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WOOD DUCK BROOD USE OF AN EAST TENNESSEE
RIVERINE HABITAT

presented by

Stephen D. Cottrell

has been accepted towards fulfillment
of the requirements for

M.S. degree in Wildlife

Harold H. Prince

Major professor

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WOOD DUCK BROOD USE OF AN EAST TENNESSEE
RIVERINE HABITAT

By

Stephen D. Cottrell

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ABSTRACT

WOOD DUCK BROOD USE OF AN EAST TENNESSEE RIVERINE HABITAT

By

Stephen D. Cottrell

Habitat utilized by wood duck (Aix sponsa) broods on the Holston River in east Tennessee during 1975-1977 was evaluated. Data were collected by using a combination of radio telemetry, river surveys, shoreline surveys, and fixed observation points. Wood duck brood numbers were estimated by using three survey methods; morning boat, helicopter, and night boat. Although all three surveys were sampling the same population, nearly twice as many birds were visible on the night surveys. Marked female wood ducks with broods moved 1.2 ± 0.3 km from nest sites to the first location on the river and then remained within 0.7 ± 0.1 km of the first location from 1 to 35 days of age.

Utilization of 44, 0.8 km, stream segments was determined by totaling all sightings of one or more ducklings by age class for all surveys. Discriminant function analysis contrasting high and low use areas was used to identify combinations of key habitat components. Wooded shorelines, fallen trees, and aquatic vegetation were significant ($P = .066$) variables related to the use of areas by class I birds. None of these variables were significant for class II and class III wood ducks. Analysis of specific sites used by wood duck broods reveal that they prefer a combination of low bank slope and increased water depth away from shore. This configuration is often located on the outer edge of a bend on a meandering river.

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TABLE OF CONTENTS

	Page
LIST OF TABLES	iv
LIST OF FIGURES	vi
INTRODUCTION	1
STUDY AREA	2
Water Flow	5
Physical Characteristics	5
Land Use	5
Vegetation	6
METHODS	7
River Surveys	7
Nesting and Marking	8
Shoreline Surveys	9
Telemetry	10
Habitat Analysis	10
Statistical Analysis	11
RESULTS	14
Comparison of Survey Techniques	14
Population Estimates	16
Population Trends	18
Nesting Information and Chronology	18
Brood Activity Periods	23
Brood Movements	23
Habitat Utilization	27
DISCUSSION	47
MANAGEMENT	51
LITERATURE CITED	

TABLE OF CONTENTS

	Page
LIST OF TABLES	iv
LIST OF FIGURES	vi
INTRODUCTION	1
STUDY AREA	2
Water Flow	5
Physical Characteristics	5
Land Use	5
Vegetation	6
METHODS	7
River Surveys	7
Nesting and Marking	8
Shoreline Surveys	9
Telemetry	10
Habitat Analysis	10
Statistical Analysis	11
RESULTS	14
Comparison of Survey Techniques	14
Population Estimates	16
Population Trends	18
Nesting Information and Chronology	18
Brood Activity Periods	23
Brood Movements	23
Habitat Utilization	27
DISCUSSION	47
MANAGEMENT	51
LITERATURE CITED	

TABLE OF CONTENTS

	Page
LIST OF TABLES	iv
LIST OF FIGURES	vi
INTRODUCTION	1
STUDY AREA	2
Water Flow	5
Physical Characteristics	5
Land Use	5
Vegetation	6
METHODS	7
River Surveys	7
Nesting and Marking	8
Shoreline Surveys	9
Telemetry	10
Habitat Analysis	10
Statistical Analysis	11
RESULTS	14
Comparison of Survey Techniques	14
Population Estimates	16
Population Trends	18
Nesting Information and Chronology	18
Brood Activity Periods	23
Brood Movements	23
Habitat Utilization	27
DISCUSSION	47
MANAGEMENT	51
LITERATURE CITED	

LIST OF TABLES

	Page
1. Name, description, and collection sources of habitat variables used in discriminant function analysis of wood duck brood habitat, per 0.8 km river segment, on the Holston River, Hawkins County, Tennessee, 1977	12
2. Total number of young wood ducks per age class per survey on a 35.4 km segment of the Holston River between April 21 and August 12 during 1975-1977	15
3. Average number and percent of nasal saddle marked female wood ducks with broods observed per river survey method in relation to the number available on a 35.4 km segment of the Holston River between April 21 and June 26, 1976, and May 24 and July 18, 1977	17
4. Wood duck nest information from artificial structures located on a 35.4 km segment of the Holston River, Hawkins County, Tennessee, 1975-1977	21
5. Total number of wood duck young (all age classes) seen per hour at three fixed point locations during six observations per time period on the Holston River during spring-summer 1976	24
6. Percent of each shoreline habitat type available on four major river segments of the Holston River, Hawkins County, Tennessee	31
7. The relationship of habitat variables to high and low use river segments for class I wood ducks on the Holston River during 1977	35
8. Number and percent of wood duck broods using three different habitat zones based on observations made during 1976 and 1977 shoreline surveys on the Holston River	36
9. Number of wood duck broods per age class contacted from shoreline surveys on the Holston River, Hawkins County, Tennessee, during spring-summer 1977	40

TABLES

Page

10. The relationship of bank slope and water depth to utilized and random sample sites for class I wood ducks on the Holston River during 1977	41
11. The relationships of bank slope and water depth in utilized and random sites for class III wood ducks on the Holston River during 1977	42

LIST OF FIGURES

	Page
1. The Holston River study area	3
2. Yearly wood duck productivity index based on the total number of class II wood ducks counted for four morning boat surveys between May 20 and July 12 during 1970-1977 on a 19 km segment of the Holston River	19
3. Movements ($\bar{X} \pm S.E.$) of marked wood duck broods in relation to first location and age of ducklings on the Holston River during 1976 and 1977	25
4. Number of times that one or more wood duck young was observed during seven survey sequences per 0.8 km segment of the Holston River for 1977	29
5. Frequency distribution of discriminant scores and location of centroids for high and low wood duck brood (age class I) use groups per 0.8 km segment of the Holston River study area for 1977.	32
6. Average distance $\pm$ S.E. away from the river's edge for wood duck broods flushed from the uplands in relation to brood age, on the Holston River, during 1976 and 1977	37
7. Frequency distribution of discriminant scores and location of centroids for utilized and random wood duck brood (age class I) use groups on the Holston River during 1977	43
8. Frequency distribution of discriminant scores and location of centroids for utilized and random wood duck brood (age class III) use groups on the Holston River during 1977	45

INTRODUCTION

The wood duck (Aix sponsa) is the only duck nesting in significant numbers in the Tennessee Valley. Although it presently is the second or third most important duck in the Tennessee hunter's bag, much greater annual production may have been realized before a considerable portion of its habitat was destroyed by river impoundment, channelization, and bankside tree removal (Allen 1971). In contrast to the general waterfowl benefits derived from TVA reservoirs, wood ducks have suffered considerable habitat losses (Hankla and Carter 1966). Current wood duck management is primarily centered upon protection of existing nesting habitat and improvement with artificial nest structures (Dill 1966, Bellrose and McGilvrey 1966). The latter has been successful in the Tennessee Valley as well as in other areas of the country (Muncy and Burbank 1975, Bellrose 1976). However, nesting sites are a small portion of the total habitat requirements of this species. Presently, inadequate information precludes the identification of crucial elements of the habitat requirements of female wood ducks and their broods.

In Maryland, Webster and McGilvrey (1966) noted that downed trees and swamp shrubs provide early cover, a key factor in high wood duck brood use. McGilvrey (1968) described optimum brood habitat in terms of dense emergent vegetation, shrubs, and downed trees interspersed with open water in a three-to-one ratio of cover to water. Radio-marked female wood ducks with broods used a variety of habitat types in north

central Minnesota including sedge meadows, shrub swamps, lake shorelines, and rivers (Ball 1971). Similar studies in South Carolina found a preference for large beaver ponds (1.51-3.80 ha) and a diversity of vegetative types by radio-marked wood duck broods (Hepp and Hair 1977). Watts (1968) and Minser (1968) described the importance of wooded shoreline, emergent vegetation, submersed aquatic vegetation, downed trees, and islands to young wood ducks on the Holston River in east Tennessee. In concurrent food habit studies, Hocutt and Dimmick (1971) concluded that the occurrence and abundance of aquatic vegetation were important in the nutritional welfare of juvenile wood ducks on the Holston River.

Although the Holston River has long been recognized as a highly productive wood duck stream (Allen 1971) scheduled plans are for construction of a nuclear power plant during 1976-1980 at river mile 121 (Figure 1). Present information is inadequate to accurately assess the impact of plant construction and operation on the resident wood duck population. This study was initiated to provide information on key habitat variables that contribute to wood duck abundance on the Holston River in east Tennessee.

STUDY AREA

The study area is a 40.2 km section of river which physiographically falls within the Tennessee portion of the Ridge and Valley Province of the Appalachian Highlands (Fenneman 1938) (Figure 1). The surrounding topography is characterized by sharp parallel ridges (427 meters to 518 meters above sea level) separated by low valleys (366 meters to 355 meters above sea level) following a general northeast-southwest orientation.

Figure 1. The Holston River study area.

Water Flow

The upper Holston River is formed by convergence of three major tributaries: the Watauga River, south fork of the Holston, and north fork of the Holston, which combined drain 7,912 square kilometers of watershed. Water flow down the Holston is highly variable, partially as a result of water retention and release from the upstream hydro-electric reservoir system. The minimum allowable flow on the Holston under current TVA operating agreements is 21 cubic meters per second. The average daily flow between 1967-1973 for the Surgoinsville gage station (river mile 118.5) was 110 cubic meters per second. Daily water levels can fluctuate a maximum of 1.9 meters during the spring and summer months of an average year (TVA 1976).

Physical Characteristics

John Sevier impoundment extends over the lower 8.8 kilometers of the study area comprising approximately 328 hectares at normal pool level. The remaining 31.4 kilometers of river meanders through a series of long pools interspersed with shallow, rocky shoals (Minser 1968). The river flood plain varies in width from 0.4 kilometer to 1.6 kilometers while average channel width is approximately 128 meters (Lindsay 1976). Bottom substrate varies from rocks, gravel, and sediments in fast water areas to bedrock and sediments in slow current areas (Peltier and Welch 1969). There are nine island or island complexes that vary in length from 0.2 kilometer to 2 kilometers within the study area.

Land Use

The land on the river flood plain is used primarily for the production of corn, tobacco, hay, and pasture. The natural riparian

vegetation is either wooded, early successional, or pasture. In low slope areas, suitable for agricultural activities, the shoreline vegetation zone is often only 12 meters or less in width, whereas shorelines formed by the base of steep ridges are usually heavily wooded over the entire slope.

Vegetation

Major forest cover on the adjacent ridges and slopes consists of mixed mesophytic associations of American beech (Fagus gradifolia), sugar maple (Acer saccharum), and yellow-poplar (Liriodendron tulipifera) along with a vareity of oaks (Quercus spp.) and hickories (Carya spp.) (Minser 1968). Shoreline flora display sharp contrasts of habitat types ranging from parklike stands (up to 80 cm d.b.h.) of sycamore (Platanus occidentalis), American elm (Ulmus americana), and box elder (Acer negundo) to permanent fescue (Festuca spp.) pasture.

Common wooded shoreline ground cover species are stinging nettle (Urtica procera), wood nettle (Laportea canadensis), heart leaf (Asarum spp.), jewel weed (Impatiens spp.), henbit (Lamium amplexicaule), and a wide assortment of grasses.

Rooted submersed and floating aquatic macrophytes are common and abundant over most of the river portion of the study area. Primary species are sago pondweed (Potamogeton pectinatus), American pondweed (P. nodosus), curly pondwood (P. crispus), water stargrass (Heranthera dubia), tapegrass (Vallisneria americana), elodea (Elodea canadensis), and duckweed (Lemna minor). Submersed macrophytes are less abundant in the lake portion of the study area and emergents such as cattail (Typha latifolia), blue-stemmed bulrush (Scripus validus),

and water primrose (Ludwigia peploides) are common plants in selected areas (Watts 1968).

Floating mats of uprooted aquatic vegetation are dislodged by current surges from upstream hydroelectric dams and often become entangled on shoreline obstructions (fallen trees, stumps, overhanging branches, etc.) or aggregate into large mats as they float downstream (Minser 1968, Watts 1968, Peltier and Welch 1969, Hocutt and Dimmick 1971, Lindsay 1976).

Common macroinvertebrate species found in the Holston River are Polypedilum sp., Simulium sp., Corbicula sp., Sphaerium sp., Pleurocera sp., Dina sp., Erpobdilla sp., Hydropsyche sp., and Chironomidae sp. (Hocutt and Dimmick 1971, Lindsay 1976, TVA 1976).

METHODS

This study was designed to identify important habitat characteristics for young wood ducks on the Holston River. Field data were collected between March and August during 1975-1977. A combination of radio telemetry, shoreline surveys, and river surveys was used to identify patterns of use for each river segment. Specific densities of birds and patterns of use were then compared with measured habitat variables of each river segment.

River Surveys

Wood duck brood counts were conducted on a 35.4 km portion of the Holston River using the four following survey methods: morning boat counts, (0630 to 0900 EDST), morning helicopter counts (0630 to 1130 EDST), afternoon helicopter counts (1130 to 2000 EDST), and night boat counts (2130 to 0300 EDST). The surveys by boat usually began at the

upstream end of the study area. An operator plus one observer conducted the surveys in an air boat or 14-foot john boat powered by a 20 hp outboard motor. The crew floated and/or motored downstream at a rate of 10 to 32 km/h following the main channel and counting all juvenile and adult birds that were observed. At night two aircraft landing lights powered by a 12-V portable generator were used to observe the birds. Aerial surveys were conducted in a Bell 47 helicopter beginning at the upstream end of the study area and proceeding down river at a rate of 20-30 km per hour at an altitude of 30-40 meters. The following information was recorded on a field map when a brood was observed: location, number of ducklings (either partial or complete brood), age of ducklings, and presence or absence of female. Ducklings were aged by both visual and behavior characteristics as developed by Gallop and Marshall (Taber 1969) and Dreis (1954).

Morning boat floats were started during spring and summer of 1970 by TVA personnel and a 19.3 km segment of the Holston River was surveyed. Except during 1974, these surveys have continued over the same route through 1977. In 1975 an additional 16 km of river were added immediately upstream. All surveys from 1975-1977 were conducted within a five-day period on a biweekly basis between April and early August. Three, six, and five series of surveys were completed from 1975 through 1977, respectively.

Nesting and Marking

TVA personnel erected 77 artificial wood duck nesting structures in 1971. Additional nest boxes have been added each subsequent year with a total of 146 boxes available in 1975, 186 in 1976, and 204 in

1977. All boxes were checked and refurbished each March and then checked at least twice during the nesting season. Incubating female wood ducks were captured by placing a long-handled net over the nest entrance and then either flushing the bird into the net or climbing to the nest box and removing the bird by hand. Clutch size and stage of embryonic development (Hanson 1954) were determined by field candling (Weller 1956) at each nest. The female was fitted with a Fish and Wildlife Service metal leg band and with an individually marked polyvinyl nasal saddle as described by Greenwood (1977). A total of 57 females (28 in 1976 and 29 in 1977) were captured and 40 (20 each year) were also fitted with radio transmitters. Apparent nest abandonment from handling and marking was 18 percent during 1976 and 17 percent during 1977.

Shoreline Surveys

Wood duck broods can be readily observed on the Holston River by walking along the shoreline. Shoreline and upland brood activities were monitored in 1976 by randomly selecting and walking along one shoreline for each 1.6 km section of river and all islands. The surveys were made between 0900 EDST and 1700 EDST between June 17 and July 13 and the location, activity, number, and age of all wood duck broods contacted were recorded. The shoreline surveys were revised in 1977 to include a 19 km portion of the river that was selected to represent all available habitat types. The 19 km sample area was surveyed within an eight-day period on alternate weeks between May 28 and July 8.

A total of 36 fixed point observations were made during three time periods at three locations of known brood activity along the river

in 1976. Each observation point was visited sometime during the morning (630 to 0930 EDST), midday (1200 to 1430 EDST), and evening (1800 to 2100 EDST) periods within a five-day interval, but never more than once during the same day. Observation periods ranged from 0.5 hour to 2.0 hours in length with an average of approximately one hour. Information collected on observed broods included number of ducklings, number of broods, age of ducklings, behavior, and length of time observed.

Telemetry

Lithium battery powered radio transmitters weighing between 15 and 20 grams with a life expectancy of 60 to 90 days were used during the study. Maximum effective ranges were approximately 0.8 km on the ground and 1.6 km from the air. The transmitters were mounted on the back of the female and held in place with a harness similar to the one described by Dwyer (1972). Scanning radio receivers with a frequency range of 150.792 to 151.115 MHz and a three-element, hand-held yagi antenna were used to track radio-marked females. During 1976 approximately 50 percent of the transmitters failed within one week after attachment due to inadequate waterproofing. In 1977, 85 percent of the transmitters worked properly. Marked birds were located by systematic ground, river, and aerial searches. Scheduled search time in 1976 included 9 hours in the air and 42 hours on the ground. In 1977 there were 13 hours of aerial monitoring and 48 hours of ground monitoring.

Habitat Analysis

McGilvrey (1968) outlines some of the more important variables associated with brood rearing habitat. He suggests that an optimum proportion and distribution of water, cover, food, and loafing sites

must be present and that for stream habitats the quantities of shoreline per hectare of water are important. In this study, the amount of wooded shoreline, early successional shoreline, pasture shoreline, total surface water, rooted aquatic vegetation, and fallen trees were measured per 0.8 km segment of river (Table 1). These six variables were then contrasted with wood duck brood use per 0.8 km segment of river. The amount of wooded shoreline, pasture shoreline, aquatic vegetation, and total surface water was measured from color aerial photographs (1 cm = 48 m) of the Holston River taken in 1975 and 1976. The number of fallen trees (≥ 7.5 cm d.b.h.) was counted during shoreline surveys in 1976.

Points along the shoreline where broods were observed during 1977 shoreline and river surveys were used as sample locations to measure shoreline slope and water depth. A stadia rod (calibrated in 25 cm intervals) and a meter stick were used to measure the slope of the river bank from the waters edge back to the edge of the upland vegetation. Water depth at 15 cm and one meter from the shoreline was measured to the nearest centimeter. For contrast, samples were taken at randomly selected sites (within the 1977 shoreline survey miles) where no brood activity was observed.

Statistical Analysis

A stepwise discriminant function technique (Nie et al. 1975) was used to analyze habitat parameters. This method is basically an extension of a standard analysis of variance technique using a multiple number of variables in some linear combination to test within and between group differences (Marriott 1974). The interpretation of dis-

TABLE 1. Name, description, and collection sources of habitat variables used in discriminant function analysis of wood duck brood habitat, per 0.8 km river segment, on the Holston River, Hawkins County, Tennessee, 1977.

Variable Name	Description	Source
Wooded shoreline communities	Shore predominantly covered with trees (≥ 7.5 cm d.b.h.)	Color aerial photographs (1 cm = 48 m)
Early successional shoreline communities	Shoreline predominantly in an early successional stage (rank weeds, grasses, and shrubs)	Color aerial photographs (1 cm = 48 m)
Pasture shoreline communities	Shoreline predominantly in permanent pasture	Color aerial photographs (1 cm = 48 m)
Total surface water	Total surface water calculated from dot grid	Color aerial photographs (1 cm = 48 m)
Aquatic vegetation	Total rooted submersed and floating leaved aquatic vegetation, calculated from dot grid	Color aerial photographs (1 cm = 48 m)
Fallen trees	Number of fallen trees (> 7.5 cm d.b.h.) along the shoreline	Shoreline surveys (1976)

criminant function output is a three-step process. The first step is the consideration of the significance of the overall discriminant function which is a composite of all variables containing any discriminating information about the two groups being tested. This is based on Wilk's lambda which is an inverse measure of the discriminating power contained in the function. Lambda can be converted into a Chi-square statistic with a given probability level for easy interpretation (Nie et al. 1975). When lambda has an acceptable probability level, the interpretation continues to the second step which focuses on the standardized discriminant function coefficient for each individual variable in the analysis. The discriminant function coefficient is a measure of each variable's relative contribution to the discriminant function (Nie et al. 1975). The third step of interpretation is a validating mechanism. Each individual case for the two treatment groups is individually analyzed according to the values of its variable set and reclassified into one of the original treatment groups. The percent of known cases correctly classified and its Chi-square value are tests of the discriminant function's ability to assign individuals of unknown membership to known groups (Nie et al. 1975).

All habitat variables (Table 1) were tested for normality (Kolomogov-Smirnov, $P < .05$) and transformations performed (Sokal and Rolf 1969) on nonnormal variables. Meters of pasture shoreline was the only variable that could not be normalized. This should not significantly affect the analysis due to the robustness of discriminant function analysis for moderate departures from normality (Marriott 1974, Nie et al. 1975).

RESULTS

Comparison of Survey Techniques

Helicopter (morning) and boat surveys (morning and night) were conducted each spring and summer on the Holston River. Nonparametric statistical tests, substituting rank values for the absolute number of birds observed, were used to analyze the variability and patterns of association between survey methods for 1975, 1976, and 1977 combined. The total number of young (all ages combined) was ranked within each survey method over time and all pairwise comparisons between survey methods were made by Spearman rank correlation (Seigel 1956). The pattern of the ranks by survey date was significantly ($p < .01$) correlated among all three survey methods.

A Wilcoxon all pairwise two-way classification test (Wilcoxon and Cox 1964) was used to test the observed differences between the three survey methods for 1975, 1976, and 1977 combined. Each survey method received a rank value of one, two, or three based on the number of young counted during each survey sequence. Ranks for each method were then summed over all survey sequences (three years) and tested to ascertain the overall significance of the observed differences among the three sets of rankings. Night boat surveys were significantly different ($P < .05$, Critical value = 12.4, $N = 14$) from both morning boat and morning helicopter surveys for class I ducklings (Table 2). A significant difference ($P < .05$, Critical value = 10.5, $N = 10$) was also present between night boat surveys and morning boat surveys for age class III wood ducks while there was no significant difference among methods for age class II ducklings. Over all age classes combined, night boat surveys were significantly higher ($P < .01$, Critical value = 15.4,

TABLE 2. Total number of young wood ducks counted per age class per survey method on a 35.4 km segment of the Holston River between April 21 and August 12 during 1975-1977.

Age Class	Survey Method		
	Morning Boat	Morning Helicopter	Night Boat
I (14 ^a)	475	355	820 ^b
II (13)	228	246	501
III (10)	54	171	318
All ages (14) combined	757	772	1639

^aNumber of surveys.

^bBroken lines indicate significant ($P < .05$) differences based on a Wilcoxon all pairwise two-way classification test.

N = 14) than both morning boat and morning helicopter surveys (Table 2).

The visibility of nasal saddle marked female wood ducks with broods (class I and II) in relation to the number of marked broods available to be observed varied among surveys (Table 3). An average of 16 and 19 percent of the marked females were observed during night boat surveys in 1976 and 1977, respectively, while 4 (1976 and 1977) and 7 (1977) percent of the marked females were observed on the two morning surveys.

The three survey methods were highly associated over the survey season and suggest in a statistical sense that they are sampling the same population. Yet, the significantly higher counts recorded for night boat surveys, along with the greater percentage of marked females with broods observed, suggest that this survey method is sampling a greater proportion of the population than morning boat or morning helicopter surveys.

Six morning (0630 to 1100 EDST) and six afternoon (1130 to 1900 EDST) helicopter surveys conducted during 1977 were compared to assess major time period in relation to aerial survey results. A total of 319 ducklings (all ages and surveys combined) was observed during morning helicopter surveys versus 405 ducklings counted during afternoon helicopter surveys. These differences were not significant based on a Wilcoxon signed ranks test (Wilcoxon and Cox 1964).

Population Estimates

Estimates of the number of broods (age class I and II combined) on a 35.4 km segment of the Holston River were made between April 22 and

TABLE 3. Average number and percent of nasal saddle marked female wood ducks with broods observed per river survey method in relation to the number available on a 35.4 km segment of the Holston River between April 21 and June 26, 1976, and May 24 and July 18, 1977.

Availability/Survey	Year			
	1976		1977	
	Mean $\pm$ S.E.	%	Mean $\pm$ S.E.	%
Mean number of marked females available to be observed	11.4 $\pm$ 2.5	100	9.8 $\pm$ 3.6	100
Mean number of marked females observed				
Morning Boat	0.4 $\pm$ 0.2	4	0.4 $\pm$ 0.2	4
Morning Helicopter	0.8 $\pm$ 0.6	7	-	-
Night Boat	2.2 $\pm$ 1.0	19	1.6 $\pm$ 0.2	16

June 14 during 1976 and May 13 and July 18 during 1977. A Schnabel index (Overton 1969) was used to compute the estimates based on the number of marked and unmarked wood duck broods (age class I and II combined) observed during night boat surveys. An average of 113 (95 percent C.I. = 55 to 204) broods were estimated to be on the study area during 1976 and 128 (95 percent C.I. = 54 to 261) during 1977.

Population Trends

A yearly index of wood duck productivity based on the total number of class II wood ducks observed between May 12 and July 12 on a 19 km segment of the Holston River has been recorded for seven years between 1970 and 1977, using biweekly morning boat surveys (Figure 2). Production was the highest in 1970 with a decline of 72 percent through 1975. The number of wood ducks increased 185 percent between 1975 and 1976. Production dropped 42 percent from 1976 levels during 1977.

Nesting Information and Chronology

A total of 51 (146 boxes available), 47 (186 boxes), and 60 (204 boxes) wood duck nest attempts were found in nest boxes on the Holston River by years (1975-1977). This amounts to an occupancy rate of 35, 25, and 29 percent for 1975, 1976, and 1977, respectively (Table 4). The earliest nest initiation was February 10, 1976, while the latest date of observed nesting activity was of an incubating hen of June 30, 1975. Chronology of wood ducks on the Holston was calculated for each field season by back dating survey brood counts and from 48 nests (during 1976 and 1977) with known histories. The major nest initiation period during 1975, 1976 and 1977 was throughout the month of March. Most nests hatched between the third week in April and the second week in May

Figure 2. Yearly wood duck productivity index based on the total number of class II wood ducks counted for four morning boat surveys between May 20 and July 12 during 1970-1977 on a 19 km segment of the Holston River.

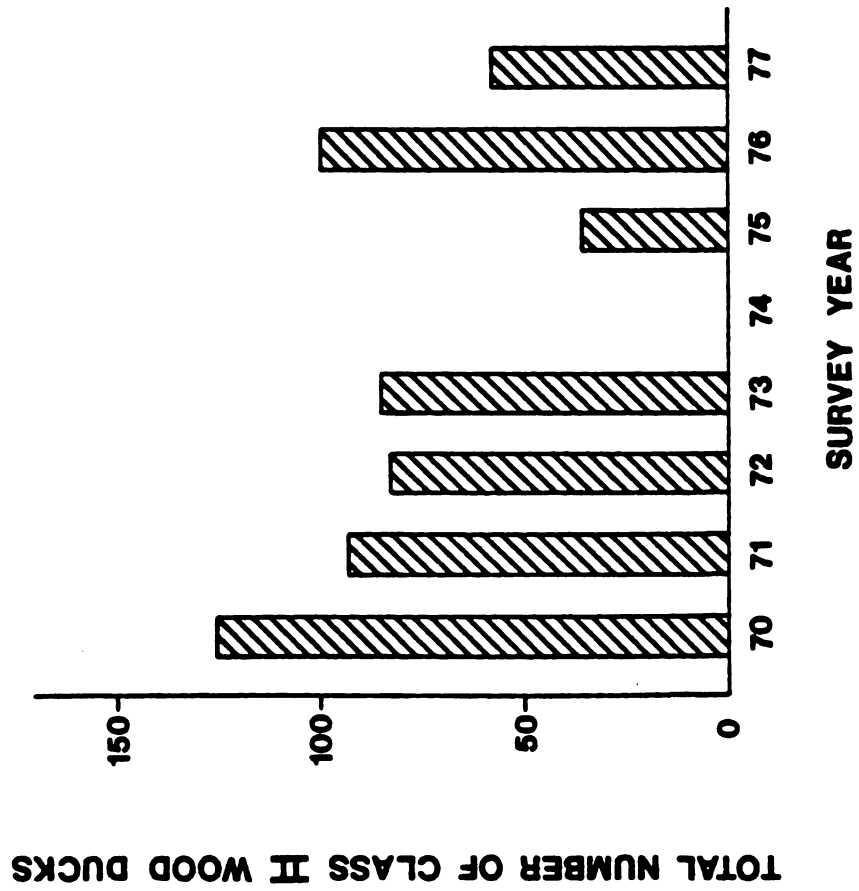


TABLE 4. Wood duck nest information from artificial structures located on a 35.4 km segment of the Holston River, Hawkins County, Tennessee, 1975-1977.

Nest Box Information	Year		
	1975	1976	1977
Number boxes available	146	186	204
Percent occupancy	35 (N=51)	25 (N=47)	29 (N=60)
Percent nest success	68 (N=38)	79 (N=33)	53 (N=28)
Mean clutch size of successful nests	12.1 $\pm$ 0.6 (N=26)	13.0 $\pm$ 0.6 (N=27)	12.5 $\pm$ 0.7 (N=28)
Mean number of young per successful nest	10.4 $\pm$ 0.7 (N=26)	11.6 $\pm$ 2.4 (N=27)	10.3 $\pm$ 0.7 (N=28)

(1975 and 1976). In 1977, the hatch was delayed by approximately one week by a major flood on April 4 that destroyed some of the early nests and forced females to renest. River flood waters were as high as three to five meters above normal pool level, flooding a known total of 14 wood duck nests. Wood duck nest success on the Holston during this study was 68, 79 and 53 percent for 1975 through 1977, respectively (Table 4). Nest failures were primarily due to harassment and competition from starlings (Sturnus vulgaris) with a few destroyed by black rat snakes (Elaphe guttata) and flooding.

Clutch size was not significantly different among years and the pooled value was 12.6 ± 0.4 ($N = 81$). The average number of young leaving a successful nest was 11.3 ± 0.3 ($N = 81$). Mean brood sizes per age class based on morning boat surveys, night boat surveys, morning helicopter surveys, and observations on marked female wood ducks with broods during 1976 and 1977 were not significantly different either between years or survey methods. The average size for age class I, II, and III was 7.5 ± 0.3 ($N = 204$), 5.0 ± 0.3 ($N = 150$), and 3.8 ± 0.3 ($N = 62$). There was a 34 percent decrease in ducklings between the average number leaving the nest and age class I broods. The decrease between age class I and II was 33 percent. The lowest duckling mortality was 24 percent found between age class II and III broods. The difference in number of young between age class II broods and age class III broods may be, in part, the result of a loss in brood identity and subsequent difficulty in counting complete broods. Overall loss of ducklings from the nest site to age class II was 56 percent, while loss from nest site to class III was 66 percent. No data on whole brood losses were available.

Brood Activity Periods

Wood duck brood activity was monitored during three time periods from three fixed observation points during 1976 (Table 5). More than twice as many young wood ducks per hour were observed during the midday period as during the morning period. This difference was statistically significant ($P < .10$, critical value = 12.3, $N = 18$) based on a Wilcoxon two-way all pairwise classification test (Wilcoxon and Cox 1964). There was no significant difference between the midday and evening periods.

Brood Movements

Movements of female wood ducks with broods were based on observations of females with telemeters and/or nasal saddles. The location of the nest site and at least one location on the river were obtained for 18 females. Ten females moved upstream from the nest site with their brood compared with eight females that moved downstream from the nest site. The mean distance between the nest site and the first location was not significant between the upstream and downstream movement and the combined average was 1.2 ± 0.3 km.

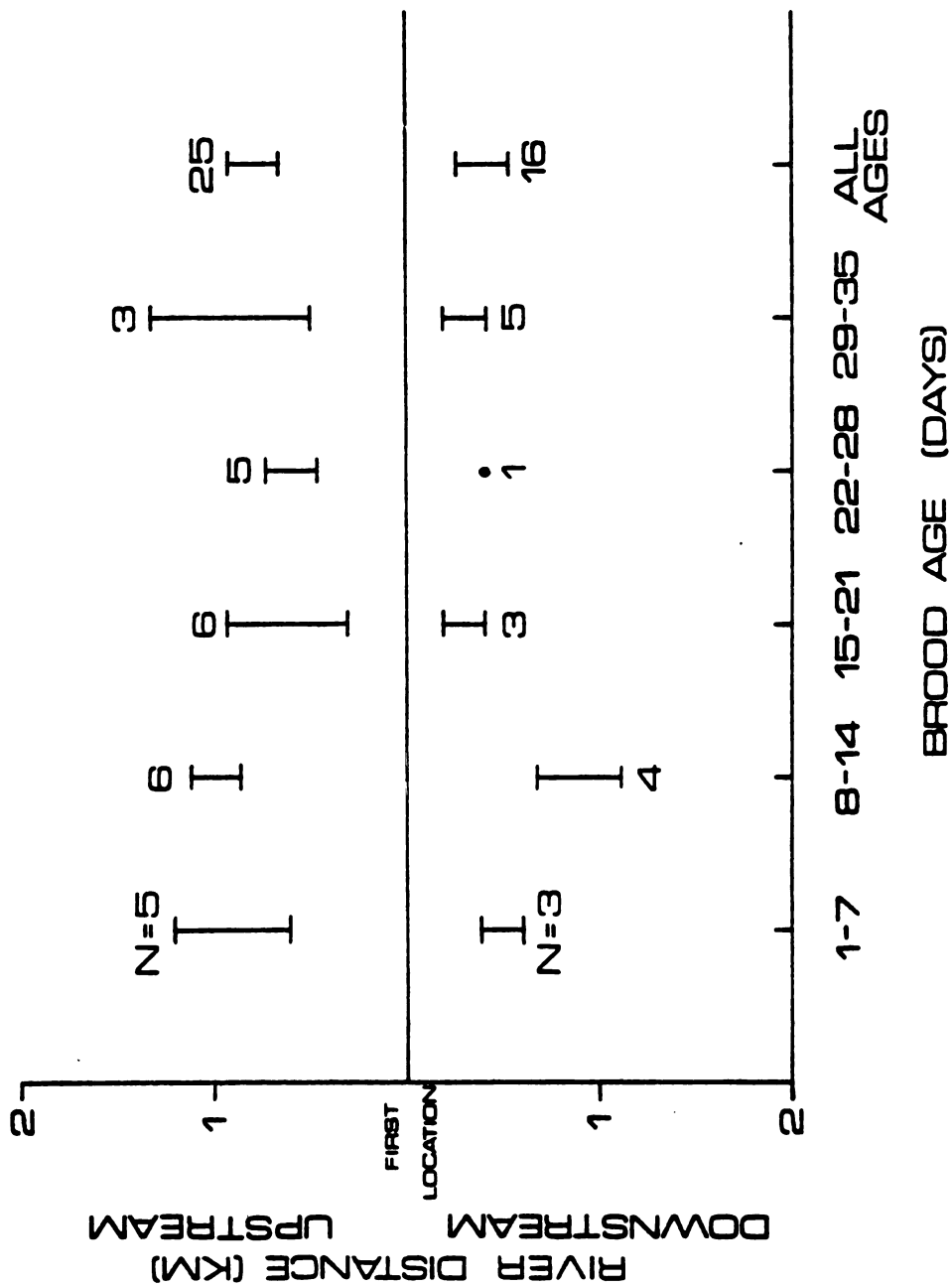
Additional records of brood movements in relation to the first location on the river were obtained for 16 females (Figure 3). The location of broods was between 1 and 35 days after hatching and 41 usable locations were plotted. The pattern of movement away from the first location was constant with increasing age of the brood. The average maximum distance between any two locations for a marked female with a brood was 1.0 ± 0.2 km. The average distance of movement away from the first location was similar between upstream and downstream directions and the combined average was 0.7 ± 0.1 km.

TABLE 5. Total number of wood duck young (all age classes) seen per hour at three fixed point locations during six observations per time period on the Holston River during spring-summer 1976.

Observation Point	Observation Period		
	Morning	Midday	Evening
128	4	32	11
125	10	21	44
112	41.5	65	53
Total	55.5	118 ^a	108

^aSignificant at $P \leq .10$, critical value 12.3, $n = 18$. (Wilcoxon and Cox 1964).

Figure 3. Movements ($X \pm S.E.$) of marked wood duck broods in relation to first location and age of ducklings on the Holston River during 1976 and 1977.



Habitat Utilization

Wood duck utilization of the Holston River was based on the analysis of the survey and telemetry data. All survey data taken from the Holston (35.2 km segment) during 1976 (three survey methods) and 1977 (four survey methods) were broken down into the number of ducklings observed per age class per 1.6 km river segment per survey method (over all survey sequences) for each survey year. This resulted in 21 arrays of 1.6 km river segments. The arrays of river segments were then ranked and subjected to all pairwise comparisons of Spearman rank correlation. The results of these analyses failed to show any consistent pattern of association between survey methods either within or between years. Since the surveys are correlated for the entire route and a low percentage of the population is observed during a particular survey, a different approach was taken to identify segments of the stream where low and high wood duck use was occurring.

Radio telemetry data from 1976 and 1977 indicated that wood duck broods were, on the average, restricting their upstream and downstream movement for the first 35 days to a 0.7 ± 0.1 km segment of river. Thus, a 0.8 km segment of river was chosen as the linear river unit which was assumed to be influential in the habitat utilization of any given wood duck brood on the Holston River.

The most obvious bias in using survey data to estimate brood use for a given linear segment of river is that wood duck broods do not recognize the arbitrary boundaries set up by the researchers. Thus, a particular brood that is observed within the lower portion of one river segment during one survey may be observed within the upper portion of the adjacent river segment during another survey. Although this bias

does occur in the experimental design of the study, it was assumed that the crossover by broods should be relatively constant over all river segments. The 1977 survey data per 0.8 km river segment were reduced to a nominal (presence or absence) scaling so that any observation of one or more ducklings (either with or without a hen) per age class during the morning float, night float, morning helicopter, and afternoon helicopter surveys was considered as wood duck use for that survey period. The total number of times (maximum seven) that wood duck use per age class was observed for each river segment over all survey sequences was then used to rank the river segments from highest to lowest in relation to the consistency of wood duck use (Figure 4). High use river segments were arbitrarily defined as those segments where ducklings were observed three or more times over the season for age class I and two or more times for class II and class III. Low use segments were those with none or one observation for age class I and age class II and no observation for age class III.

All shoreline habitat (including islands) within the study area was classified into one of three types: pasture, early successional, or wooded. Over the entire study area 57 percent of the shoreline is wooded, 34 percent is in early successional, and 9 percent is in pasture (Table 6). Discriminant function analysis of habitat variables that contrasted high and low use 0.8 km river segments was made. There were significant ($P = 0.066$, 6 df) contrasts among habitat variables for class I wood ducks and there were no significant differences between low and high use areas for class II and III wood ducks. The relationship between the high and low use groups for class I wood ducks based on their discriminant scores (standardized standard deviations) is shown in Figure 5.

Figure 4. Number of times that one or more wood duck young was observed during seven survey sequences per 0.8 km segment of the Holston River for 1977.

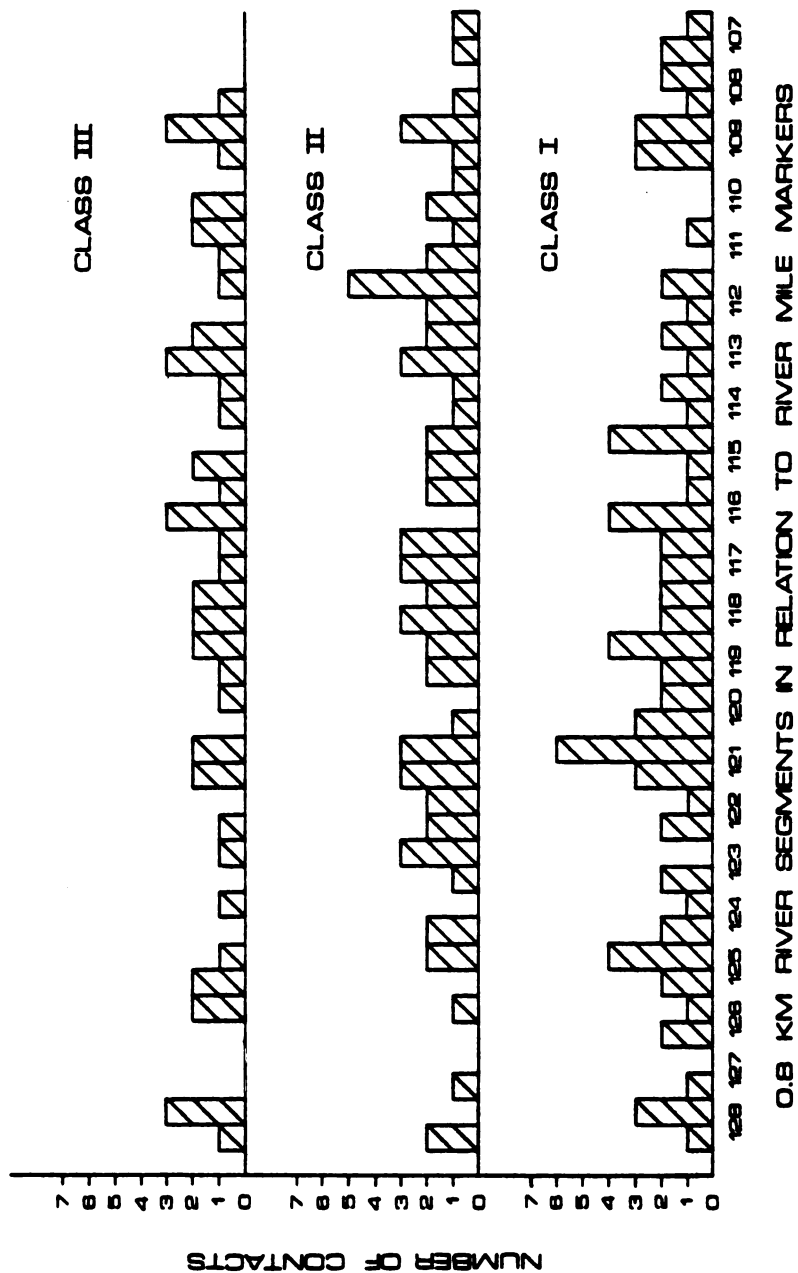
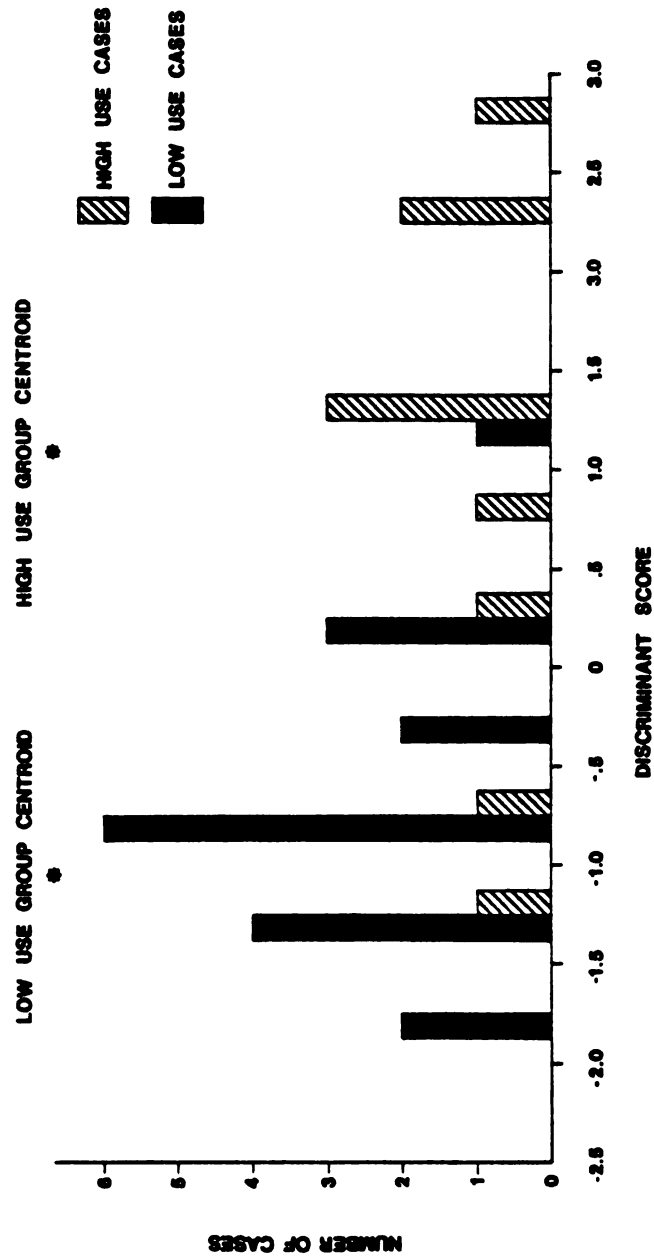


TABLE 6. Percent of each shoreline habitat type available on four major river segments of the Holston River, Hawkins County, Tennessee.

River Mile Sections	Shoreline Habitat Type		
	% Pasture	% Early Successional	% Wooded
128-123	4	33	63
122-117	1	39	60
116-111	13	29	58
110-107	18	35	47
Total (128-107)	9	34	57

Figure 5. Frequency distribution of discriminant scores and location of centroids for high and low wood duck brood (age class I) use groups per 0.8 km segment of the Holston River study area for 1977.



The three most important habitat variables in the analysis for class I wood ducks were wooded shoreline, fallen trees, and aquatic vegetation (Table 7). These three variables combined accounted for 73 percent of the variation between the high and low use groups. Early shoreline, amount of surface water, and pasture shoreline were the least powerful variables in the analysis with a combined relative contribution of 27 percent to the discriminant function. The correct reclassification of 78.6 percent of the class I cases was significant ($P = .002$).

Wood duck broods of all ages were observed utilizing shorelines, upland, and open water habitat zones based on 1976 and 1977 shoreline walk data (Table 8). The majority (72.9 percent in 1976 and 75.3 percent in 1977) of brood use took place along the shoreline zone of the river. This zone was utilized for feeding, resting, and traveling by wood duck broods. The open water zone (at least 6 meters from shoreline) was used periodically by young wood ducks (6.3 percent in 1976 and 3.4 percent in 1977). Broods observed in the open water zone were most often seen feeding in drifting floating mats of uprooted aquatic vegetation. Upland habitat zones received substantial utilization by wood duck broods for escape and undisturbed uses. During 1976 shoreline surveys, 10 out of 48 broods contacted were flushed exclusively from the uplands while 5 out of 89 broods contacted during 1977 surveys were flushed from the uplands only. An additional 14 broods were flushed at the shoreline and ran into the uplands during 1977 surveys.

Upland broods (all ages) were contacted on the average 10 ± 1.0 m from the shoreline (Figure 6). Class I broods ($N = 16$) were most frequently observed in the uplands followed by class II ($N = 10$) and class III broods ($N = 3$).

TABLE 7. The relationship of habitat variables to high and low use river segments for class I wood ducks on the Holston River during 1977.

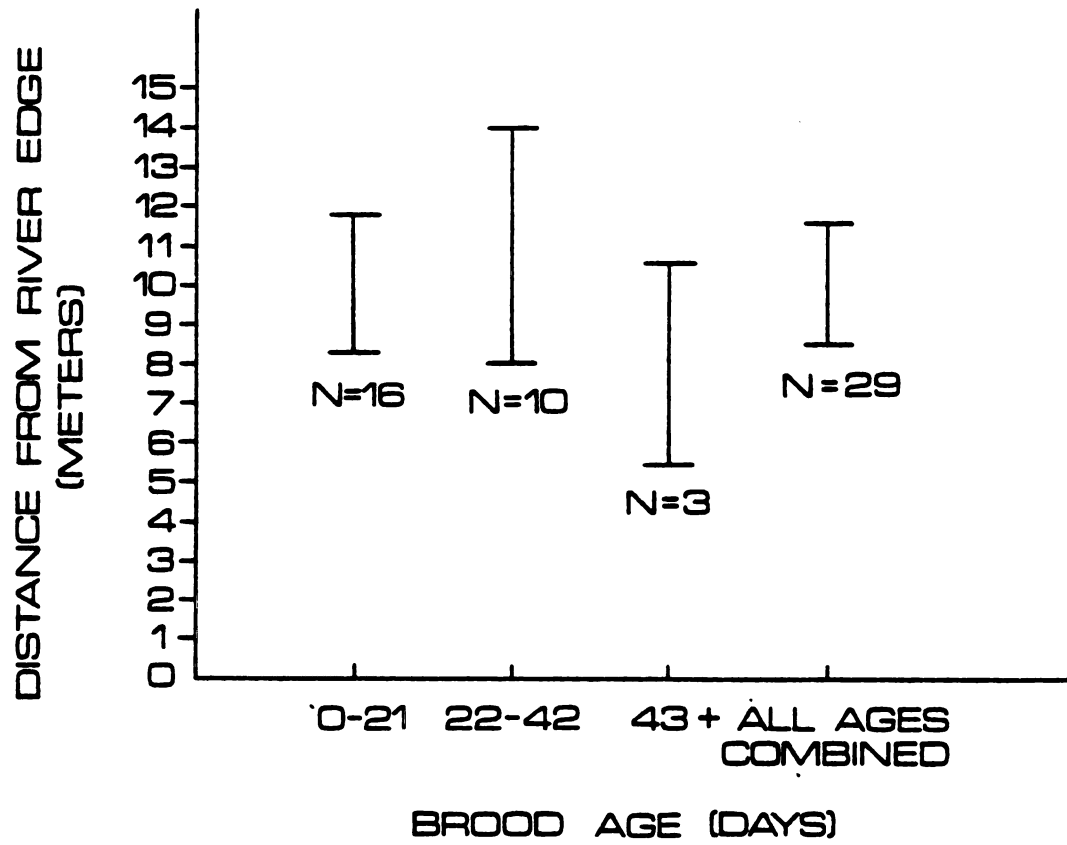
Variable	High Use Group Mean (L_1-L_2) (N=10)	Low Use Group Mean (L_1-L_2) (N=18)	Discriminant Analysis	
			Discriminant function coefficient ^a	Relative contribution to function %
Wooded shoreline (m)	1610 (950-2270)	940 (690-1190)	0.757	34.0
Fallen trees	8.8 (2.8-20)	3.2 (1.9-4.8)	0.522	23.4
Aquatic vegetation (ha)	5.28 (1.43-9.12)	2.76 (1.35-4.17)	0.348	15.6
Early shoreline (m)	980 (670-1280)	710 (500-930)	0.238	10.7
Surface water (ha)	13.1 (8.57-18.7)	13.2 (9.73-17.3)	-0.204	9.2
Pasture shoreline (m)	50 (0-110)	330 (50-600)	-0.158	7.1
Wilks lambda = 0.6112 Chi-square = 11.82 DF = 6 P = .066				

^aAbsolute value of D.F.C. most important; sign indicates positive or negative contribution of variable (Nie et al. 1975).

TABLE 8. Number and percent of wood duck broods using three different habitat zones based on observations made during 1976 and 1977 shoreline surveys on the Holston River.

Habitat Zone	1976		1977	
	Number of Broods	Percent of Total	Number of Broods	Percent of Total
Shoreline	35	72.9	67	72.3
Upland	10	20.8	19	21.3
Open Water	3	6.3	3	3.4

Figure 6. Average distance $\pm$ S.E. away from the river's edge for wood duck broods flushed from the uplands in relation to brood age, on the Holston River, during 1976 and 1977.



A total of 41 sample sites utilized by young wood ducks and 30 random sample sites were selected from 89 observations of brood activity recorded for 19 km of river shoreline walked biweekly between May 12 and July 8 during 1977 (Table 9). An additional seven utilized sites were chosen from 1977 river surveys and visual contacts with marked broods. A utilized sample site was designated as a point along the shoreline where any brood activity (feeding, resting, locomotor, or escape into uplands) was observed. A random sample site was defined as any point within the 19 km of shoreline walked where no brood activity was observed during any of the surveys.

Bank slope along with water depth 15 cm and one meter from the shoreline was used in a discriminant function analysis to test the variation between shoreline use sites and random sites. The discriminant function was highly significant ($P = .002$, 3 df) for class I ducklings (Table 10), not significant for class II ducklings, and moderately significant ($P = .099$, 3 df) for class III ducklings (Table 11). Although bank slope and water depth at one meter from shore were the most important variables, these two variables were reversed in importance between class I and III wood ducks. In areas utilized by class I and class III wood duck broods, the water was deeper one meter away from the shoreline than in the random samples and the bank slope was less where broods were observed than in the random samples. Figures 7 and 8 graphically depict the frequency distributions of the discriminant scores (a standardized standard deviation) for the high and low use groups for age class I and age class III, respectively.

TABLE 9. Number of wood duck broods^a per age class contacted from shoreline surveys on the Holston River, Hawkins County, Tennessee, during spring-summer 1977.

Date	Age Class			Total
	I	II	III	
May 12 to May 20	16	0	0	16
May 31 to June 7	16	8	0	24
June 14 to June 21	6	15	1	22
June 28 to July 8	6	6	15	27
Total	44	29	16	89

^aOne or more ducklings with or without a female considered a brood.

TABLE 10. The relationship of bank slope and water depth to utilized and random sample sites for class I wood ducks on the Holston River during 1977.

Variable	Utilized Group Mean (L_1-L_2) (N=22)	Random Group Mean (L_1-L_2) (N=30)	Discriminant Analysis	
			Discriminant function coefficient	Relative contribution to function %
Bank slope	0.81 (0.46-1.0)	2.3 (1.6-3.0)	1.142	59.6
Water depth (cm) 1 meter from shore	40 (30-50)	35 (24-46)	-0.536	27.9
Water depth (cm) 15 cm from shore	13 (9-17)	11 (7-17)	0.239	12.5
Wilks lambda = 0.7423	Chi-square = 14.75		D.F. = 3	P = .002

TABLE 11. The relationship of bank slope and water depth in utilized and random sites for class III wood ducks on the Holston River during 1977.

Variable	Utilized Group Mean (L_1-L_2) (N=10)	Random Group Mean (L_1-L_2) (N=30)	Discriminant Analysis	
			Discriminant function coefficient	Relative contribution to function %
Water depth (cm) 1 meter from shore	52 (29-75)	35 (24-46)	-1.019	47.5
Bank slope	1.4 (0.73-2.1)	2.3 (1.6-3.0)	0.837	38.9
Water depth (cm) 15 cm from shore	16 (10-22)	11 (7-17)	0.291	13.6
Wilks lambda = 0.8457	Chi-square = 6.27		D.F. = 3	P = 0.99

Figure 7. Frequency distribution of discriminant scores and location of centroids for utilized and random wood duck brood (age class I) use groups on the Holston River during 1977.

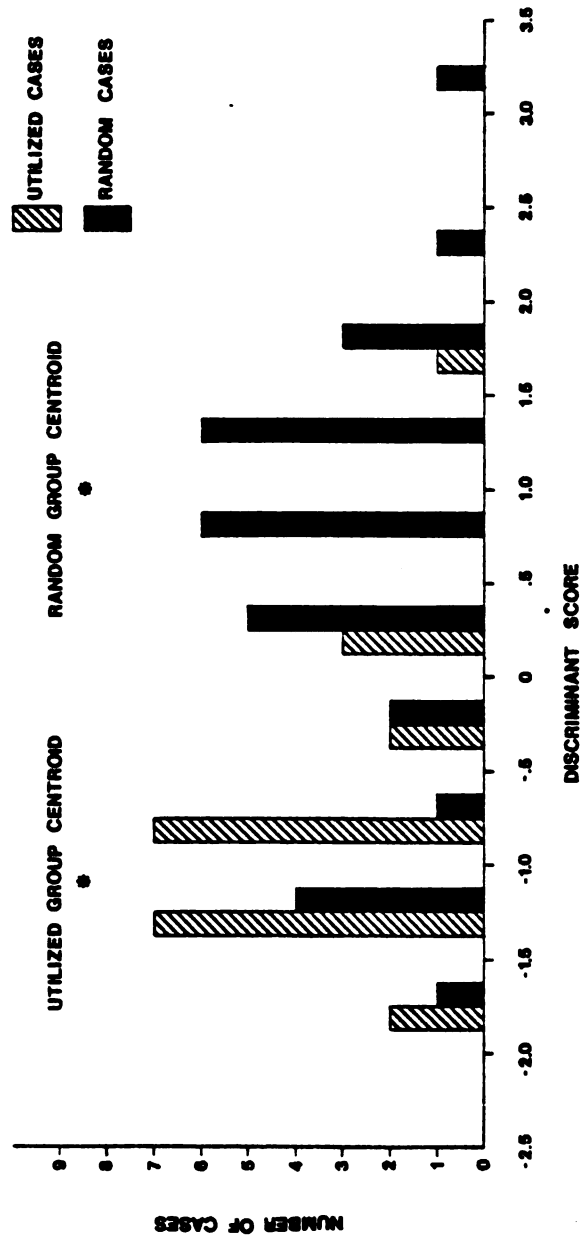
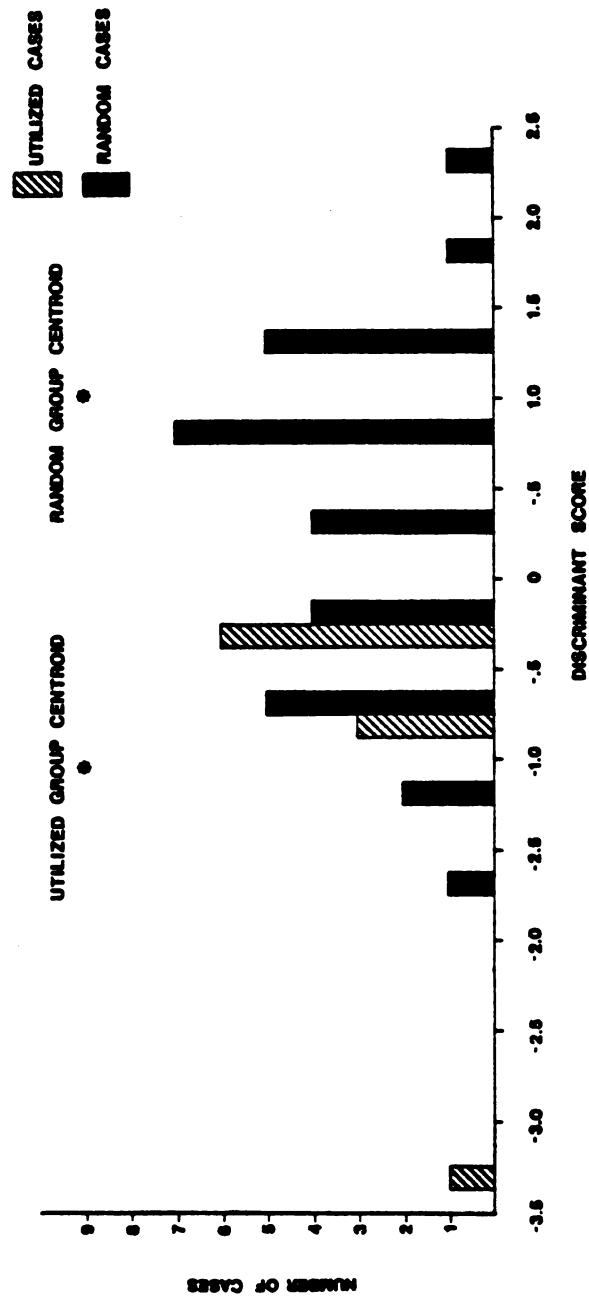


Figure 8. Frequency distribution of discriminant scores and location of centroids for utilized and random wood duck brood (age class III) use groups on the Holston River during 1977.



DISCUSSION

Bellrose (1976) has reported that, on the average, 11 young wood ducks leave a successful nest. He reports that the average size of class I, II, and III broods is 6.9, 5.7, and 5.4 ducklings. These brood sizes are consistent with averages on the Holston for age class I (7.5 ± 0.3) and age class II (5.0 ± 0.3), but higher with respect to age class III (3.8 ± 0.3). Brood mortality from nest departure to flight stage is 66 percent on the Holston, which is higher than estimates of 44 percent in Mississippi (Baker 1970), 53 percent in Massachusetts (Grice and Rogers 1965), and 50 percent in Alabama (Beshears 1974), and similar to reports of 68 percent in Georgia (Odum 1969), 64 percent in New York (Klein 1955), 59 percent in Minnesota (Ball et al. 1975), 60 percent in Arkansas (Brown 1973), and 58 percent in Maryland (Alexander 1971). These estimates do not consider the loss of an entire brood. Ball et al. (1975) found that production estimates in Minnesota were overinflated by 38 percent if total brood losses were not taken into account.

Although the breakup of a brood can occur as early as two weeks of age (Farmer 1970), most reports are of a gradual dissolving process that begins at five to six weeks of age (Stewart 1958a, Beard 1964, Prince 1965, Ball et al. 1975). McGilvrey (1969) found that mortality estimates for wood duck broods in Maryland were unreliable after five weeks of age. Only one marked female wood duck with a class III brood was observed out of 46 observations on marked broods during two field seasons on the Holston River, while 13 observations were recorded for class II and 32 observations recorded for class I broods. Thus, an average overall duckling loss per surviving brood on the Holston is probably best calculated from nest exit to age class II.

Substantial movements of wood duck broods in relation to age of young and the nest site have been recorded. Ohio studies by Stewart (1958a) observed both primary moves from the nest site to the nearest vegetated water area after hatching and secondary moves at two weeks of age ranging from 0 to 5.6 km. Prince (1965) also observed a two stage movement pattern in New Brunswick. Primary moves (from nest site to first wetland used more than one day) of wood duck broods in Minnesota averaged 1.4 km (range 0.2 - 2.3 km), while some broods made secondary moves (between 9 and 20 days of age) that averaged 2.2 km (range 1.4 - 3.7 km) (Ball 1971). Hardister et al. (1962) recorded movements of up to 2.4 km from nest site to flight stage between pond habitats in North Carolina, while Farmer (1970) on the same study area observed moves of 3.1 to 4.1 km (mean = 3.5 km) for class I broods as well as maximum linear range of 2.4 km for two class I broods utilizing a river habitat. Movement of broods from the nest site to first wetland used for at least 24 hours ranged from 0 to 3.5 km (mean = 1.4 ± 1.5 km) between beaver pond habitats in South Carolina (Hepp and Hair 1977). On the Holston River, radio- and/or nasal saddle-marked female wood ducks with broods exhibited a strong fidelity up to 35 days of age for a rather small segment of river that was near the nest site. The longest upstream and downstream moves by broods were from the nest site to first radio or visual contact (mean = 1.2 ± 0.3 km) and decreased thereafter. Secondary movement patterns by marked wood duck broods were not observed on the Holston River.

Young wood ducks of all ages were observed moving freely between open water, shoreline, and upland habitat zones on the Holston River. Primary habitat utilization occurred along the shoreline zone with

secondary and tertiary use of the upland and open water zones, respectively. Wood duck broods used the shoreline zone for feeding, resting, and traveling during daylight hours and appeared to use the shoreline zone at night primarily for roosting with little feeding or traveling activity observed. Open water zones were utilized for feeding in drifting and rooted aquatic vegetation. Although wood duck broods were often observed using upland habitats as escape cover, a substantial number of broods contacted on the Holston during shoreline surveys were flushed directly from the uplands during the daytime without prior disturbance. Other studies have also noted the use of upland habitats by young wood ducks for both escape (Audubon 1840 quoted in Bent 1923:163, Stewart 1958a, Prince 1965, Minser 1968, Ball 1970) and undisturbed uses (Schreiner and Hendrickson 1951, Dreis and Hendrickson 1952, Dreis 1954).

Collias and Collias (1963) contrasted the specialized bill structure and pecking type feeding strategy of young wood ducks with that of straining feeders such as ruddy ducks (Oxyura jamaicensis) and generalized feeders such as mallards (Anas platyrhynchos). Beard (1964) remarked on the jumping ability and skillfulness of young wood ducks in capturing insect prey clinging to emergent sedge stems. Musselman (1948) observed captive wood duck young actively feeding on grasshoppers and crickets in grass. Wood duck food habit analysis on the Holston River by Hocutt and Dimmick (1971) and Lindsay (1976) identified terrestrial insects as a major component of the animal matter in the diet of young wood ducks. Thus, it is suggested that wood duck broods on the Holston may actively use the upland habitats adjacent to the river for foraging, as well as a substitute for water based emergent escape cover.

Wood duck broods are generally considered most active and visible during morning and evening periods (Beard 1964, Grice and Rogers 1965, McGilvrey 1969, Farmer 1970, Hepp and Hair 1977). Decker (1959) found wood duck broods active throughout the day in Pennsylvania. Results from fixed observation points and afternoon helicopter surveys indicate that young wood ducks on the Holston are active and visible all day long with peak numbers observed during the midday and evening periods.

Steward (1958b) estimated that less than 25 percent of the available broods were observed during float counts on the Scioto River in Ohio. The visibility of marked female wood ducks with broods during morning floats on the Holston was also low with an average of only 4 percent observed in both 1976 and 1977. More marked females with broods were observed during night float counts with an average of 16 and 19 percent observed during 1976 and 1977, respectively. A higher number of wood duck young were almost always observed during night boat surveys than during corresponding morning boat or morning helicopter surveys. These results are similar to those from studies on the Holston by Minser (1973) who observed significantly higher numbers of wood duck broods (all ages combined) during night boat floats versus morning boat floats. Several investigators have questioned the usefulness of morning boat survey data because of its variable nature (Stewart 1958b, Geis 1966, Minser 1968, Minser 1973). Based on data from the present study, morning boat, morning helicopter, and night boat surveys are statistically sampling the same population, but not at the same level of intensity.

A stepwise discriminant function analysis was used to assess wood duck brood habitat on the Holston River. Increased amounts of wooded shoreline, fallen trees, and aquatic vegetation were found to be the

most important combination of habitat variables that distinguished between high use and low use river segments for class I wood ducks. These results are consistent with habitat components found to be important to wood duck broods in other studies (Webster and McGilvrey 1966, McGilvrey 1968, Watts 1968, Minser 1968, Hocutt and Dimmick 1971). In all of these studies one or more of the aforementioned variables were common to areas of high wood duck brood use. The most important parameters that were measured in the immediate vicinity of class I and III broods were increased water depth one meter from shore and a decreased bank slope.

The combination of low bank slope, increased water depth away from the shoreline, and wooded shoreline suggests a rather specific habitat preference by female wood ducks and their broods. This type of habitat structure is most likely to occur in a meandering, lotic environment. Wooded stream banks tend to be the most stable and resist erosion, which should encourage a moderate bank slope, yet allow substantial stream cut immediately below the shoreline water interface. This in turn creates exposed root complexes and overhanging bank vegetation. These characteristics appear to provide shoreline cover for the birds as well as clinging points for some of their insect food items, while a moderate bank slope allows ease of access to upland escape cover.

Class I wood ducks showed the most significant discrimination between sets of habitat variables which may be indicative of more specific habitat needs for this age class in comparison to class II and III wood ducks.

MANAGEMENT

Data from the Holston River study area suggest that given the proper habitat conditions, wood duck brood rearing requirements can be met

within relatively small sections of riverine habitats. The necessary habitat combination for class I broods seems to be keyed to primary use of wooded shorelines and a moderately sloping bank which act as a baseline for additional utilization of adjacent upland habitats and aquatic vegetation. Based on these results, the following recommendations are made pertaining to construction and operation of nuclear power plants within wood duck riverine habitats. Disturbance of stream shorelines should be kept to a minimum. Construction activities such as clear cutting along stream banks and channelization have a devastating effect on wood duck habitat. Wooded shorelines should be encouraged to provide bank stabilization, overhead shoreline cover, and exposed root complexes. Fallen trees along the shoreline are important as loafing sites, roosting sites, and escape cover for broods and should be maintained. Submersed aquatic vegetation appears to act as a substrate for duckling insect food as well as food for older ducklings and adult birds. This type of natural vegetation complex should be protected. Upland habitat adjacent to the river shoreline furnishes young wood ducks with escape cover and possible foraging sites for terrestrial insects. A buffer zone at least 30 meters wide should be established along each shoreline to safeguard this critical habitat component.

Overall, wooded shorelines, fallen trees, moderate bank slopes, and aquatic vegetation are key habitat variables to young wood ducks on the Holston River and should be considered in any nuclear power plant related activities within this riverine system.

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