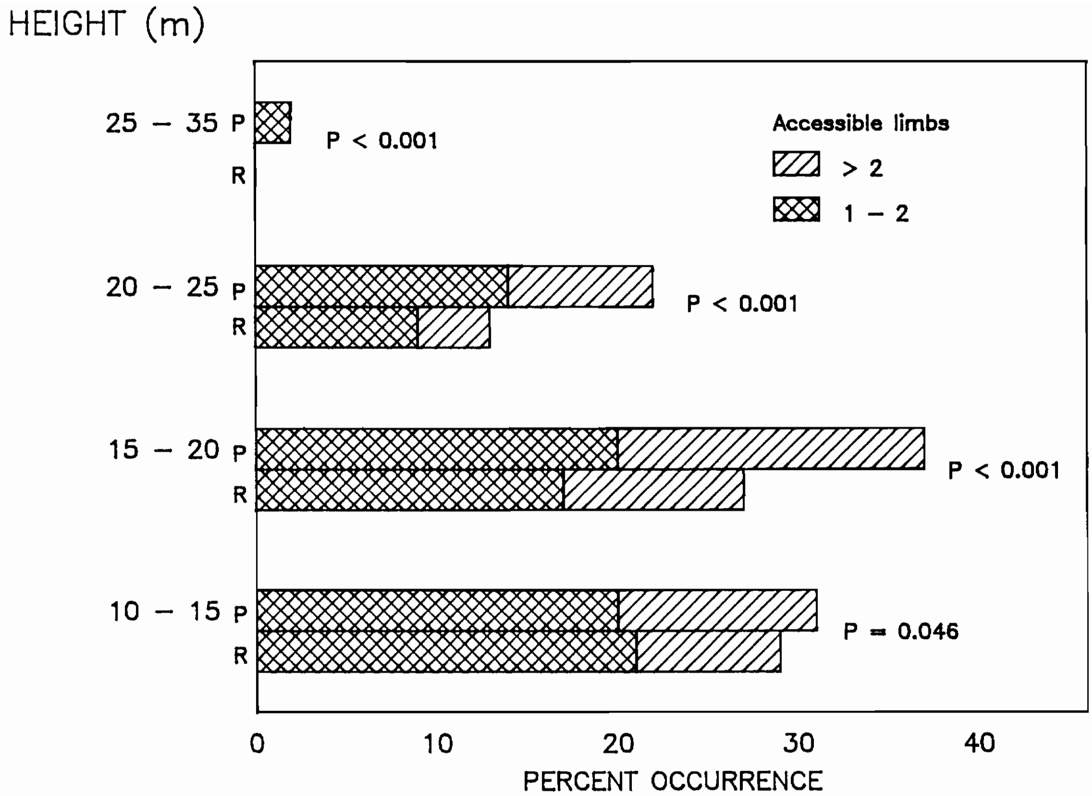

Figure 18. Accessible limbs within height classes for all transects sampled at bald eagle perch sites (P, n = 64) and paired random sites (R, n = 64), B. Everett Jordan Lake and Falls Lake, North Carolina, 1986-87. Significance values are for chi-square tests of homogeneity within levels.

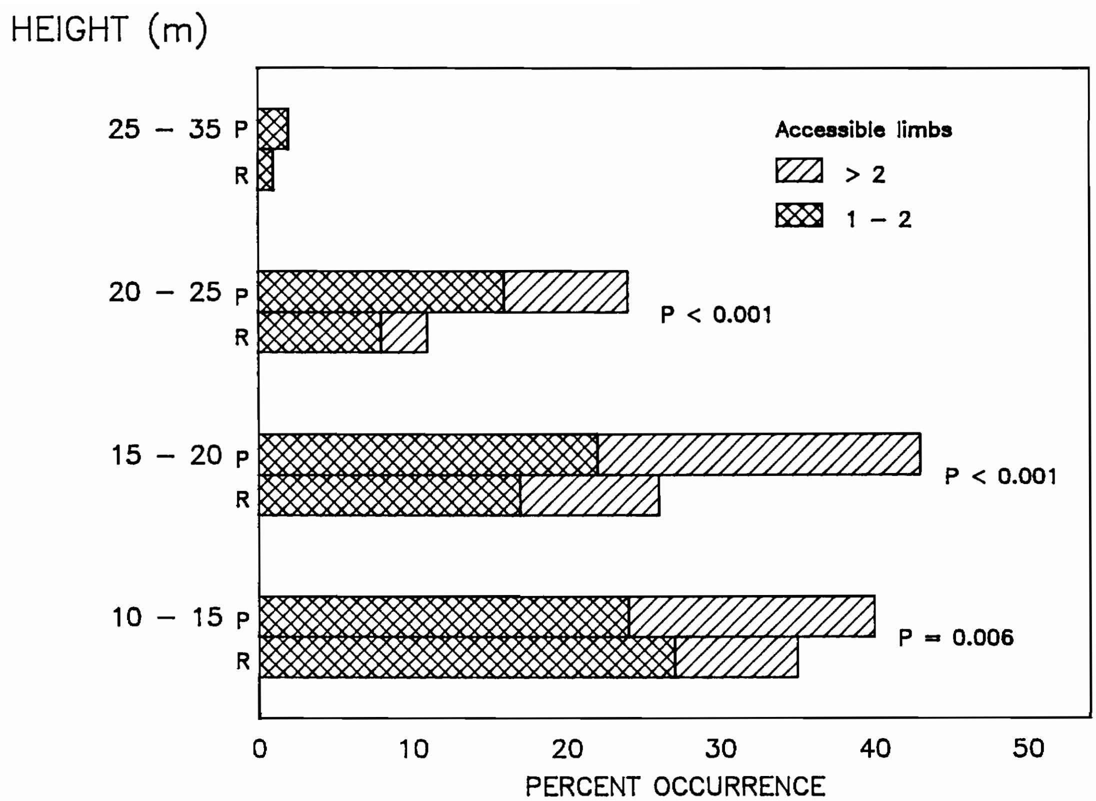

Figure 19. Accessible limbs within height classes for front transects sampled at bald eagle perch sites (P, n = 64) and paired random sites (R, n = 64), B. Everett Jordan Lake and Falls Lake, North Carolina, 1986-87. Significance values are for chi-square tests of homogeneity within levels.

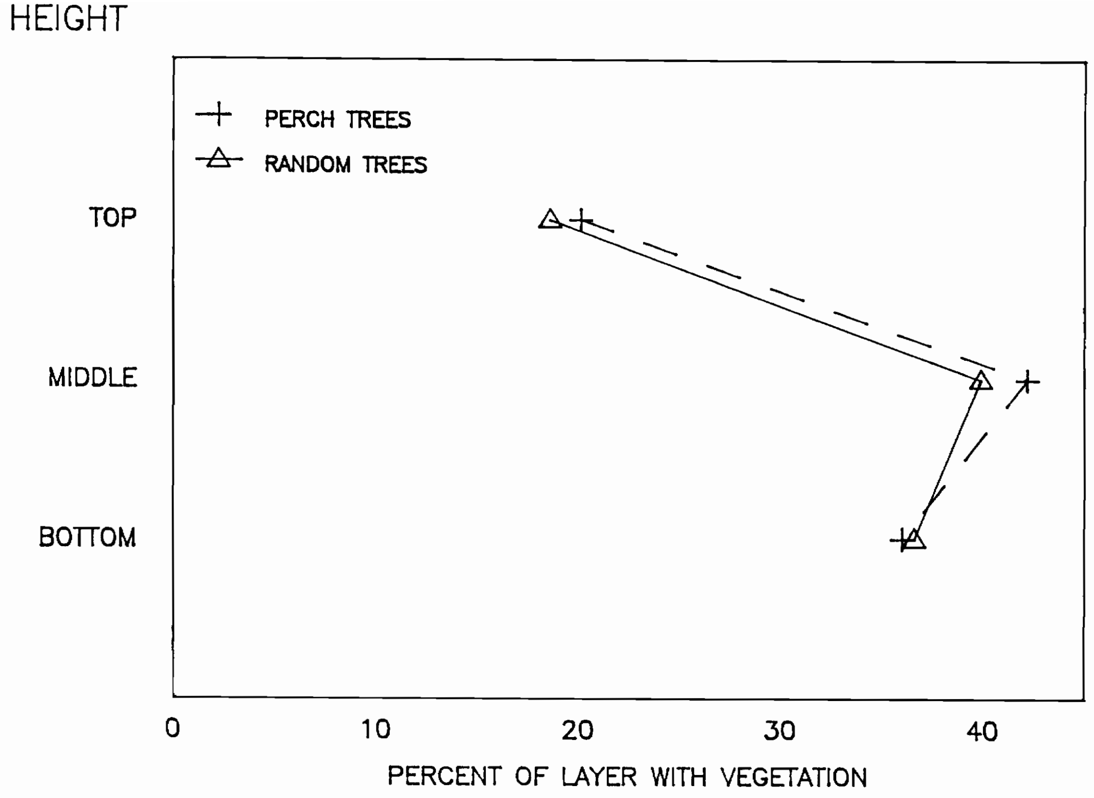

Figure 20. Foliage volume (%) in 3 height classes within crowns of bald eagle perch trees and paired random trees (n = 64 pairs), B. Everett Jordan Lake and Falls Lake, North Carolina, 1986-87. We used paired t-tests for comparisons within levels.

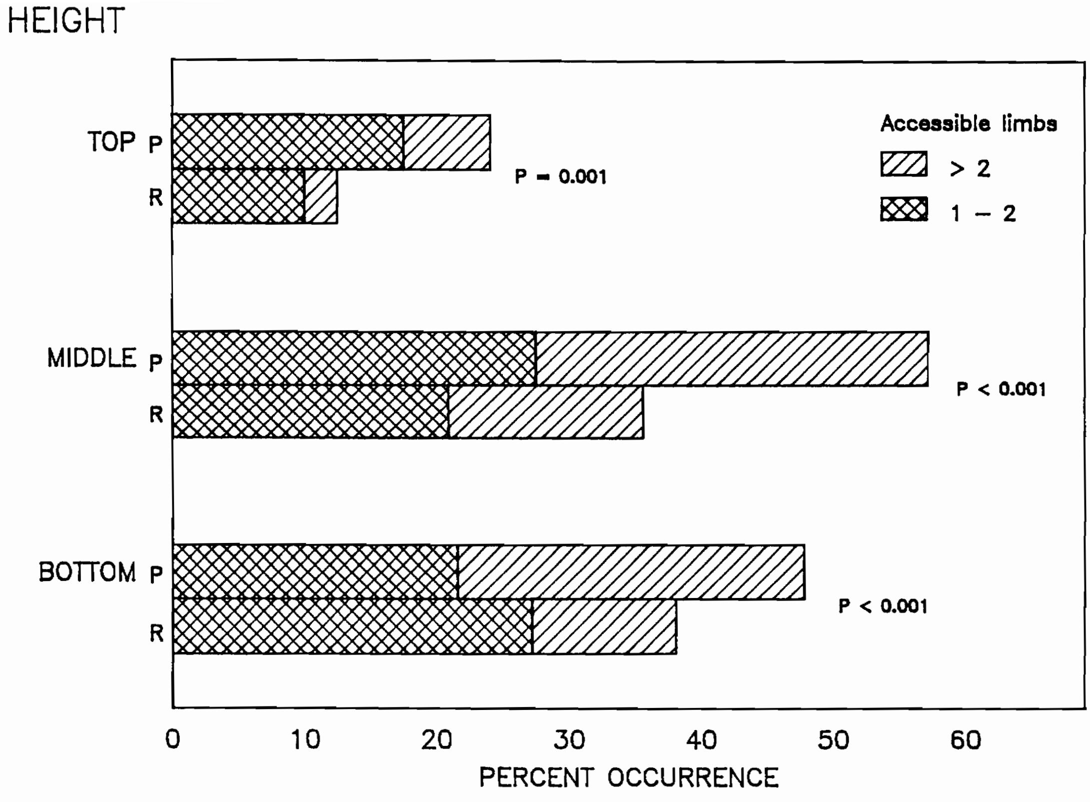

Figure 21. Accessible limbs in 3 height classes within crowns of bald eagle perch trees (P, n = 64) and paired random trees (R, n = 64), B. Everett Jordan Lake and Falls Lake, North Carolina, 1986-87. Significance values are for chi-square tests of homogeneity within levels.

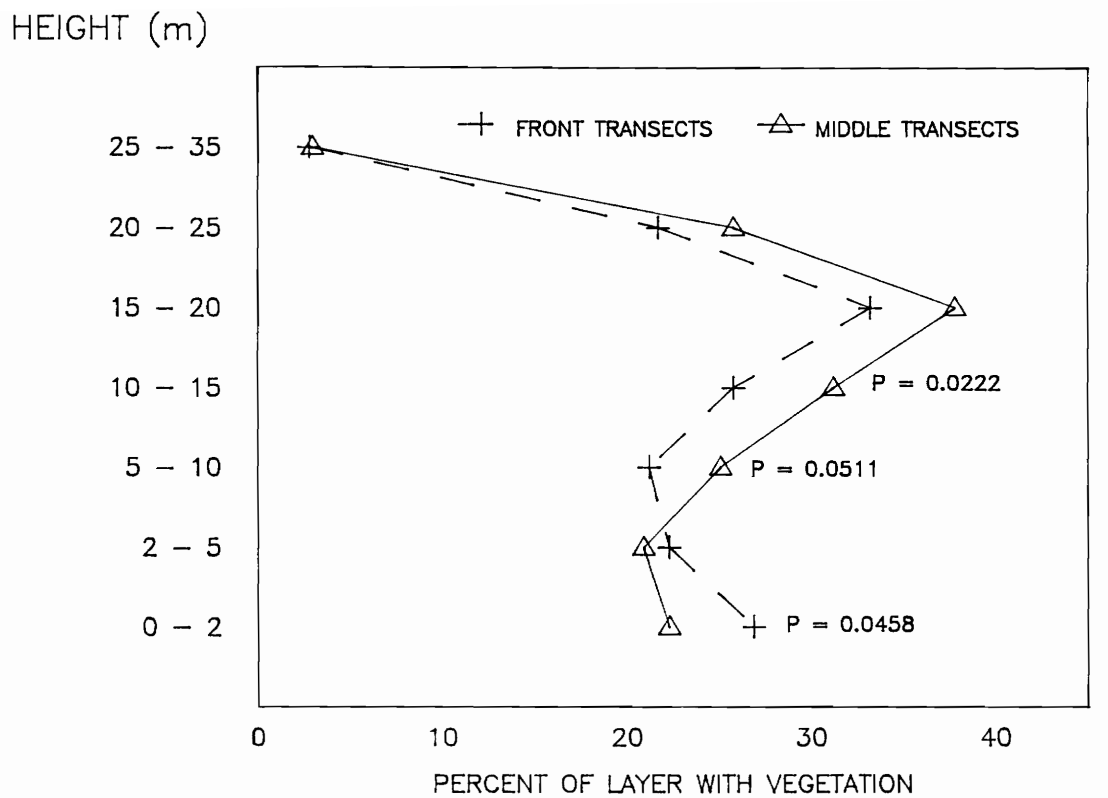

Figure 22. Foliage volume (%) within height classes for front transects and middle transects sampled at bald eagle perch sites (n = 67 pairs), B. Everett Jordan Lake and Falls Lake, North Carolina, 1986-87. Significance values are for paired t-tests (normally distributed data) or signed rank tests (non-normally distributed data) within levels.

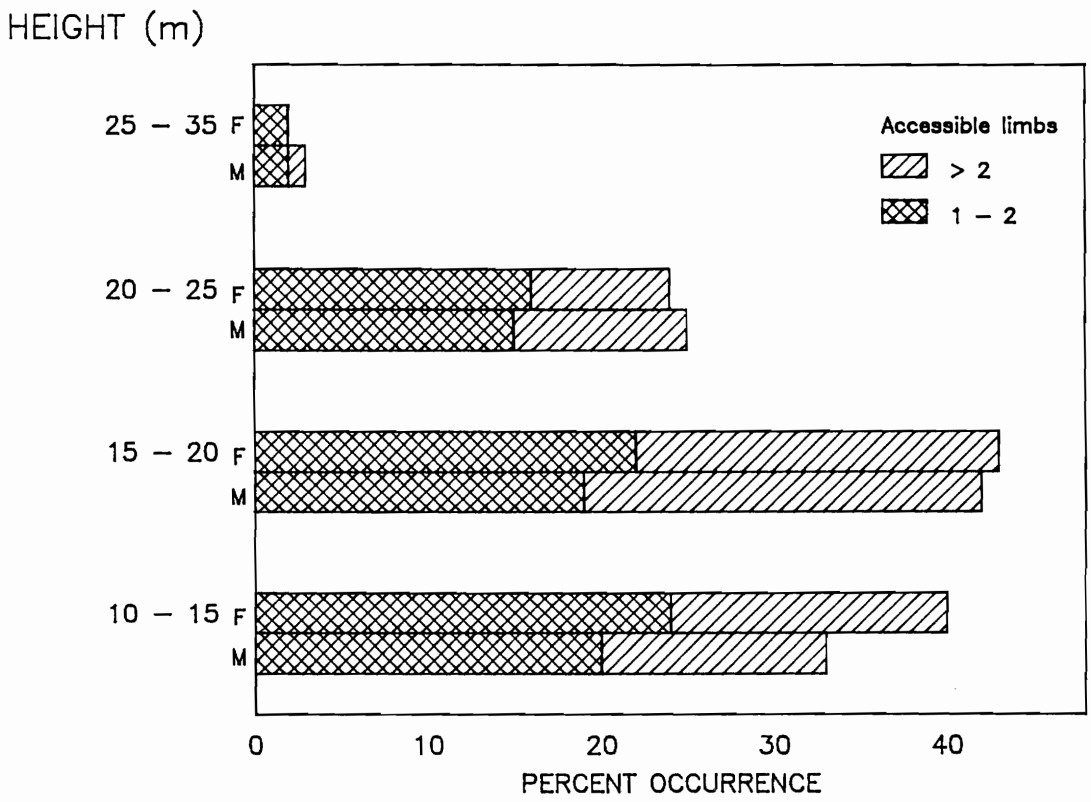

Figure 23. Accessible limbs within height classes for front transects (F) and middle transects (M) sampled at bald eagle perch sites (n = 67), B. Everett Jordan Lake and Falls Lake, North Carolina, 1986-87. We used chi-square tests of homogeneity for comparisons within levels.

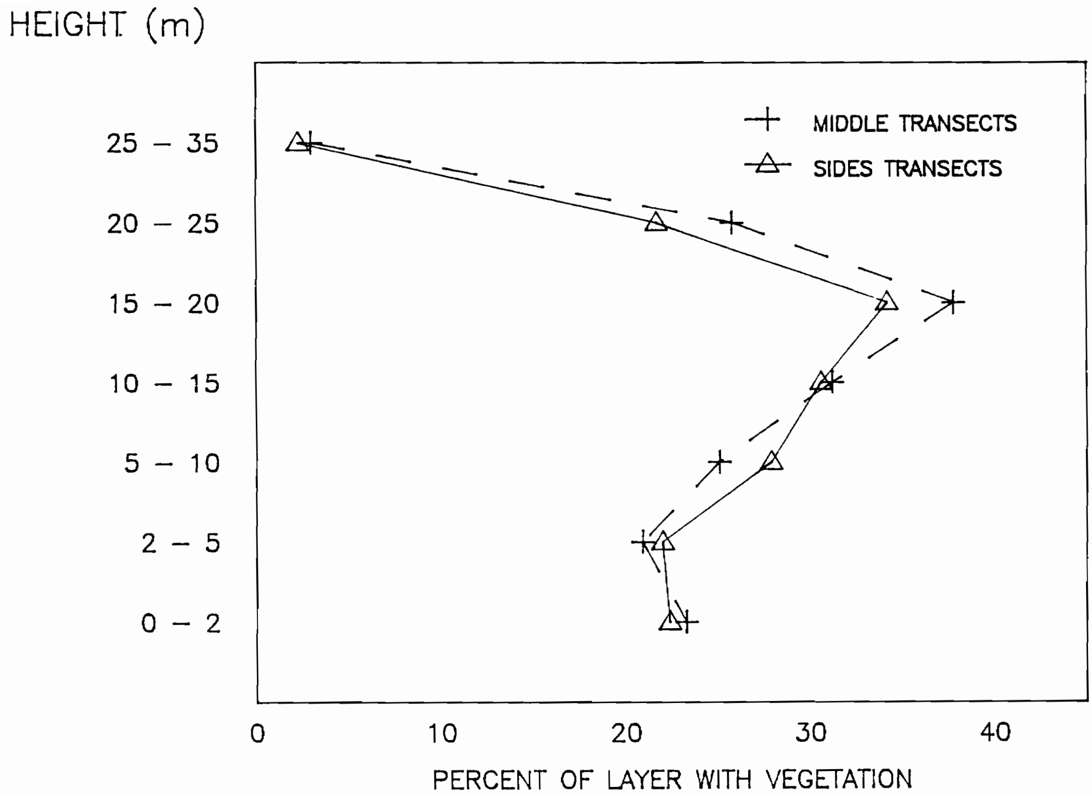

Figure 24. Foliage volume (%) within height classes for middle transects and side transects sampled at bald eagle perch sites (n = 67 pairs), B. Everett Jordan Lake and Falls Lake, North Carolina, 1986-87. We used paired t-tests (normally distributed data) or signed rank tests (nonnormally distributed data) for comparisons within levels.

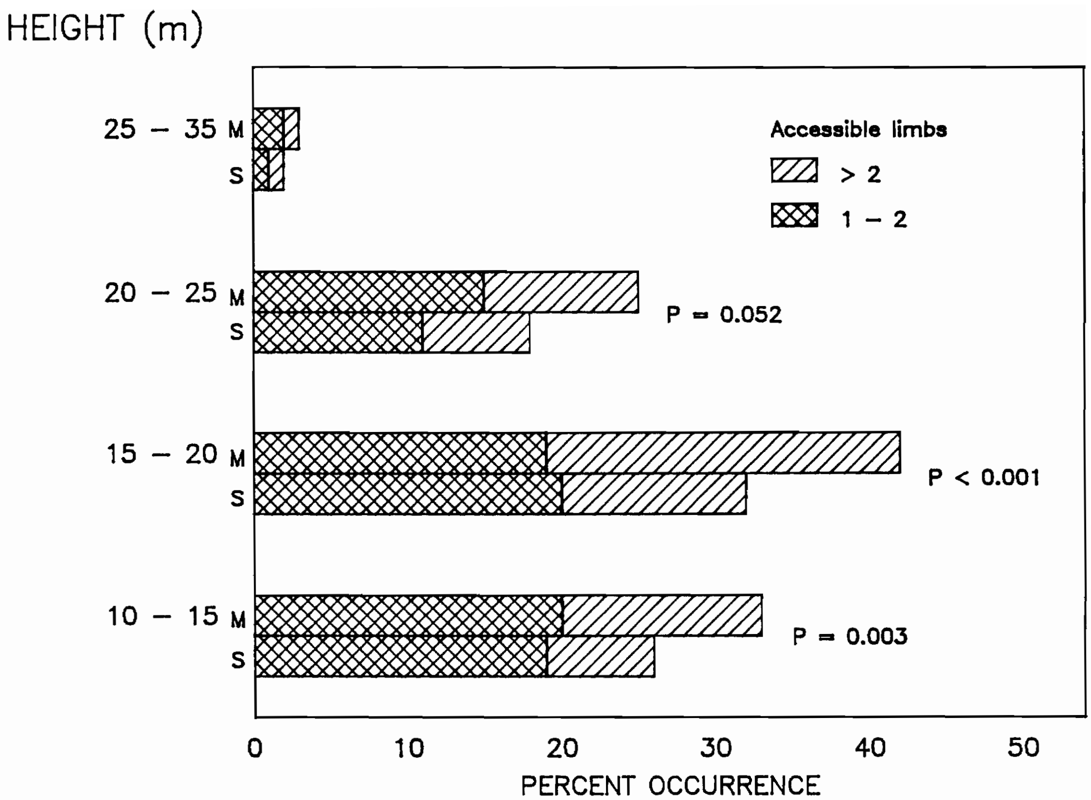

Figure 25. Accessible limbs within height classes for middle transects (M) and side transects (S) sampled at bald eagle perch sites (n = 67), B. Everett Jordan Lake and Falls Lake, North Carolina, 1986-87. Significance values are for chi-square tests of homogeneity within levels.

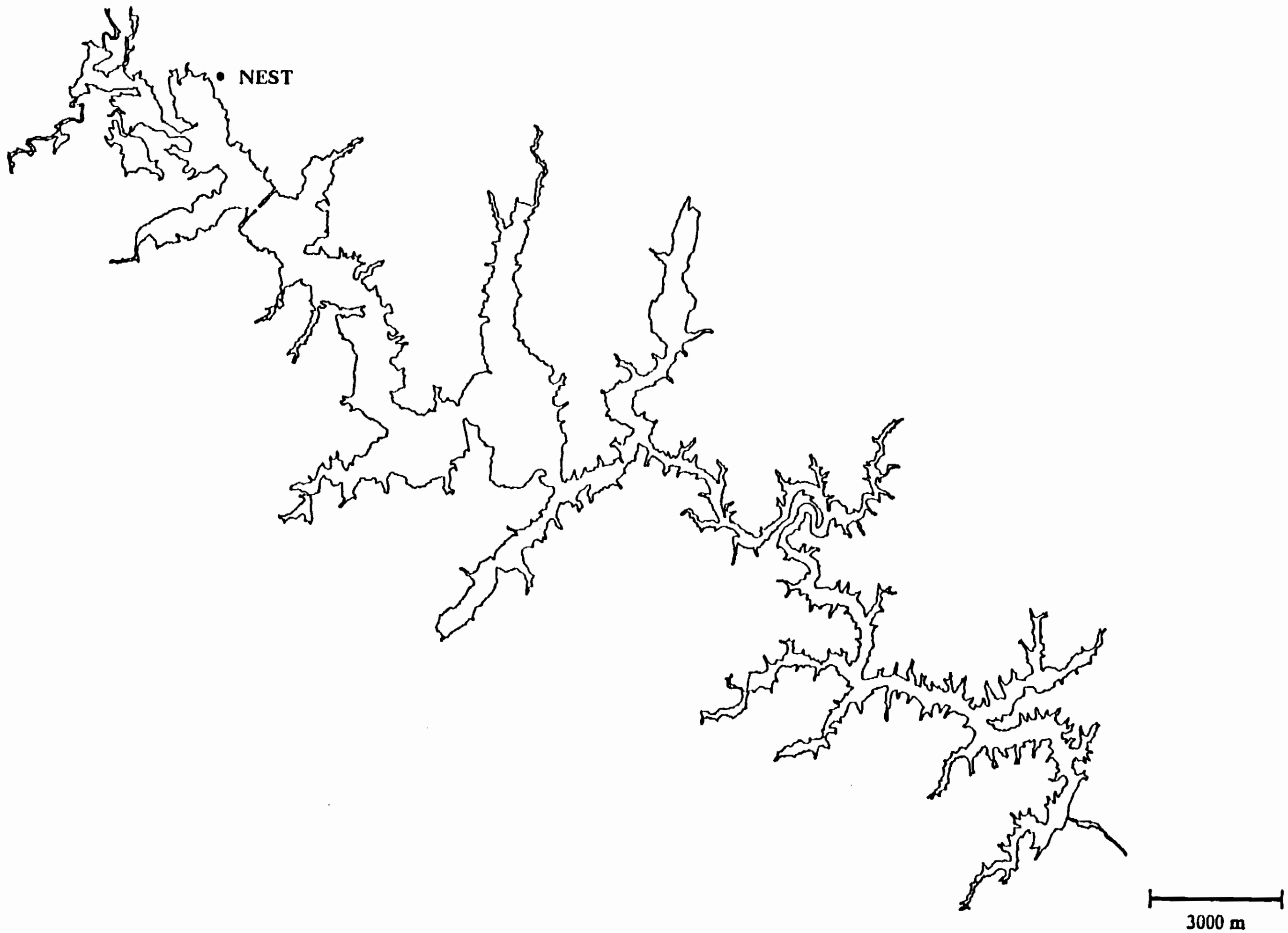

Figure 26. Location of the bald eagle nest on Falls Lake, North Carolina, 1987.

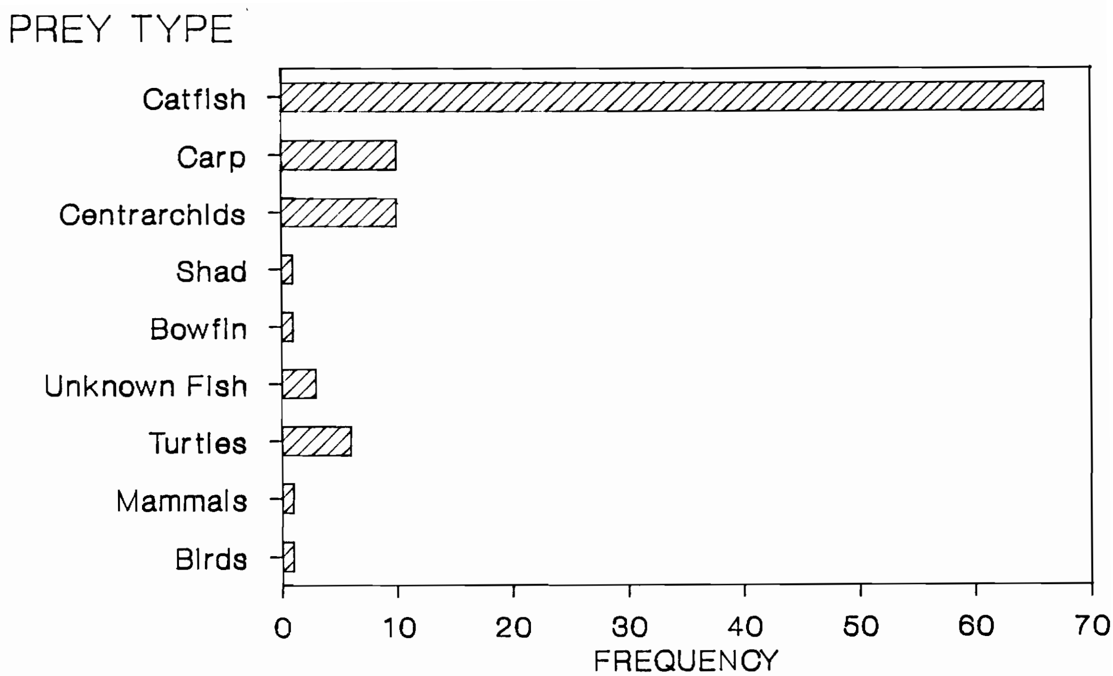

Figure 27. Total number of individuals of each prey type found in 30 collections of prey remains under bald eagle perch trees, B. Everett Jordan Lake and Falls Lake, North Carolina, 1986-87.

VITA

Dennis N. Chester was born 30 December 1959 in Takoma Park, Maryland to David K. and Diane L. Chester. He graduated from A&M Consolidated High School in College Station, Texas in 1977. From 1977 to 1981 he attended Texas A&M University and graduated (Summa Cum Laude) with a BS degree in Wildlife and Fisheries Science. He worked as a Port Agent for L.G.L. Ecological Research Associates, Inc. during the winter of 1981 before moving to Columbia, Missouri to work for the U.S. Fish & Wildlife Service's National Fisheries Contaminant Research Center. He was awarded a graduate research assistantship at Virginia Tech University in May 1986. He was elected vice-president of the Virginia Tech Chapter of The Wildlife Society during 1987-88 and served as a Wildlife Graduate Student Representative for the School of Forestry and Wildlife Resources.

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