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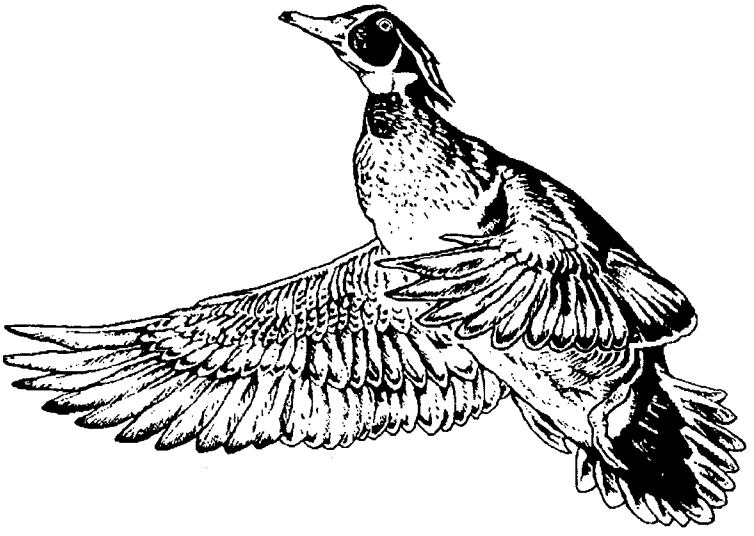

Wood Duck Investigations
W-118-R-4-5-6

Final Report to

Illinois Department of Natural Resources

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20 November 1998

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EXECUTIVE SUMMARY

Aerial (helicopter) line-transect (LT) methodology was employed at three study areas to estimate breeding wood duck (Aix sponsa) populations in bottomland forests of the Illinois River valley. The wood duck indicated breeding pair (IBP) density estimated from the LT surveys at the Sanganois study site ranged from 0.039 to 0.116 IBPs/acre for each spring, 1996-1998. Breeding wood duck densities estimated at the Princeton (0.015-0.058 IBPs/ac) and the Meredosia (0.008-0.055 IBPs/ac) sites were smaller than densities estimated at Sanganois and were also less precise. The costs of the helicopter surveys with three observers averaged $55.69/mi^2, or $236.31/observer/survey.

The density of natural cavities suitable for nesting by wood ducks (suitable cavities) at the Sanganois Conservation Area (CA) in 1994 (0.86 suitable cavities/ac) and 1997 (0.76 suitable cavities/ac) were similar, indicating that cavity densities remained unchanged as a result of losses from tree mortality associated with the 1993 and 1995 floods, and increases from decay and pileated woodpecker (Dryocopus pileatus) activity.

Raccoons (Procyon lotor) were the primary users of suitable cavities. Evidence of raccoon use was found in 29.3 to 35.3 percent of cavities. Fox squirrels (Sciurus niger) were the other primary inhabitants and occupied 5.2 to 11.8 percent of the monitored cavities. A large number of suitable cavities (43.2-46.6%) were not used during the springs of 1996-1998; therefore, cavity availability does not appear to be limiting wood duck production at the Sanganois CA.

No differences in wood duck nest densities were detected during springs of 1994-1998, suggesting that the breeding wood duck population remained stable over the 5-yr study. Wood duck nest success rates varied from 0.0 to 100.0 percent during these springs. A combined sample of 26 nests from 1994, 1997, and 1998 provided a simple estimate of wood duck nest success of 57.7 percent at the Sanganois CA.

IBP estimates of wood ducks from LT surveys in 1997 for each observer ranged from 39.8 to 73.5 percent of the wood duck nest densities obtained from inspections of natural cavities; in 1998 IBP estimates were 43.9 to 70.4 percent of nest density values. Variability in the IBP density estimates prevented precisely defining breeding populations. The high variability in nest density estimates in both 1997 and 1998 limited the ability to detect differences between the LT and cavity inspection methods of estimating wood duck densities.

We recommend further research evaluating the LT methodology for estimating densities of breeding wood ducks in bottomland forests. LT surveys should employ transect lengths long enough to provide 200-300 wood duck observations. Surveys incorporating this number of sightings should provide precise (coefficient of variation [CV] < 10%) estimates of wood duck densities. Flights should not be initiated when winds exceed 15-20 mph to facilitate the pilots abilities to strictly adhere to transect lines. Additionally, excessive winds create ripples on the water surface that increase the difficulty of identifying flushing locations of wood ducks. Multiple surveys should be flown in spring to assess the chronology of migration and the emergence of tree foliage

that hinders detection of wood ducks. Researchers should consider the possible disturbance effects of low-altitude aerial surveys on nontarget species, such as bald eagles (Haliaeetus leucocephalus), great blue herons (Ardea herodias), great egrets (Casmerodius albus), and double-crested cormorants (Phalacrocorax auritus), in bottomlands.

Artificial wood duck nest boxes were monitored during June-July each year from 1996 to 1998 at the Sanganois CA. Only a small percentage (6.2-16.3%) of the boxes were used for nesting by wood ducks. Simple estimates of nest success in the boxes ranged from 57.1 to 100.0 percent. Metal boxes received the highest use (16.7-27.0%) each year, while only 1.5 to 9.1 percent of the plastic boxes were used during the springs of 1996 to 1998. An estimate of the density of wood duck nests derived from boxes was 0.001-0.003 nests/ac of bottomland forest for each spring.

The mortality of 61 trees containing potentially suitable wood duck nest cavities (potential cavities) was monitored subsequent to the Great Flood of 1993. Tree mortality at Sanganois CA appeared to have peaked after 1996 when 55.7 percent of the monitored trees had perished. Sixty-five natural cavities were examined annually beginning in the winter and spring of 1993-1994. By July 1998, 40 of these 65 cavities (61.5%) had become unsuitable for nesting by wood ducks. The daily survival rate for suitable cavities was 0.99942 with an annual survivorship of 80.8 percent (75.5-86.4 [95%CI]).

SUMMARY OF ACCOMPLISHMENTS

STUDY I AERIAL HELICOPTER SURVEYS OF BREEDING WOOD DUCKS IN BOTTOMLAND FOREST

JOB I-1 Potential Population Estimate for Breeding Wood Ducks in Bottomland Forest in Illinois.

We evaluated the feasibility and cost for using helicopters to aerially census wood duck populations in bottomland forests during springs, 1996-1998. Two aerial line-transect surveys were flown each spring at three locations in the Illinois River valley. Breeding wood duck densities were estimated for each year. Costs of aerial surveys were compared with previous studies in other locations.

JOB I-2 Comparison of Aerial Surveys with Densities of Wood Ducks Nesting in Natural Cavities.

The density of breeding wood ducks estimated in JOB I-1 was compared with the density of nesting wood ducks estimated from inspections of natural cavities the same year. Suitable nesting cavities were monitored for vertebrate use and wood duck nest success, 1996 to 1998. Natural cavities suitable as wood duck nest sites were surveyed during winter 1996-1997 to increase the sample of suitable cavities for monitoring. Tree mortality was estimated from a sample originally identified in 1992-1993.

FINAL REPORT
Wood Duck Investigations
Federal Aid in Wildlife Restoration
W-118-R-4-5-6
1 July 1995 through 30 June 1998

STUDY I: AERIAL HELICOPTER SURVEYS OF BREEDING WOOD DUCKS IN BOTTOMLAND FOREST

OBJECTIVES:

Study objectives were to: 1)estimate breeding wood duck populations in bottomland forests by evaluating an aerial (helicopter) census technique, and 2) compare aerial population estimates of breeding wood ducks in bottomland forests with population densities of wood ducks nesting in natural tree cavities.

INTRODUCTION

A major challenge in wood duck management is the inability to estimate population sizes because of its secretive nature and inhabitation of forested wetlands. Bellrose (1980) stated that the wood duck is the most difficult of ducks to census and that aerial population estimates are inadequate. However, helicopter surveys have been used for estimating breeding populations since 1990 in association with the Black Duck Joint Venture of the North American Waterfowl Management Plan in Maine and eastern Canada. Wood ducks are detected on these surveys, but estimates of precision are not reported. Likewise, helicopters are currently used in Wisconsin to survey a variety of waterfowl in marsh habitats. Sherman et al. (1992) used helicopters to census wood duck populations in forested habitat, but they suggested further evaluation was needed to produce reliable population estimates.

Information on the breeding population size of wood ducks is necessary to enhance management of this endemic North American species. Sampling theory and design used for aerial surveys of wildlife populations in other habitats have been defined and need only slight modifications for use in bottomland forests. Aerial surveys have been used to monitor many species including: manatees (Trichechus manatus) (Packard et al. 1985), kangaroos (Macropus spp.) (Choquenot 1995), seabirds (Briggs et al. 1985), finless porpoise (Neophocaena phocaenoides) (Yoshida et al. 1998), harbor porpoise (Phocoena phocoena) (Laake et al. 1997), pronghorn antelope (Antilocapra americana) (Johnson et al. 1991; Pojar et al. 1995), African ungulates (Norton-Griffiths 1978), white-tailed deer (Odocoileus virginianus) (Pietsch 1954), mule deer (O. hemionus) (White et al. 1989), northern bobwhite (Colinus virginianus) (Shupe et al. 1987), and waterfowl (Havera 1998).

Bateman (1970) reported that helicopters were a reliable method of censusing mottled ducks (Anas fulvigula) in Louisiana coastal marshes. Johnson et al. (1989) used helicopters to survey mottled ducks in salt marshes and found they were superior to fixed-wing aircraft. Helicopter surveys of waterfowl in the boreal forest produced similar results to more costly ground counts on the same areas (Ross 1985). Likewise, aerial observers identified more wintering American black ducks (A. rubripes) than did ground observers (Heusmann 1990). Helicopters provide increased visibility over fixed-wing aircraft because of slower air speeds and more associated noise, which induces birds to flush. Thus, helicopters are a reasonable alternative to fixed-

wing aircraft for use in surveying wood ducks (Bateman 1970, Broome 1985).

In 1993, states in the Atlantic and Mississippi flyways along with the U.S. Fish and Wildlife Service developed a wood duck management strategy to outline databases needed to effectively manage wood duck populations (Kelley 1997). One goal identified in this strategy was to assess ways to monitor wood duck breeding populations. However, the preseason banding and roadside survey data used to achieve this goal generally have been inadequate. Therefore, this study was designed to evaluate the feasibility of using helicopters to estimate breeding numbers of wood ducks in selected bottomland forests in Illinois.

ACKNOWLEDGMENTS

Project W-118-R was supported by Federal Aid in Wildlife Restoration Act (Pittman-Robertson), with funds administered by the U.S. Fish and Wildlife Service (USFWS) and the Illinois Department of Natural Resources (IDNR). The following IDNR staff at the Sanganois Conservation Area contributed assistance and advice during this project: D. Cowen, J. Hopps, R. Smith, and R. Mann. The following Illinois Natural History Survey (INHS) staff assisted with this project: P. White and L. Anderson provided field assistance, K. Roat supplied technical assistance, and F. Bellrose added helpful comments and insights. F. Johnson of the USFWS assisted with the study design and data analysis. Illinois Department of Transportation (IDOT), Division of Aeronautics, Springfield, Illinois, furnished aerial support for the project.

JOB NO. I.1. Potential Population Estimate for Breeding Wood Ducks in Bottomland Forest in Illinois.

Objectives:

To evaluate the feasibility and cost for using helicopters to aerially census breeding wood ducks in bottomland forest.

To compare aerial helicopter estimates of breeding wood ducks in bottomland forest at varying geographic locations.

STUDY AREA

Three study sites were classified as bottomland forests of the Illinois River (Fig. 1) including: 1) portions of the Sanganois CA and nearby private lands (Sanganois) at Chandlerville; 2) the Meredosia National Wildlife Refuge (NWR) of the Illinois River National Wildlife and Fish Refuges and adjacent private lands (Meredosia) at Meredosia; and 3) the Princeton Game and Fish Club and surrounding bottomlands (Princeton) at Hennepin. Habitats on the study areas were considered representative of other palustrine forested wetlands (Cowardin et al. 1979) in the Illinois River valley and were selected because of their vast expanses of bottomland forest. Habitats included at Sanganois were sloughs, backwater lakes, forested ponds, and bottomland forest (IL Dept. Cons. 1975). Major tree species on the area included: silver maple (*Acer saccharinum*), eastern cottonwood (*Populus deltoides*), willow (*Salix* spp), red ash (*Fraxinus pennsylvanica*), and American elm (*Ulmus americana*) (Yetter et al. 1999). A forest inventory of the Meredosia NWR in 1985 indicated that silver maple (84%) and eastern cottonwood (13%) represented 97 percent of the tree basal area (Haley 1985). Site visits demonstrated that forest and tree

species composition at Meredosia and Princeton were similar to Sanganois.

The Sanganois study site encompassed portions of southwest Mason, northwest Cass, and east Schuyler counties and represented 8,150 ac of bottomland habitat (Fig. 2). Study area boundaries were marked on the north and south by the Illinois and Sangamon rivers, respectively. Longitude lines defined east (90^0 18′ 39″) and west (90^0 21′ 57″) boundaries. Meredosia encompassed portions of southwest Cass and northwest Morgan counties and consisted of 4,800 ac of bottomland habitat (Fig. 3). Study area boundaries were marked on the west and east by the Illinois River and the Meredosia Lake Drainage and Levee District, respectively. Latitude lines designated north (39° 55′ 00″) and south (39° 51′ 26″) boundaries. Princeton consisted of 4,150 ac of bottomland habitat and was located in southeast Bureau County (Fig. 4). Study area boundaries were marked on the east by the Illinois River and by the Chicago Rock Island and Pacific Railroad tracts on the west. North and south boundaries were identified as latitude lines 41° 17′ 00″ and 41° 14′ 38″, respectively.

MATERIALS AND METHODS

Surveys

Study area boundaries and size were determined from National Wetlands Inventory (NWI) maps and measured using a digitizing board and Measugraph 2.1 software. NWI data were obtained from aerial photographs dated spring 1984 and spring 1986. Parallel transects were systematically spaced (White et. al. 1989) every 12" of latitude or longitude (Figs. 2-4). Seventeen, 13, and 18

transect lines were selected at Sanganois, Princeton, and Meredosia, respectively.

Aerial surveys of wood ducks at each study site were conducted twice each year during April, 1996-1998. The timing of aerial surveys corresponded with nesting activities of wood ducks in Illinois. Aerial surveys were initiated after the peak spring migration of wood ducks in central Illinois but before leaf emergence (Bellrose 1980, Heitmeyer and Fredrickson 1990, Yetter 1992, Bellrose and Holm 1994, Ryan et al. 1998, Havera 1998). All surveys were flown using a Bell Long Ranger helicopter with 1 pilot and 3 observers (left front [LF], left rear [LR], and right rear [RR]). Helicopters and pilots were contracted from the Division of Aeronautics, IDOT, Springfield, Illinois, USA. Helicopters were flown at an altitude of 150 ft above ground level (AGL) to provide sufficient clearance above bottomland timber and at ground speeds of 50-64 mph (Sherman 1990, R.M. Kaminski, Mississippi State Univ., pers. commun.). Helicopters were equipped with LORAN-C to aid in the navigation of transect lines and a radar altimeter to maintain a constant altitude.

Density Estimates

Densities of breeding wood ducks along transect lines were estimated by employing a LT approach (Burnham et al. 1980) using grouped, perpendicular distance classes and analyzed with Program DISTANCE version 2.1 (Buckland et al. 1993, Laake et al. 1994). The LF observer monitored the proper course and altitude of the aircraft and also recorded all wood ducks within 450 ft and five distance classes (0-75[1], 76-150[2], 151-225[3], 226-300[4], and

301-450[5] ft) on the left side of the aircraft in 1997 and 1998 (Fig. 5). In 1996, the LF observer only monitored distance classes 1 and 2. Wood ducks recorded by the LF observer in 1996 were used to determine visibility of birds under the aircraft, but no density estimates were generated. The rear observers could not see the 150-ft wide path directly below the aircraft fuselage; therefore, distance classes for the rear observers were offset 75 ft on either side of the transect line (Fig. 5) (Johnson and Lindzey 1990, Buckland et al. 1993). The rear observers recorded wood ducks within a 375-ft strip on their side of the aircraft and placed the birds into four distance classes (0-75[1], 76-150[2], 151-225[3], and 226-375[4] ft). Wood ducks flushing from underneath the aircraft were recorded by the rear observers but were not used to calculate density estimates.

We established the orientation of line transects to satisfy independence relative to the distribution of wood ducks on the study sites. Ground elevation was used to identify a density gradient of wood ducks on sites because lower elevations were more likely to be inundated during high water periods in spring. Because the southern edge of Sanganois and the western edges of Meredosia and Princeton were at higher elevations above mean sea level (MSL), we established transect lines perpendicular to this inferred density gradient (White et al. 1989, Buckland et al. 1993:298-299, Yoshida et al. 1998). Transects were oriented in a north-south direction at Sanganois and an east-west direction at Meredosia and Princeton (Figs 2-4).

A ground observer was placed near the halfway point along 10 transects at Sanganois during a survey on 20 April 1997. This

observer recorded the number of ducks that flushed before the arrival of the helicopter in order to determine if wood ducks were leaving transects prior to detection by aerial observers. After the passage of the aircraft, the ground observer moved via all terrain vehicle (ATV) to the next transect location.

All observers recorded wood ducks detected on transects with hand-held tape recorders. During the second survey of each study site in 1997 and all surveys in 1998, the LR observer estimated the percentage of the transect inundated with water by denoting when the aircraft was over wet or dry ground. The time needed to complete each transect, as measured from the audio tapes, was used to determine the average velocity of the aircraft along transect lines.

Observers recorded wood ducks in distance classes as they were detected (pairs, mixed sex flocks, single sex flocks, single sex, and unknown sex). To avoid confusion, only observations of wood ducks and not other species were recorded in distance classes. Surveys were conducted on days with good visibility and with winds < 25 mph (U.S. Fish Wildl. Serv. and Can. Wildl. Serv. 1987).

In order to place a wood duck observation (cluster) into its respective distance class, reference lines were marked on the helicopter windows using wax pencils. A second set of reference marks were made on a string mounted from the door to the ceiling. Aligning the reference marks and lines insured that the observers' heads were in the proper position when a wood duck cluster was sighted (Norton-Griffiths 1978, Johnson et al. 1989, Johnson and Lindzey 1990, Buckland et al. 1993, and Yoshida

1998). Upon reaching a right angle to the sighting location, the observer would assign the cluster to its respective distance class. Reference marks were generated mathematically and validated prior to LT surveys using ground measurements (Norton-Griffiths 1978).

The total number of IBPs of wood ducks identified in distance classes by each observer was determined by summing observations of segregated pairs, trios (pair and extra male), lone males, males in bachelor groups $\leq$ 4, and lone females (Hammond 1969, Stewart and Kantrud 1972, U.S. Fish Wildl. Serv. and Can. Wildl. Serv. 1987, Yetter 1992, Bellrose and Holm 1994). Groups of unknown wood ducks were classified as IBPs according to the minimum number they could represent. For example, one unknown wood duck was classified as one IBP because it was either a lone male or lone female, both of which represented a pair. A cluster of two unknown wood ducks was grouped as one IBP because they may have been a pair as opposed to two males or two females. A cluster of three unknown wood ducks was considered as one IBP because they were likely a trio. Four unknown wood ducks were considered as two IBPs because they could have been two pairs rather than four males or females. However, observations of four unknown wood ducks were rare and only occurred on 11 occasions over the 18 individual surveys.

Data Analysis

Data were computerized and analyzed using the Statistical Analysis System (SAS) version 6 (SAS Inst. Inc. 1988) and Program DISTANCE version 2.1 (Laake et al. 1994). A Pearson product-

moment correlation (Proc CORR, SAS Inst. Inc. 1988) was used to identify any buildup of wood ducks observed on transects as surveys progressed from one side of a study area to the other. Tukey/Kramer post hoc multiple comparison tests (Proc GLM, SAS Inst. Inc. 1988) were employed to determine if differences existed in the mean cluster size of wood ducks recorded among the distance classes by each observer in 1997 and 1998. All tests were considered significant when $\underline{P} \leq 0.05$.

The density of wood duck IBPs along transect lines was calculated using program DISTANCE. DISTANCE generated densities based on the number of IBPs observed in each distance class along transects. The wood duck IBP density was estimated for each survey and observer using the formula: $\hat{D} = n\hat{f}(0)/2L$, where $\underline{n}$ was the number of IBPs observed, $\underline{L}$ was the total length of all transects sampled, and $\hat{f}(0)$ was the estimated probability density function of perpendicular distance classes from the transect line evaluated at distance zero. Density estimates were calculated for each observer because of the varying detection probabilities among observers. IBP densities and standard errors were doubled for each observer and survey because observers only viewed one side (½) of each transect.

Two models were fitted to the perpendicular distance data to estimate f(0): 1) the uniform key function with a cosine series expansion (Fourier Series model); and 2) the half-normal key function with a cosine series expansion. The model that best fit the shape criterion outlined by Burnham et al. (1979) and Buckland et al. (1993) with the smallest CV (Johnson and Lindzey

1990) and/or smallest Akaike Information Criterion (AIC) value (Buckland et al. 1993) was selected.

RESULTS

Survey Chronology and Wood Duck Movement

Observers noted the numbers of Canada geese (Branta canadensis), mallards (Anas platyrhynchos), blue-winged teal (A. discors), green-winged teal (A. crecca), American coots (Fulica americana), and double-crested cormorants identified incidentally to wood ducks during aerial LT surveys. Discussions after the flights by observers were used to assess the chronology of the spring waterfowl migration on that day and location. The large number of migrant waterfowl and waterbirds observed on surveys conducted on 15-16 April 1996 indicated that the spring waterfowl migration was not yet complete, even though ground surveys conducted at Chautauqua NWR, approximately 20 miles northeast of the Sanganois CA, suggested that the wood duck migration was essentially over by 9-12 April 1996-1998 (Fig. 6). Because of these late migrants, the first survey of each area in 1996 was not used to calculate wood duck IBP densities. Similarly, the second survey at each location was used in 1997 to prevent inclusion of migrant wood ducks. In 1998, the first survey at each location was used to estimate wood duck IBP densities because of the limited visibility resulting from leaf emergence encountered during the second surveys.

Aerial LT surveys were systematically designed to begin on one side of a study area (east boundary at Sanganois and south boundary at Princeton and Meredosia) and proceed west or north to

the opposite side with transects spaced every 12" of latitude or longitude. To determine whether wood ducks were being moved or herded from one side of the study area to the other, a correlation analysis was used to compare the total number of wood ducks observed by each observer on each transect with the transect number. A significant correlation was identified in only one of 54 tests (3 yr × 6 surveys/yr × 3 observers). A correlation (r_{xy} = 0.582, $\underline{P}$ = 0.037) was identified in the RR observer's data for the 23 April 1998 survey at Princeton, and was likely the result of the low number of wood ducks detected during this survey (Table 1). Consequently, correlation analyses did not substantiate that wood ducks observed on one transect were recorded again on subsequent transects.

The ground observer at Sanganois did not detect any movement of waterfowl prior to the arrival of the aircraft on eight of the ten transects monitored during 20 April 1997. The ground observer noted on three occasions that as the helicopter passed, flushing ducks immediately returned to the water near their original departure location. Although we acknowledge some wood ducks avoided detection by aerial observers, we believe the number of observations missed because of early flushes was minimal.

1996

Surveys and Observer Comparisons.--Six LT surveys were conducted during April between 9:00 a.m. and 5:00 p.m. CST (Table 1). The number of transects at each location varied somewhat from the number planned due to fuel constraints and availability

of the aircraft. Fifteen and 16 transects at Sanganois, 12 and 13 transects at Princeton, and 16 and 18 transects at Meredosia were flown during the first and second surveys at each location, respectively (Table 1). The number of wood ducks detected by rear observers during surveys varied from 79 to 438 and the number of IBPs varied from 42 to 210.

Originally, it was thought that all wood ducks located directly below the aircraft would flush so that the rear observers could identify wood ducks flying into the first distance class. This possibility was tested by comparing the observations of the LF observer with the simultaneous observations recorded by the LR observer. Comparisons of observations along transect lines indicated that not all wood ducks observed directly below the aircraft flushed, and of those that flushed, not all were identified by the LR observer. Some birds flushed to the right while others flew parallel to the transect either in front or behind the aircraft. Those wood ducks that did not flush directly to the left or at an angle ahead and to the left of the approaching aircraft could not be observed by the LR observer.

The LF observer recorded 55 wood duck observations in the second distance class (76-150 ft) during the second survey of all study sites combined. Of these 55 observations, the LR observer recorded 46 (83.6%). The LR observer recorded 25 additional wood duck observations in this distance class that were not recorded by the LF observer. These additional records provided a total of 80 wood duck observations, of which the LR observer detected 71 (88.8%). The varying number of wood duck observations recorded

by the front and rear seat observers was attributed to differences in visibility from these positions. As a result, the 150-ft strip under the aircraft was excluded from analyses for rear observers, and density estimates were generated for each observer because of differences in sighting probabilities.

Princeton.--The number of wood duck IBPs detected by each observer during the 27 April survey at Princeton was low (Table 1). Consequently, output statistics provided by Program DISTANCE were affected. Models fit the data poorly for the LR observer (Fig. 7), and AIC values were the same for each model (Table 2). However, the uniform model provided the smallest CV value (26.9%) and provided a mean of 0.039 IBPs/ac. The wood duck IBP data for the RR observer was best represented by the uniform model (Fig. 7). This model also provided the smaller AIC and CV values, yielding a density of 0.025 IBPs/ac (Table 2).

Meredosia.--A limited number of wood duck IBP observations were detected by rear seat observers during the 27 April survey at Meredosia (Table 1). The half-normal model (Fig. 8) was used for the LR observers data; however, neither model provided a good fit to the data. The density estimate for the LR observer was 0.055 IBPs/ac (Table 3). The uniform cosine model (Fig. 8) fit the data obtained by the RR observer and indicated a density of 0.026 IBPs/ac, but the CV was 28.9 percent (Table 3).

Sanganois.--Rear observers identified a greater number of wood duck IBPs (99-111) during the 22 April survey at Sanganois than for the second surveys at both Princeton and Meredosia

(Table 1), and Program DISTANCE achieved a better fit to each observers data (Fig. 9). The half-normal model best fit the detection curve for the data generated by both rear observers. IBP density estimates for the LR and RR observers were 0.116 and 0.084 IBPs/ac, respectively (Table 4). Density estimates for both observers had CV values below 20 percent, indicating better levels of precision when compared with density estimates for Princeton and Meredosia (Tables 2 and 3).

1997

Surveys and Cluster Sizes.--Six LT surveys were completed during April 1997 and were flown between 8:50 am and 3:06 pm CST (Table 1). The second survey at Sanganois was interrupted near the halfway point because of mechanical difficulties. That survey was completed the following afternoon. The number of wood ducks recorded by observers ranged from 99-439 wood ducks, and the number of IBPs ranged from 55-242 (Table 1).

Habitat conditions were drier at Princeton (39% of the transect area was inundated) than Meredosia (76% inundated) and Sanganois (68% inundated) during the second survey of each site in 1997. The estimate from Meredosia was misleading because much of this coverage was from open water portions of transects over Meredosia Lake. The majority of the bottomland forest at Meredosia was dry, which was similar to Princeton, and subsequent wood duck observations were low.

The comparison of the mean cluster sizes between distance classes revealed only minor discrepancies (Tables 5-7). We identified a difference in cluster size between the distance

classes in only one instance across all surveys and observers. The mean cluster size observed by the LR observer during the 13 April survey at Sanganois was smaller in distance class three than in distance class four (Table 7). This difference was in part caused by two large groups of wood ducks (six and eight) observed in the outermost distance class. When these two observations (outliers) were omitted from the data set, no significant differences were detected. Therefore, IBPs rather than clusters were used to estimate populations of locally breeding wood ducks.

Princeton.--Density estimates from this study site may be biased due to the limited number of wood duck observations (14-25 IBPs) recorded during each survey (Table 1). Models poorly fit the detection curve for the LF observer's data (Fig. 10) from the second survey at Princeton. The density estimate generated by the uniform-cosine model was 0.015 IBPs/ac for the 22 April survey (Table 2). Despite smaller percent CV and AIC values for the uniform model (Table 2), the half-normal model best fit the data recorded by the LR observer during the second survey (Fig. 10). The estimated density by the LR observer was 0.018 IBPs/ac. The fit of the detection curve and the AIC value suggested the half-normal model best represented the data recorded by the RR observer (Fig. 10, Table 2) even though the percent CV values were smaller for the uniform model. The density estimate generated for the RR observer by the half-normal model was 0.023 IBPs/ac.

Meredosia.--The low number of wood duck observations (16-30 IBPs) limited the reliability of LT surveys at Meredosia (Table 1) (Burnham et al. 1980). Both models yielded similar results using data collected by the LF observer (Table 3). The half-normal model (Fig. 11) generated a density estimate of 0.045 IBPs/ac. Analysis of the LR observer's data from 21 April with the half-normal model provided a density estimate of 0.035 IBPs/ac (Fig. 11, Table 3). Data collected by the RR observer was best represented by the half-normal model (Fig. 11, Table 3). A density estimate of 0.040 IBPs/ac was obtained during the 21 April survey at Meredosia by the RR observer.

Sanganois.--Both models fit the LF observer's data for the 20-21 April survey (Fig. 12, Table 4). Percent CV values varied, but AIC values indicated that the half-normal model best represented the data. The density estimate for the LF observer's data was 0.039 IBPs/ac. The half-normal model achieved a reasonable fit of the detection curve to the LR observer's data during the second survey (Fig. 12). The AIC value also suggested a better fit of the half-normal model, and the estimated density was 0.066 IBPs/ac (Table 4). Data collected by the RR observer provided a good fit of the detection curve from both models, but the AIC value indicated the half-normal model better represented the data (Fig. 12, Table 4). The corresponding density estimate generated for the RR observer was 0.072 IBPs/ac.

1998

Surveys and Cluster Sizes.--Six LT surveys were flown in April between 9:02 am and 4:57 pm CST. The number of wood ducks

recorded by observers during each survey ranged from 50-340, and the number of IBPs ranged from 33-203 (Table 1).

Princeton (64-75% of transect area was inundated) was drier than Meredosia (97-100% inundated) and Sanganois (93-95% inundated) during both surveys, but all three study areas hosted higher river stages than in 1996 and 1997. However, fewer numbers of wood ducks were recorded (Table 1) by observers in 1998 than in 1996 and 1997.

The comparison of the mean cluster sizes between distance classes revealed only minor discrepancies (Tables 8-10). Observed cluster sizes of wood ducks between the distance classes did not vary during either survey at Sanganois (Table 10). Differences were detected for the LF and RR observer during surveys at Princeton and Meredosia; however, a limited number of wood ducks were detected during these surveys by all observers, and no wood ducks were detected in some distance classes (Tables 8-9). Therefore, IBPs rather than clusters were used to estimate populations of locally breeding wood ducks.

Princeton.--The half-normal model best fit the data for each observer during the 15 April survey (Fig. 13). The limited number of wood duck observations (Table 1) again hampered estimates of wood duck densities (Table 2). Estimates for the LF and LR observers were similar; 0.057 and 0.058 IBPs/ac, respectively. However, estimates were more precise for the LF observer (CV = 21.0%) than for the LR observer (CV = 30.0%)(Table 2). The density estimated for the RR observer was 0.040 IBPs/ac, and it had a higher CV value (35.2%).

Meredosia.--The low number of IBP observations (4-15 IBPs) recorded limited the reliability of LT surveys at Meredosia (Table 1). The half-normal model best fit the data for each observer although the fit for the RR observer's data was poor (Fig. 14). Density estimates for all observers ranged from 0.008-0.025 IBPs/ac, and precision was lacking with CV values ranging from 34.9-54.9 percent (Table 3).

Sanganois.--The half-normal model again provided the best fit of the detection curve for all observers data during the 14 April survey (Fig. 15), and AIC values for the half-normal models were smaller than the uniform models for each observer (Table 4). The density estimate of wood ducks obtained by the LF observer during the 14 April survey was 0.056 IBPs/ac with a CV value of 15.6 percent. Program DISTANCE generated a similar density for the LR observer (0.069 IBPs/ac) and had a small CV value (17.7%). The RR observer detected a smaller number of wood ducks (Table 1) than the LF and LR observers, and the corresponding density estimate was lower (0.043 IBPs/ac) with a higher CV value (22.3%; Table 4).

Costs

In order to evaluate the cost of conducting aerial LT surveys of bottomland habitat, we rented a helicopter and pilot including fuel from the IDOT for a cost of $85/passenger/hr. The average cost for the six surveys each year was $2,976. The area of the three study sites totaled 26.72 mi^2. Because each study site was flown twice each spring, the total area inventoried was

53.44 mi^2. Bottomlands of the Illinois River valley were surveyed with three observers for a cost of \$55.69/mi^2, or \$18.56/mi^2/observer. The Sanganois area represented 12.73 mi^2 and it was inventoried for \$55.69/mi^2, or \$708.93/survey and \$236.31/observer/survey.

DISCUSSION

Feasibility and Chronology

Aerial LT sampling of wood ducks during spring may generate population estimates in bottomland forests. However, bottomland forests in Illinois large enough to inventory with this method are limited. Observations of wood duck clusters at Princeton and Meredosia were not numerous enough to provide the precise density estimates required for management recommendations; nevertheless, they may depict trends.

Although Meredosia, Princeton, and Sanganois were among the largest tracts of bottomland forests remaining in the Illinois River valley, the minimum number of wood duck observations ($\geq$ 40; Burnham et al. 1980) needed to estimate population densities with LT models was only achieved at Sanganois. When selecting study sites, spring inundation and habitats avoided by wood ducks (ie., open water) should be considered. For example, the forests at Meredosia and Princeton were flooded just during the 1998 surveys whereas Sanganois generally contained water. In addition, the low number of wood ducks observed at Princeton and Meredosia as compared with Sanganois (Table 1) resulted from their smaller size (i.e., smaller transect lengths). Sanganois contains a myriad of historic stream beds, swales, ponds, and sloughs that

hold water during lower river stages and provide loafing and foraging sites for wood ducks. Waterfowl management units at Sanganois CA contained water and overall conditions at Sanganois provided habitat more conducive to LT surveys than either the Princeton or Meredosia sites.

Aerial LT sampling should be evaluated elsewhere in areas containing vast expanses of flooded bottomland forests(> 6,000 ac) where observations of wood duck clusters can exceed the minimum needed to estimate densities using LT methodology. Burnham et al. (1980) recommended a minimum of 40 observations for LT surveys and suggested 60-80 would be preferable. White et al. (1989) indicated that ≥ 200 observations of mule deer were needed to achieve a < 10 percent level of precision during aerial helicopter surveys in northwestern Colorado. Based on data collected during the 22 April 1996, 20-21 April 1997, and 14 April 1998 surveys at Sanganois, total lengths of transects on each survey should be increased from 3-7 times to achieve CV values of 10 percent (Burnham et al. 1980:35-36, Kelley 1996:33). This level of precision is not possible because this entire study area was systematically covered by the transects. We suggest that an even greater number of observations (~300) are necessary to achieve a 10 percent level of precision during aerial LT surveys of wood ducks in palustrine forested wetlands.

The chronology of surveys was critical because leaf emergence was rapid and visibility to the forest floor was reduced within a few days. On 14 April 1998, visibility was adequate; however, observers noted that by 22 April leaf-emergence severely limited visibility. Kelley (1996) noted

decreased visibility associated with leaf-out while conducting ground LT surveys of wood duck populations in Missouri.

Validity of Assumptions

Several assumptions have been established to ensure unbiased estimates of density when using LT sampling theory (Burnham et al. 1980:14,30; Buckland et al. 1993:29-37; Guthrey 1988).

Assumption 1.--All objects on the transect line are detected, $g(0) = 1$. This assumption was violated because the LR observer only identified 46 of 55 (83.6%) wood duck clusters recorded by the LF observer in the first distance class during the second survey of all study sites in 1996. Therefore, density estimates for the LR observer were potentially biased and approximately 16 percent low due to these missed observations (Buckland et al. 1993:30). This situation could be corrected by having 2 observers collectively view the same side of the transect line to increase sightings in the first distance class, thus ensuring $g(0) = 1$.

Assumption 2.--Objects do not move prior to detection. We presume this assumption was satisfied because wood ducks that flushed upon arrival of the helicopter could be placed in their original location via ripples on the water. Buckland et al. (1993:32) suggested recording the flushing location in this instance because it is the flush that leads to the detection. The speed of the helicopter as well as our low altitude (in some instances < 25 ft above the canopy) allowed observers to detect clusters before substantial movement by wood ducks occurred. The

ground observer during the 20 April 1997 survey at Sanganois also substantiated our conclusion that wood duck movement prior to the arrival of the aerial observers was minimal.

Movement of wood ducks in response to the aircraft varied in direction. Some flushed a few feet and landed, some flushed away from the transect, some flew towards the transect, others flew parallel with the helicopter, and still others dove beneath the water only to resurface within a few feet. Many wood ducks remained in their original location while swimming rapidly in a tight circle. Buckland et al. (1993:34) suggested bias would be trivial if incorrect distances were recorded < 5 percent of the time due to animal movement in response to the observer. We concluded that undetected wood duck movement was minimal during our surveys.

Assumption 3.--Distance measurements are exact. We believe this assumption was satisfied because data were gathered in grouped perpendicular distance classes; therefore, violations of this assumption should have occurred only near the distance class borders. Our method of determining distances by aligning two sets of reference marks minimized errors in distance determinations (Norton-Griffiths 1978, Johnson et al. 1989, Johnson and Lindzey 1990, Buckland et al. 1993, and Yoshida 1998). Reference marks were validated prior to each survey using known distances on land. Helicopters were equipped with radar altimeters so that transects could be flown at the proper altitude at all times, and pilots navigated transect lines using LORAN-C. The LF observer monitored the radar altimeter and

LORAN-C unit to ensure transects were flown at the proper altitude and adherence was maintained to the transect line. The LR observer also spot-checked the altitude during each survey.

Assumption 4.--Sightings are independent events. The mean cluster size of wood ducks detected during LT surveys in 1997 and 1998 was generally <2 (Tables 5-10), which indicated that most observations were either single males or pairs of wood ducks. In a few instances, groups of IBPs flushed at the same time; however, in these infrequent situations the IBPs usually fled in separate directions, thus increasing the probability of the flushes being independent events. Mixed-sex groups of wood ducks that did not separate into pairs upon flushing were considered migrants and were not counted as IBPs. We surmise that this assumption was not violated.

Assumption 5.--Individual animals are not counted more than once. We identified a buildup of IBPs on successive transects in only one of the surveys and by only one observer; however, a limited number of wood ducks were sighted during this survey. The ground observer during the 20 April 1997 survey at Sanganois also indicated that flushed wood ducks immediately returned to their original location after the helicopter had passed. We think violation of this assumption was minimal.

Assumption 6.--Guthrey (1988) suggested that the probability of sighting a cluster of animals should be independent of group size. This assumption was tested using a comparison of the mean cluster sizes among the distance classes for individual observers

during each survey in 1997 and 1998 (Tables 5-10). We detected significant differences in only a few instances, most of which occurred when a limited number of wood duck observations were recorded. We conclude that this assumption was met.

Costs

We estimated populations of breeding wood ducks in bottomland forests of the Illinois River valley with helicopters and three observers for a cost of \$55.69/mi^2, considerably less than the \$290/mi^2 for helicopter surveys of bottomland timber with one observer and \$259/mi^2 for ground LT surveys in flooded bottomland forests in Mississippi (Sherman et al. 1992). Shupe et al. (1987) reported a somewhat similar cost of \$27.20/mi^2 for helicopter surveys of northern bobwhite with two observers in Texas rangeland. These researchers reported that helicopter surveys were less expensive than using a Lincoln Index (mark-recapture; \$101.01/mi^2). If we used two observers instead of three, costs for aerial surveys would be reduced to \$37.12/mi^2, which more closely resembled estimates from Texas (Shupe et al. 1987). Fixed-wing aircraft with one observer have been used to survey mallards and wood ducks in forested wetlands for a cost of \$32.38/mi^2 (Sherman et al. 1992). However, helicopters offer advantages (decreased velocity, increased visibility, and maneuverability) over fixed-wing aircraft for waterfowl surveys in emergent and forested wetlands (Johnson et al. 1989, Sherman et al. 1992).

JOB NO. I.2. Comparison of Aerial Surveys with Densities of Wood Ducks Nesting in Natural Cavities.

Objectives:

To examine whether helicopter surveys of breeding wood ducks relate with nesting densities of wood ducks determined from natural cavity surveys at Sanganois Conservation Area.

To continue monitoring natural tree cavities suitable for use by nesting wood ducks at Sanganois Conservation Area.

To determine nesting success of wood ducks in natural tree cavities at Sanganois Conservation Area.

The number of suitable cavities identified in sample plots in 1993-1994 decreased due to extensive tree mortality caused by the extreme flooding in 1993 and 1995 of the Illinois and Sangamon rivers (Yetter et al. 1999). Consequently, bottomland forest at the Sanganois CA was resurveyed for cavities during December 1996-April 1997, and another density of suitable cavities was generated. Nest success and other information were derived from the entire sample of suitable cavities identified during both the 1993-1994 and the 1996-1997 cavity surveys.

STUDY AREA

The natural cavity study area encompassed portions of southwest Mason, northwest Cass, and east Schuyler counties (Fig. 16) and included 9,476 ac of the Sanganois CA. Sanganois CA lies at the confluence of the Illinois and Sangamon rivers and is a state-owned refuge and public hunting area. Sanganois CA was created in 1948 when the state of Illinois purchased several private duck clubs. The largest of these clubs was the Sanganois Gun Club from which the area received its name (Ill. Dept. Cons. 1975). Over the years, other land purchases have expanded

Sanganois CA to its current size of approximately 10,300 ac. Habitats on the area were consistent with the Sanganois study site described in Job I.1.

MATERIALS AND METHODS

Habitat Classification

Wetland and upland habitats on the study area were classified using NWI data stored on the Illinois Geographic Information System (IGIS), IDNR, Springfield, Illinois, USA. NWI data were obtained from aerial photographs dated spring 1986. NWI data were ground-truthed for accuracy and identification of tree species within various habitat types.

Wood duck nesting habitat was defined as any palustrine forested wetland within the Sanganois CA regardless of water regime and/or special modifiers. Forested/scrub-shrub, forested/emergent, scrub-shrub, and scrub-shrub/emergent wetland habitats were excluded from sampling because the dominant trees growing in these habitats (determined from ground truthing) were willow saplings that were not large enough to produce cavities suitable for nesting wood ducks.

Surveys

Natural cavities suitable as wood duck nest sites were initially identified in 1993-1994 when 86 suitable cavities were located (Yetter et al. 1999). This sample of cavities decreased to 43 by spring 1996 due to tree mortality caused by extensive flooding in 1993 and 1995. Therefore, further sampling of bottomland timber was conducted in 1996-1997, to increase the sample size of suitable cavities. The same techniques and

criteria were used to inspect and identify suitable cavities (Yetter et al. 1999) so that direct comparisons could be made between the two cavity density estimates.

Ninety-seven and 58 sample points were selected for tree cavity investigations (Figs. 17-18) during 1992-1993 and 1996-1997, respectively. Study area boundaries were drawn on NWI maps and placed on a digitizer. Latilong coordinates were randomly selected and located on a digitizing board using Measugraph 2.1 software. Only those coordinates selected within desired habitats (palustrine forested wetland) were utilized. Approximately two percent and one percent of the palustrine forested wetlands at Sanganois CA were surveyed for suitable wood duck nest cavities in 1992-1993 and 1996-1997, respectively. Sample points were located in bottomland timber with a global positioning system (GPS) and NWI maps. ATVs and a jon boat were used for transportation.

Circular plots (1.24 ac) (Bookhout 1986) centered on each sample point were marked using orange tree paint. All trees within the 1.24-ac plots were searched by two observers with binoculars. Ground surveys were conducted at Sanganois CA for potential cavities after leaf fall in 1992 and 1993 and again in 1996-1997. Trees containing potential cavities were marked with tree paint and a numbered aluminum tag. Tree and cavity variables enabling observers to relocate potential cavities for subsequent inspection were recorded including: tree species, dbh, status (dead or alive), height, and location within the plot and entrance orientation and height. All trees having potential cavities were ascended in 1993-1994 and 1996-1997 to determine if

the cavities were actually suitable as wood duck nest sites. All suitable cavities were inspected after the nesting season each spring to determine their use by wood ducks and other vertebrates (Gigstead 1938, Bookhout 1986, Bellrose and Holm 1994).

Cavity Inspection

Natural cavities were examined for suitability using a modified version of the single rope, rope-walking system (Montgomery 1982, Meredith and Martinez 1986, Nadkarni 1988, Warild 1990, Padgett and Smith 1992, Stanback and Koenig 1994) and with climbing spikes and safety belt. Various methods of placing a climbing rope over a support branch in the cavity tree were employed. The best method was utilizing a compound bow equipped for bow fishing (Weier 1966, Greenlaw and Swinebroad 1967). After shooting a fish arrow over a support branch above the cavity, a heavy nylon string was tied to the fishing line (Munn 1991). Following the removal of the arrow, the fishing line was retrieved thereby pulling the heavier nylon string over the branch. The nylon string was then tied to a climbing rope and pulled over the branch and anchored.

Natural cavities were considered suitable as wood duck nest sites if they had entrance dimensions at least 2.5 × 3.5 in (Grice and Rogers 1965), platform dimensions at least 5 × 7 in, and were not more than 197 in deep (Bellrose et al. 1964, Bookhout 1986). Cavities were classified as unsuitable if they held water, contained excessive debris, were too shallow to conceal the incubating hen (Robb and Bookhout 1995), or were

hollow to the ground (F.C. Bellrose, Ill. Nat. Hist. Surv., pers. commun.).

An instrument for cavity inspection was constructed from two 6 in sections of 2 in PVC pipe and a right angle PVC coupler. A mirror was attached inside the right angle coupler, and a small flashlight was attached to one end of the device. With this instrument, researchers could inspect cavities for internal dimensions and evidence of use. Cavities, whose platforms were not visible or difficult to inspect for evidence of nesting activity, were examined by lowering adhesive tape on a weighted string (Nagel 1969, Bookhout 1986, Robb and Bookhout 1995). Thus, any nest material from the platform would adhere to the tape and could be examined. Nests were considered successful if they hatched at least one egg, and nest success was determined from eggshells and membranes (Stewart 1957, Bellrose and Holm 1994). Vertebrate use of suitable cavities was determined by the presence of hair, feathers, or scats.

Data Analysis

All data were computerized using Lotus 1-2-3 software Release 5.0 for Windows, and analyzed using SAS (SAS Inst. Inc. 1988). The estimated wood duck IBP density obtained from spring LT surveys at Sanganois (Job I.1.) was compared to the wood duck nest densities obtained from natural cavity investigations at Sanganois CA with two sample t-tests (Hinkle et al. 1988:259, Zar 1996:129). A two sample t-test (Proc TTEST, SAS Inst. Inc. 1988) was used to compare the 1994 and 1997 densities of suitable cavity, and a X^2 goodness-of-fit test was used to compare wood

duck nest success rates (Proc FREQ, SAS Inst. Inc. 1988). We tested for differences in wood duck nest densities among the years (1994-1998) using Tukey/Kramer post hoc multiple comparison tests. All statistical tests were considered significant when $P \leq 0.05$.

The Mayfield method was used to determine the annual longevity of suitable cavities (Mayfield 1975). Cavity mortality (a suitable cavity becoming unsuitable for wood duck nesting) was assumed to be the midpoint between our cavity visits. Cavity exposure was defined as the number of days between visits. A 95% confidence interval for the estimated annual cavity survival rate was calculated according to Johnson (1979).

RESULTS

1996

Cavity Availability and Vertebrate Use.--Of the 86 original suitable cavities, 14 (16.3%) were no longer available to wood ducks prior to the 1996 nesting season, 15 (17.4%) trees with cavities were no longer climbable during inspections in spring 1996, and 14 (16.3%) cavities were classified as not suitable after the 1996 inspections. The remaining 43 (50.0%) cavities were located in stable trees and available for use by wood ducks.

Late spring flooding by the Illinois River inundated 9 of the remaining 43 cavities, further reducing the sample to 34 suitable cavities. Of these 34 suitable cavities, 15 (44.1%) had no evidence of vertebrate use, 12 (35.3%) had been occupied by raccoons prior to inspection, and 4 (11.8%) had evidence of fox squirrel use. Only 3 (8.8%) cavities were used for nesting by

wood ducks, yielding a density of 0.025 nests/ac (SE = 0.014, CI_{95} ± 0.029) of bottomland forest. All three nests were successful, and all were located in cavities excavated by pileated woodpeckers.

Density Comparisons.--The wood duck IBP density estimated from the LT surveys at Sanganois on 22 April 1996 by the LR observer ($\bar{x}$ = 0.116 IBPs/ac, CV = 18.0%, n = 45, Job I.1.) was significantly greater than the 1996 wood duck nest density ($\bar{x}$ = 0.025 IBPs/ac, SE = 0.014, n = 97, Job I.2.) observed during natural cavity investigations (t = 6.22, 105 df, $P \leq 0.05$)(Fig. 19). IBP densities generated by the RR observer ($\bar{x}$ = 0.084 IBPs/ac, CV = 17.2%, n = 23) were also greater than the 1996 wood duck nest density (t = 4.04, 104 df, $P \leq 0.05$).

1997

Cavity Availability and Vertebrate Use.--Thirty-eight suitable cavities were identified in the 58 sample plots yielding a suitable cavity density of 0.76 cavities/ac of bottomland forest (SE = 0.13, CI_{95} ± 0.26), which was similar to the 0.86 cavities/ac (SE = 0.09, CI_{95} ± 0.19) found in 97 sample plots in 1993-1994 (t = 0.631, 153 df, P = 0.529).

In 1993-1994, 86 suitable cavities were identified (Yetter et al. 1999). This number steadily decreased every spring through 1997. Only 34 (39.5%) of the original 86 suitable cavities were inspected during June and July of 1997. The other cavities and/or trees were no longer climbable (20.9%), fallen or logged (8.1%), or no longer suitable (26.7%). Two cavities

(2.3%) were discarded due to inaccessibility, and two cavities (2.3%) could not be located, presumably a result of tree fall.

Two additional suitable cavities were identified during the reinspection of potential cavities in two sample plots initially surveyed in 1993. These cavities were not included in suitable cavity or nest density estimates in order to maintain independence among the data sets. However, these additional cavities were included in the sample available to wood ducks during spring 1997. Therefore, a total of 74 suitable cavities was monitored during June/July 1997.

Evidence of vertebrate use was found in 56.8 percent of the 74 suitable cavities. Raccoons were the primary users (32.4%) of the inspected cavities (not including 1 cavity containing a wood duck nest destroyed by a raccoon). Wood ducks nested in 10.8 percent of the suitable cavities, and fox squirrel evidence (hair or nesting material) was identified in 6.8 percent of cavities. The density of wood duck nests at Sanganois CA was 0.098 nests/ac of bottomland forest (SE = 0.035, $CI_{95} \pm 0.070$).

Five of the wood duck nests were located in cavities created by pileated woodpeckers, two wood ducks nested in cavities formed by limb rot, and one hen nested in a hollow snag with both a top entrance (bucket) and a pileated woodpecker entrance. Six of the wood duck nests were successful (75%) and two were depredated (25%), one each by a raccoon and possibly a fox squirrel.

Density Comparisons.--The wood duck IBP densities estimated from LT surveys varied from 0.039 IBP/ac to 0.072 IBP/ac (Table 4) and were similar ($P > 0.05$) to the 1997 wood duck nest density

($\bar{x}$ = 0.098 nests/ac, SE = 0.035, n = 58) observed during natural cavity investigations (Fig. 20). Whereas no differences were found between the aerial LT and cavity inspection estimates, the high variability in the nest density estimate may have prevented the detection of any differences.

1998

Cavity Availability and Vertebrate Use.--Thirty-one of the 38 cavities (81.6%) identified in the 58 sample plots in 1996-1997 were still suitable as wood duck nest sites. Two cavities (5.3%) were no longer climbable, two cavity trees (5.3%) had fallen, one cavity each was full of debris (2.6%), held water (2.6%), or had an exposed platform (2.6%).

Twenty-five of the 86 cavities (29.1%) identified in 1993-1994 remained suitable as wood duck nest sites during spring 1998. The other cavities and/or trees were no longer climbable (19.8%), fallen or logged (12.8%), or no longer suitable (33.7%). Four cavities (4.7%) were discarded due to inaccessibility.

Two additional suitable cavities were identified during the reinspection of potential cavities in two sample plots initially surveyed in 1993. These cavities were not included in suitable cavity or nest density estimates in order to maintain independence among the data sets but were included in the sample available to wood ducks during spring 1998. Therefore, a total of 58 suitable cavities were monitored for vertebrate use during June-July 1998.

Evidence of vertebrate use was found in 31 (53.4%) of the 58 suitable cavities. Raccoons were the primary users of 17 (29.3%)

inspected cavities (three cavities with wood duck nests destroyed by raccoons and one cavity containing a hatched wood duck nest with evidence of raccoon use were not included). Wood ducks nested in nine (15.5%) suitable cavities, fox squirrel hair or nesting material was identified in three (5.2%) cavities, one cavity was used by an unknown mammal, and one cavity was occupied by a nesting screech owl (*Otus asio*) with 5 chicks. The density of wood duck nests at Sanganois CA was 0.098 nests/ac of bottomland forest (SE = 0.035, $CI_{95} \pm 0.070$). This density was a minimum estimate because of the large number of suitable cavities that were located in trees no longer stable for climbing and the availability of artificial wood duck nest boxes on the area.

Seven of the nine wood duck nests were located in cavities created by pileated woodpeckers, one wood duck nested in a cavity formed by limb rot, and one hen nested in a hollow snag with both a top entrance (bucket) and a pileated woodpecker entrance. Six of the wood duck nests were successful (66.7%) and three were destroyed by raccoons.

Density Comparisons.--The wood duck IBP densities estimated from LT surveys during 14 April 1998 varied among observers from 0.043 IBP/ac to 0.069 IBP/ac (Table 4) and were similar ($P > 0.05$) to the 1998 wood duck nest density ($\bar{x}$ = 0.098 nests/ac, SE = 0.035, n = 58) resulting from natural cavity investigations (Fig. 21). The high variability (272% CV) in the nest density estimate may have limited the ability to detect any differences.

Nest Density and Success, 1994-1998

No differences (F = 1.72; 4,406 df; P = 0.146) in wood duck nest densities were identified during springs, 1994-1998, indicating the breeding wood duck population remained stable over the 5-yr study. Wood duck nest success rates varied from 0.0 to 100.0 percent during the springs and a X^2 goodness-of-fit test indicated that nest success rates differed among years (X^2 = 11.92, 4 df, P = 0.018). However, the number of monitored suitable cavities was lower in 1995 and 1996 when only three and five wood duck nests were found in natural cavities. If these two years were omitted from analyses, no differences resulted in the wood duck nest success rates for 1994, 1997, and 1998 (X^2 = 3.47, 2 df, P = 0.177). Therefore, a combined estimate of nest success during these three years was 57.7 percent (n = 26).

Artificial Nest Boxes

From 98 to 113 artificial wood duck nest boxes were inspected during June-July each year from 1996 to 1998 at the Sanganois CA (Table 11). Only a small percentage (6.2-16.3%) of the boxes were used by wood ducks each spring. In 1996, nest success in the artificial boxes was at least 68.8 percent with one hen still incubating when last inspected. Nest success in nest boxes fell to 57.1 percent (4 of 7 nests hatched) in 1997, but was 100 percent in 1998 when all 7 nest attempts were successful. Nest boxes were constructed mainly of plastic (Ducks Unlimited, Inc.) and metal with a few wooden boxes. Metal boxes received the highest use by wood ducks (16.7-27.0%) each year, while only 1.5 to 9.1 percent of the plastic boxes were used

during the springs of 1996 to 1998. A simple estimate of wood duck nest density derived from nest boxes was 0.001-0.003 nests/ac of bottomland forest during the springs of 1996-1998.

Cavity Tree Mortality and Natural Cavity Loss

The mortality of 61 trees containing potentially suitable wood duck nest cavities was monitored after the Great Flood of 1993 (Fig. 22). In early (January-April) 1994, only 1.6 percent of the trees were dead; however, many were showing signs of stress. By July 1994, 11.5 percent of the cavity trees had perished. A record flood in the spring of 1995 exacerbated mortality when 50.8 percent of the monitored trees were dead. Mortality in the bottomland forest at Sanganois CA appeared to have reached a plateau after 1996 when 55.7 percent of the monitored trees were dead.

Survival of the original 86 suitable cavities was determined in 1998 from 65 cavities that were located in trees still stable enough to climb and that were monitored annually since the winter and spring 1993-1994. Forty of the 65 natural cavities (61.5%) became unsuitable for nesting by wood ducks. The daily survival rate for suitable cavities was 0.99942 with an annual survivorship of 80.8 percent (75.5-86.4 [95%CI]).

DISCUSSION

Natural Cavity Densities

The natural cavity density estimates obtained at Sanganois CA in 1994 (0.86 suitable cavities/ac; Yetter et al. 1999) and 1997 (0.76 suitable cavities/ac) were similar indicating that cavity densities have not changed from tree mortality associated

with the 1993 and 1995 flood, decay, and pileated woodpecker activity.

Nest Success

Success rates from the combined sample of 26 nests in 1994, 1997, and 1998 was 57.7 percent; this value was comparable to the 63.6 percent estimate of success from a sample of upland and bottomland nesting wood ducks in southern Illinois (Ryan et al. 1998) but was greater than that previously found in central Illinois (39.9% [Bellrose et al. 1964]; 31.3% [Shake 1967]). Nest success at Sanganois was greater than studies reported for Georgia (44.4% [Almand 1965]), Missouri (33.3% [Weier 1966]), and southcentral Indiana (36.4% [Robb and Bookhout 1995]).

Raccoons and Fox Squirrels

Raccoons were the primary users of suitable natural cavities. Evidence of raccoon use was found in 29.3 to 35.3 percent of suitable cavities. Fox squirrels were the other primary inhabitant of cavities; however, use by squirrels was lower (5.2-11.8%). Similar rates of raccoon and fox squirrel use were observed in 1994 and 1995 in natural cavities at Sanganois CA (Yetter et al. 1999). Robb and Bookhout (1995) observed lower cavity use rates by raccoons (18.5%) but higher rates for fox squirrels (22.7%) in southcentral Indiana. However, because 43.2 to 46.6 percent of suitable cavities were not used during the springs of 1996 to 1998, the number used by raccoons, fox squirrels, and other vertebrates does not appear to be limiting wood duck production.

Artificial Nest Boxes

Wood duck use of artificial nest boxes was low and ranged from 6.2 to 16.3 percent. This value was comparable to occupancy rates in the northern-tier states of the Mississippi Flyway, which averaged 16.1 percent, but was lower than the 43.3 percent use rate by wood ducks in central states (including Illinois) of the Mississippi Flyway (Soulliere 1990). The percentage of natural cavities occupied by wood ducks each year at Sanganois CA ranged from 8.8 to 15.5 percent, indicating an abundance of suitable natural cavities on the area. The percentage of preferred but unused pileated woodpecker cavities (50-69%) each year also suggested that natural cavities were not limiting wood duck production at Sanganois CA. Nest box programs on the area appear unjustified because of the comparable wood duck nest success rates in artificial nest boxes (75.9%) and natural cavities (57.7%), the high cost ($25-$120) of producing a flighted juvenile wood duck from a nest box (Soulliere 1986), and the abundance of natural cavities.

Tree Mortality and Cavity Survival

Estimates of tree mortality in 1995 at Sanganois CA were 42.7 percent (Yetter et al. 1999). Continued monitoring of a sample of these trees indicated mortality resulting from the 1993 and 1995 floods reached a peak of 55.7 percent in 1996. Yin et al. (1994) found mortality rates of 37.2 percent on Pool 26 of the Upper Mississippi River the year following the Great Flood of 1993; mortality increased to 45.6 percent by August of 1995 (Robert J. Cosgriff, INHS, personal communication). Some short-

term effects of flooding on tree mortality at Sanganois CA have been realized; however, the extent of long-term effects may not be known for several decades.

Comparison of Line Transect and Nest Density Estimates

Wood duck IBP densities obtained from LT surveys in 1997 and 1998 by all three observers were similar to nest densities obtained from natural cavity inspections. IBP density estimates obtained by rear seat observers in 1996 were greater than nest densities determined from natural cavities. The lower nest density observed in 1996 compared with IBP densities from LT surveys was likely the result of the reduced sample of natural cavities rather than an actual difference in estimates from these two methods.

IBP estimates of wood ducks from LT surveys in 1997 for each observer ranged from 39.8 to 73.5 percent of wood duck nest densities obtained from natural cavities; in 1998 IBP estimates were 43.9 to 70.4 percent of nest density values. Variability in the IBP density estimates from LT surveys precluded defining populations precisely, even though CV values were below 20 percent for 5 of the 6 estimates in 1997 and 1998. Also, the high variability in nest density estimates in both years (CV = 272%) limited detection of differences between these methods of estimating wood duck density.

We expected IBP densities from LT surveys to be greater than nest densities observed from cavities because of the inclusion of possible late migrants, upland nesting wood ducks loafing in bottomlands, and male-biased sex ratios (Bellrose and Holm 1994).

Ryan et al. (1998) reported 82 percent of nests attempted by radio-collared hens in southern Illinois were located in upland forests. Nests in uplands were found as far as 2.3 miles from capture sites and 0.9 miles from the nearest wetland (Ryan et al. 1998). However, we found IBP densities to be larger than nest densities only in 1996 when the sample of suitable cavities monitored was small (n = 34). Post hoc multiple comparison tests indicated that wood duck nest densities in cavities were similar during springs of 1994 through 1998.

MANAGEMENT RECOMMENDATIONS

We recommend further research evaluating LT methodology to estimate the densities of breeding wood ducks in bottomland forests. Multiple observers should cooperatively monitor the same side of transect lines to guarantee that all wood ducks in the first distance class are detected (ie., ensuring $g(0) = 1$). Surveys should be conducted in areas where the length of transect lines allows the detection of 200 to 300 wood duck clusters. Flights should not be initiated when winds exceed 15-20 mph so that pilots can strictly adhere to transect lines. Additionally, excessive winds create ripples on the water surface which increases the difficulty of correctly identifying flushing locations. Observers need to speak loudly and clearly into tape recorders to overcome excessive engine noise in the helicopter fuselage. Multiple surveys should be flown in spring to assess the chronology of the migration and the emergence of tree foliage that hinders the detection of wood ducks. Finally, researchers should consider the possible negative effects of low-altitude

helicopter surveys on nontarget species, such as bald eagles, great blue herons, great egrets, and double-crested cormorants. These species were incubating or brooding their nestlings during our surveys.

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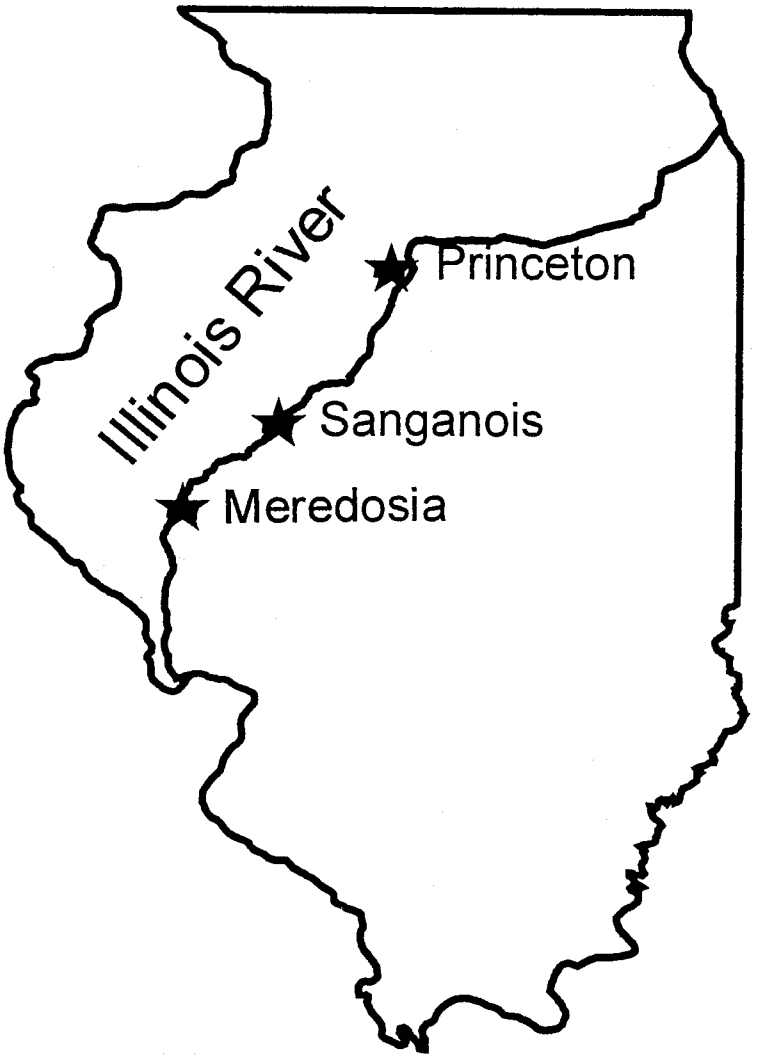


Figure 1. Study areas for aerial line transect surveys of breeding wood ducks in Illinois during April, 1996-1998.

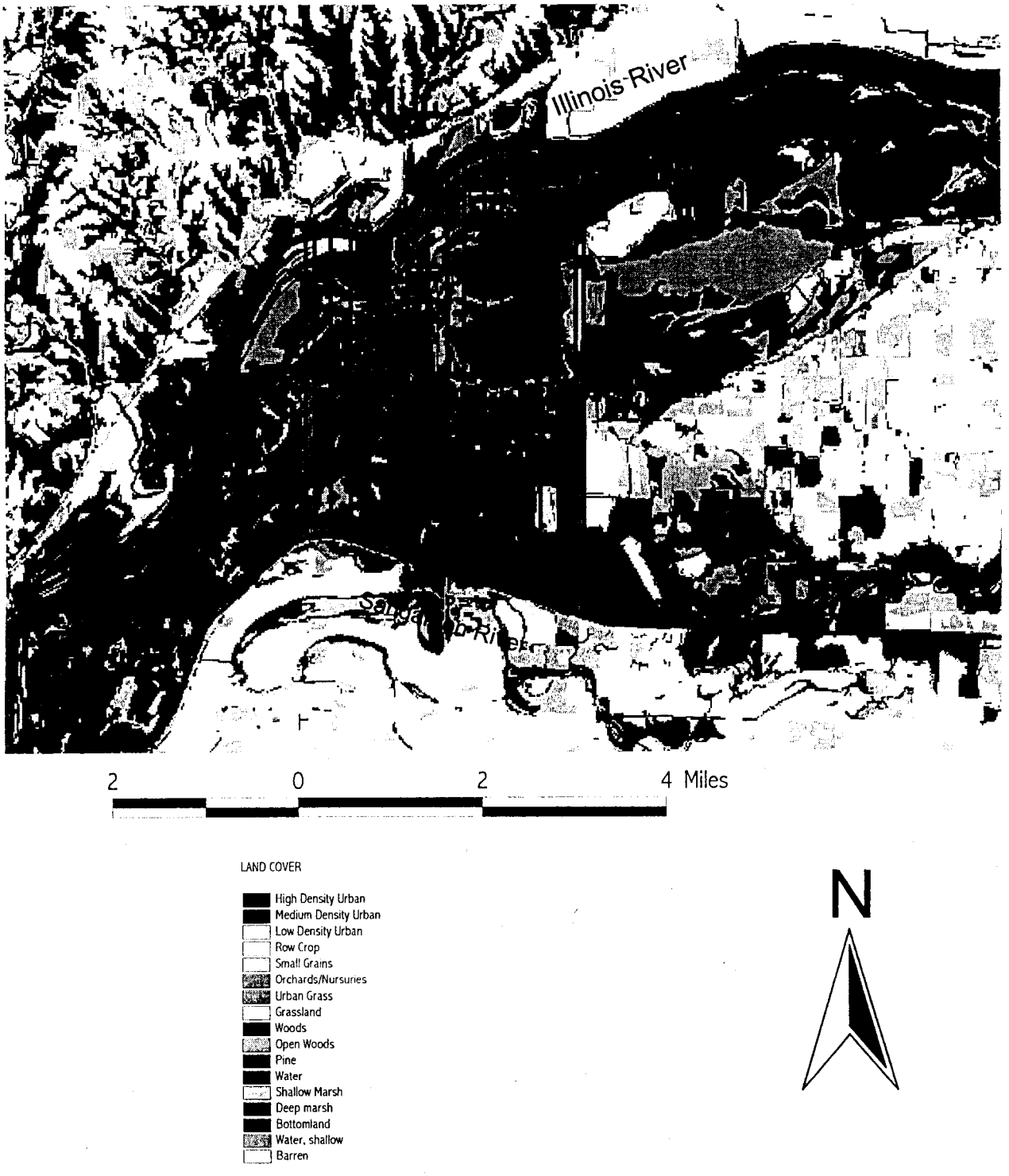


Figure 2. The Sanganois study site near Chandlerville, Illinois, depicting transect lines that were flown with a helicopter to estimate breeding populations of wood ducks during April, 1996-1998. The study site included portions of Sanganois Conservation Area and adjacent private lands.

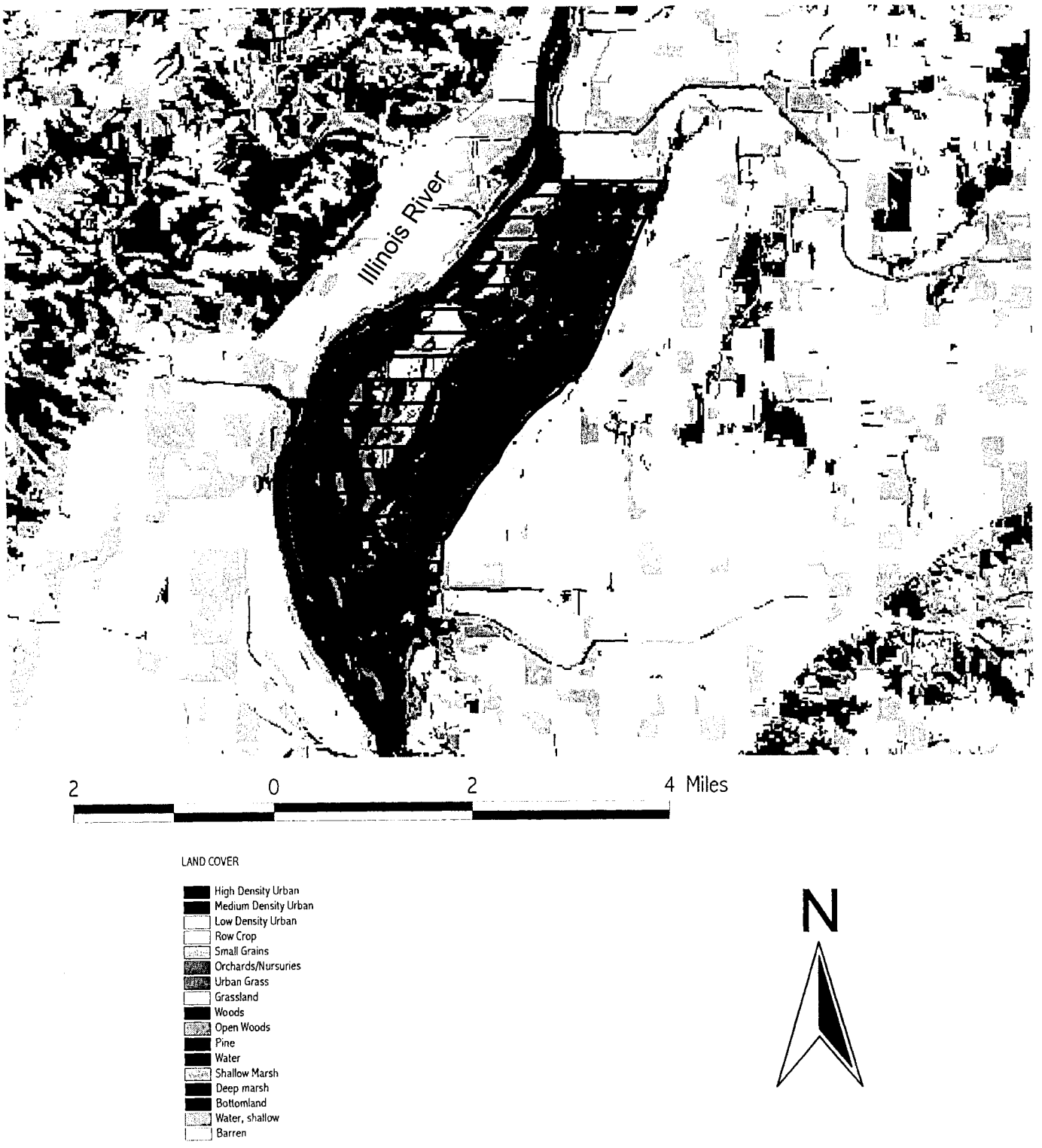


Figure 3. The Meredosia study site near Meredosia, Illinois, depicting transect lines that were flown with a helicopter to estimate breeding populations of wood ducks during April, 1996-1998. The study site included portions of the Meredosia National Wildlife Refuge and adjacent private lands.

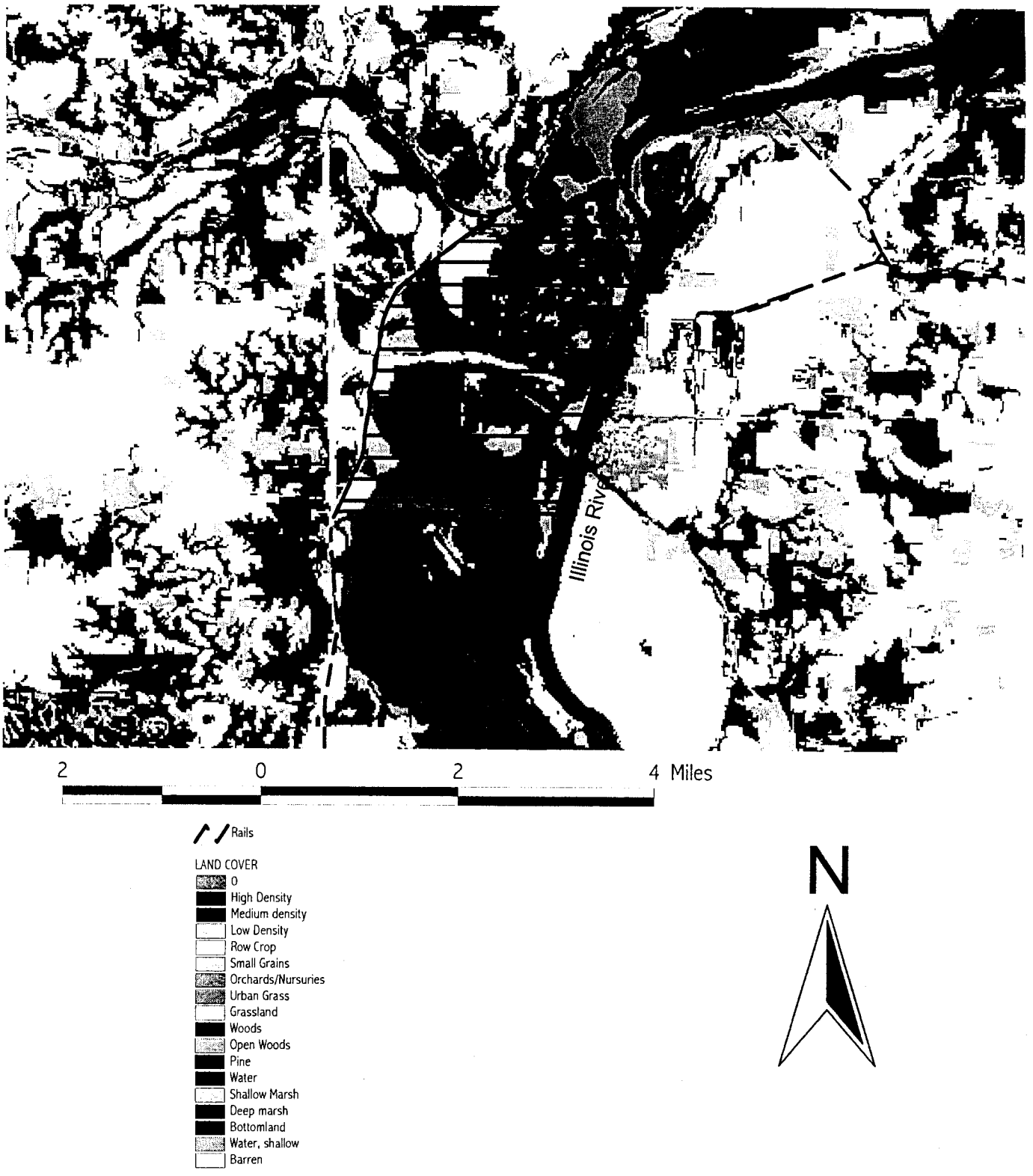


Figure 4. The Princeton study site near Hennepin, Illinois, depicting transect lines that were flown with a helicopter to estimate breeding populations of wood ducks during April, 1996-1998. The study site included portions of the Princeton Game and Fish Club and surrounding bottomlands.

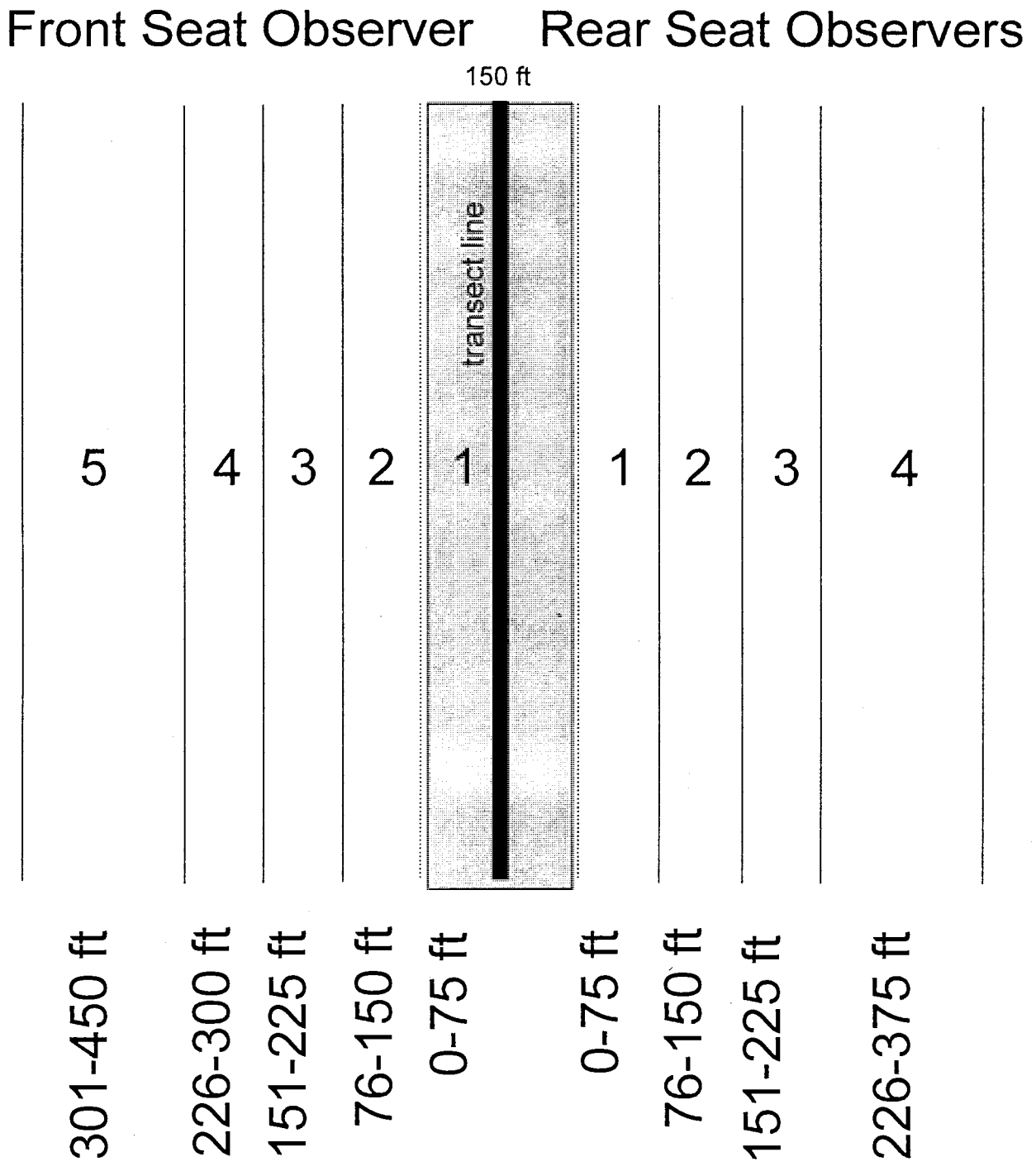
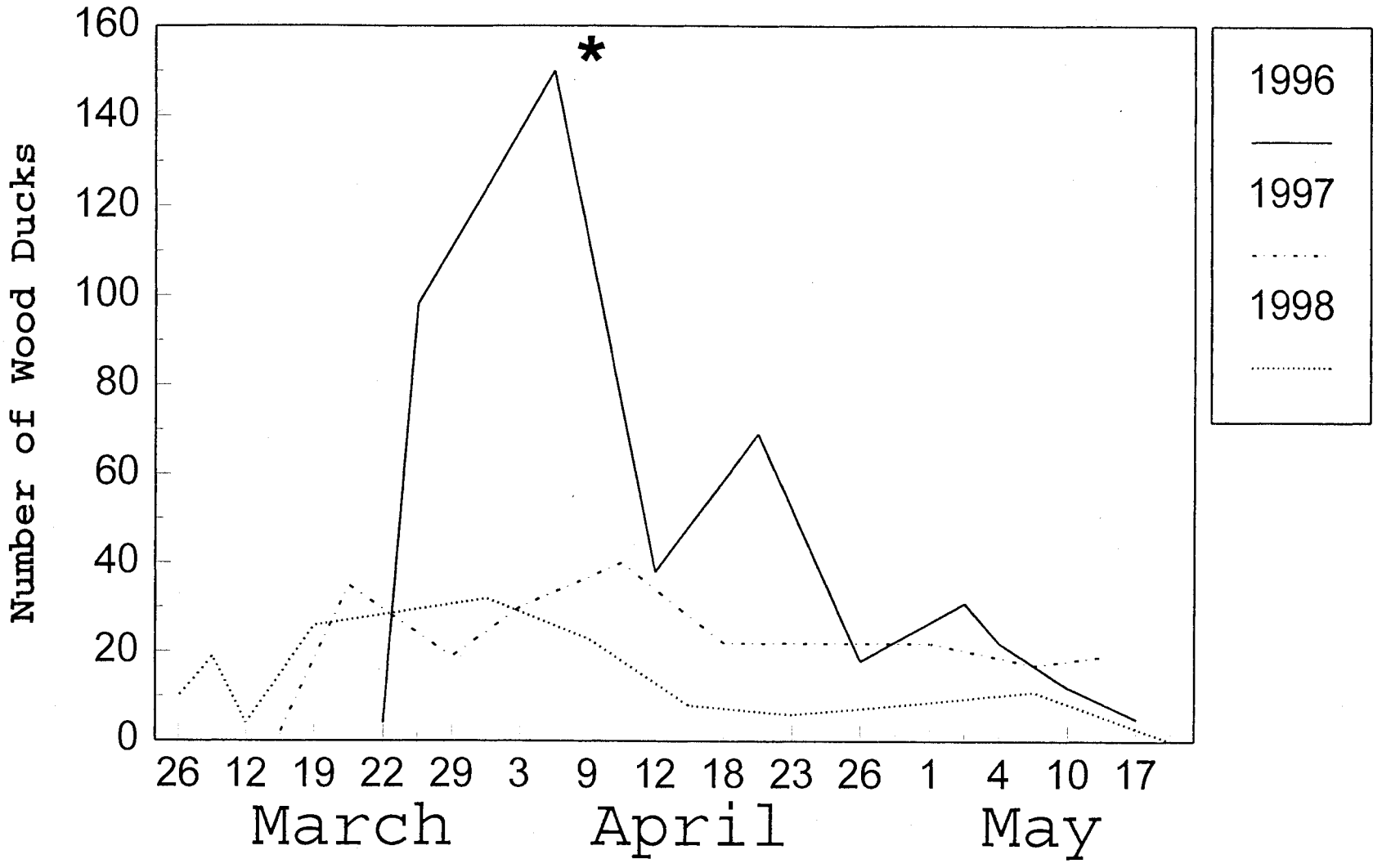


Figure 5. Distance classes along transect lines for the front seat observer and both rear seat observers. Classes were offset 75 feet on both sides of the transect line for rear seat observers because the helicopter fuselage blocked the view underneath. The front seat observer could see in front as well as under the aircraft; this observer viewed distance classes one and two in 1996 but all five classes in 1997 and 1998.



* Actual count on 6 April 1996 was 4,302 wood ducks.

Figure 6. Spring migration chronology of wood ducks at Chautauqua National Wildlife Refuge near Havana, Illinois, 1996-1998. (Bjorklund and Bjorklund, Unpubl. Info.)

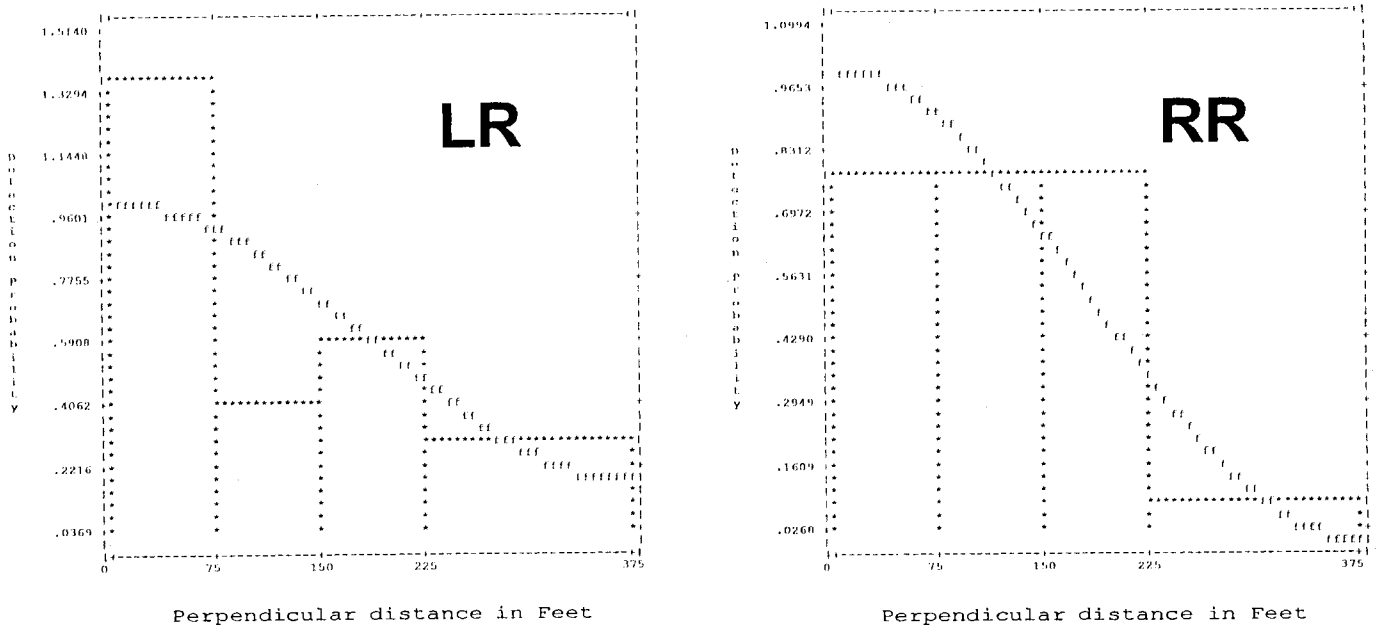


Figure 7. Distribution of indicated breeding pair (IBP) observations of wood ducks in perpendicular distance classes obtained by the left rear (LR) and right rear (RR) aerial observers and the fit of key function models to data generated during the aerial line transect survey at the Princeton study site on 27 April 1996. Graphs represent the uniform key function with cosine adjustment for both observers.

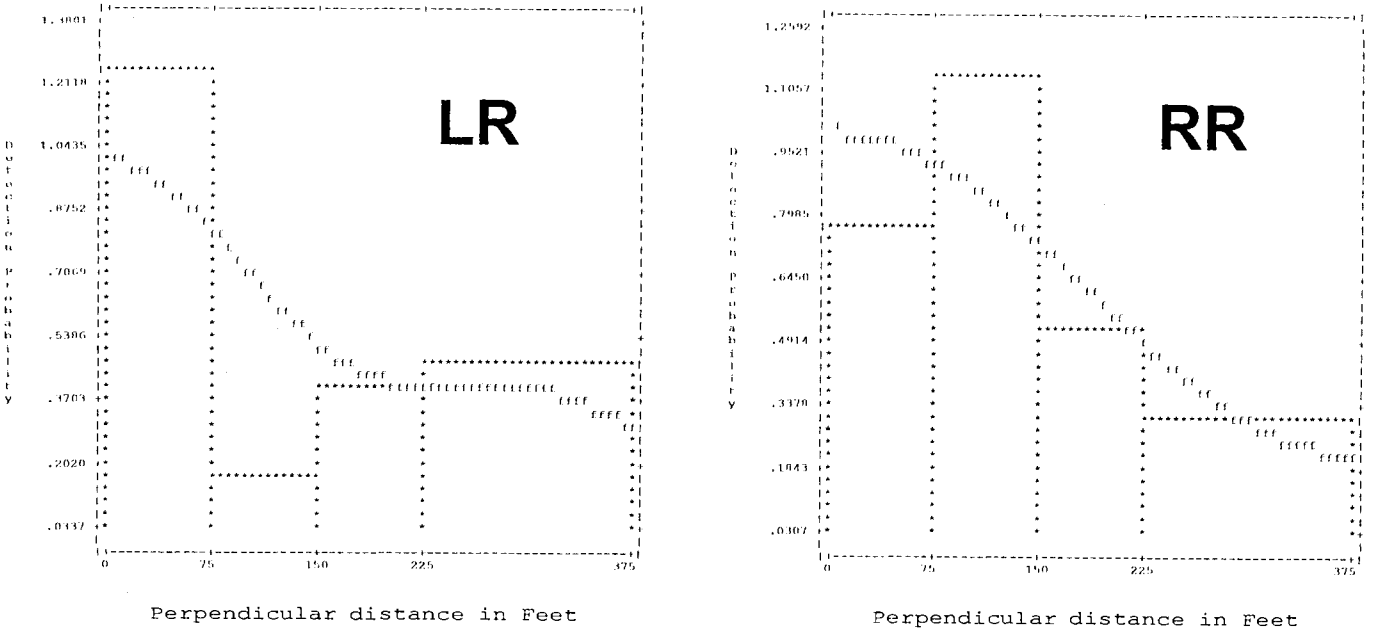


Figure 8. Distribution of indicated breeding pair (IBP) observations of wood ducks in perpendicular distance classes obtained by the left rear (LR) and right rear (RR) aerial observers and the fit of key function models to data generated during the aerial line transect survey at the Meredosia study site on 27 April 1996. Graphs represent the half-normal key function with cosine adjustment for the LR observer and the uniform key function with cosine adjustment for the RR observer.

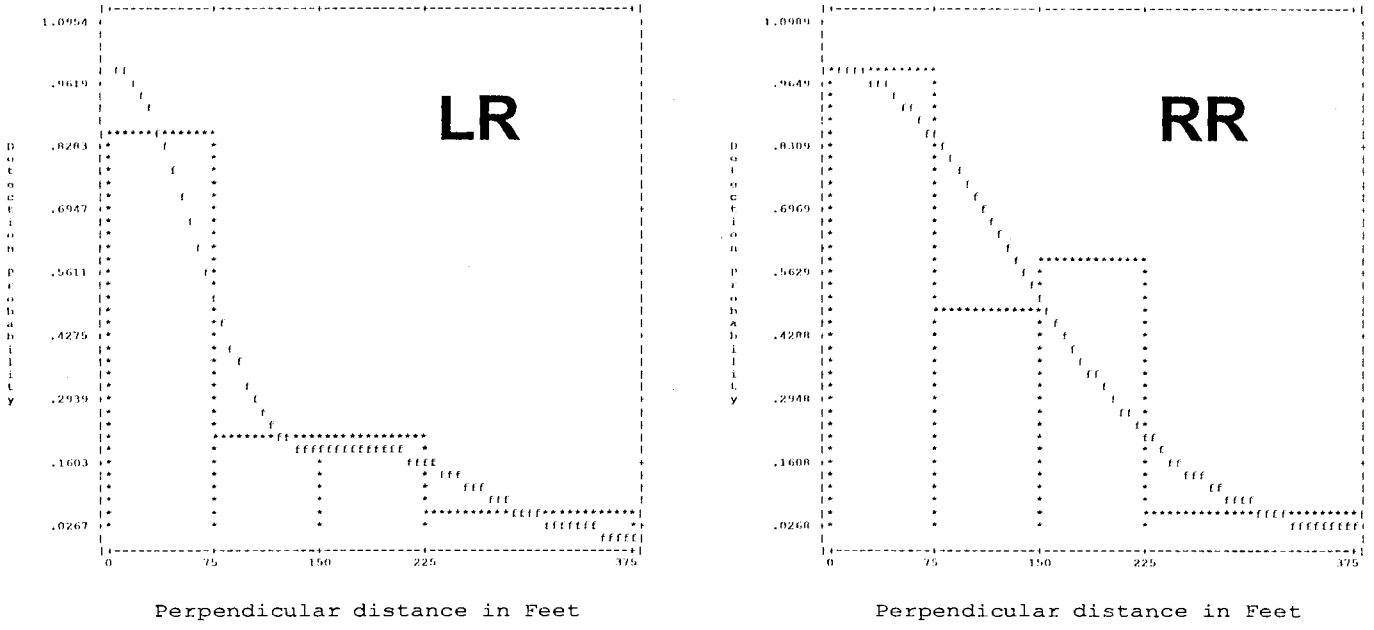
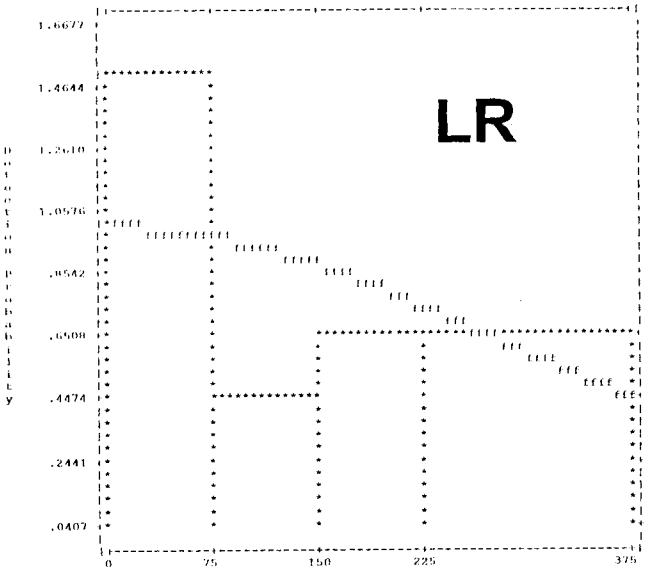
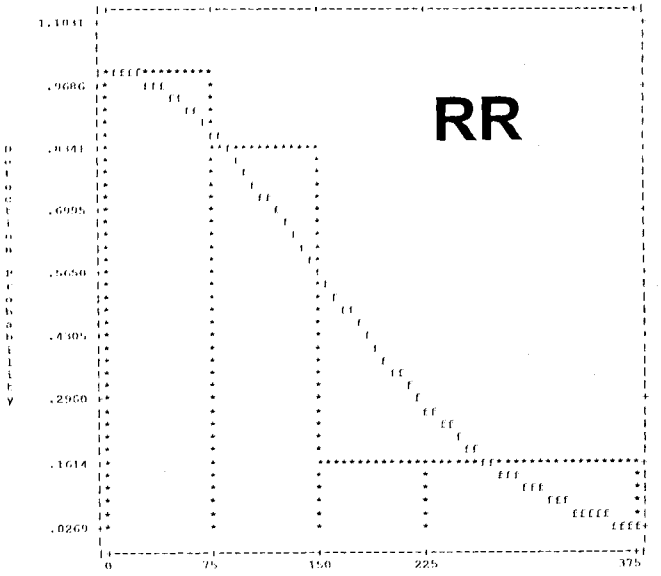


Figure 9. Distribution of indicated breeding pair (IBP) observations of wood ducks in perpendicular distance classes obtained by the left rear (LR) and right rear (RR) aerial observers and the fit of key function models to data generated during the aerial line transect survey at the Sanganois study site on 22 April 1996. Graphs represent the half-normal key function with cosine adjustment for the LR and RR observers.





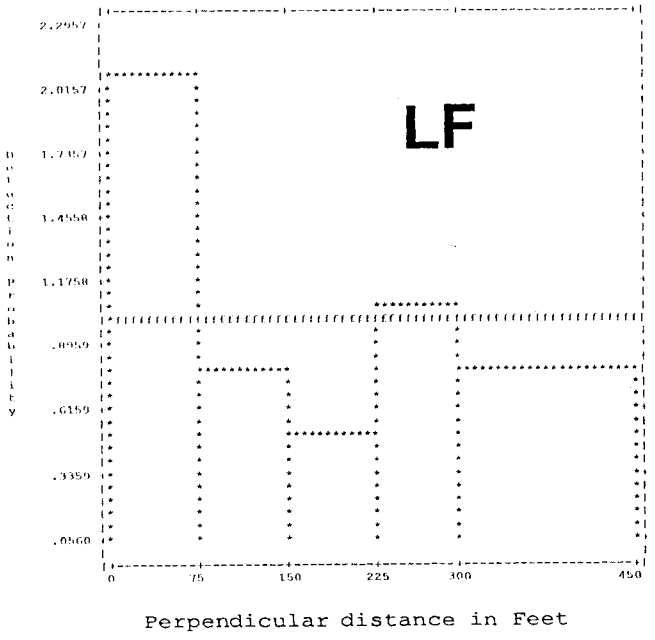
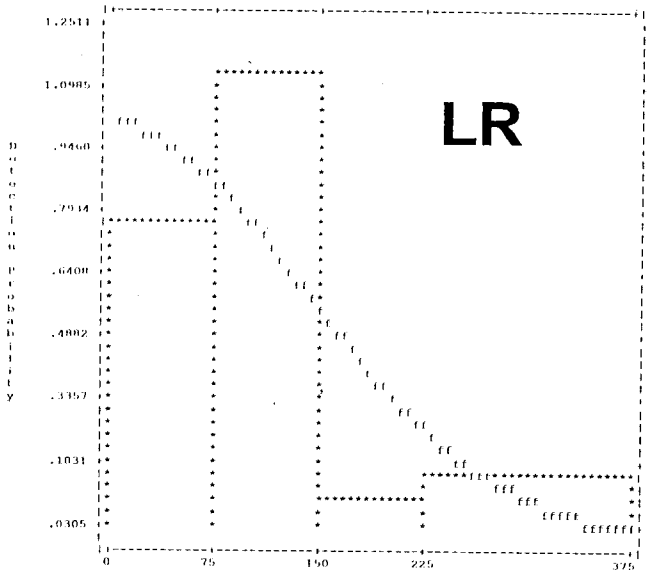
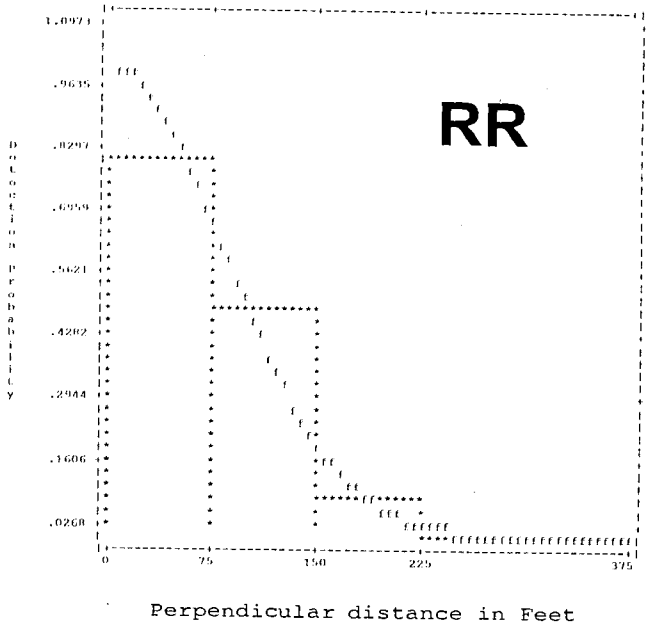


Figure 10. Distribution of indicated breeding pair (IBP) observations of wood ducks in perpendicular distance classes obtained by the left rear (LR), right rear (RR), and left front (LF) aerial observers and the fit of key function models to data generated during the aerial line transect survey at the Princeton study site on 22 April 1997. Graphs represent the half-normal key function with cosine adjustment for the LR and RR observers and the uniform key function with cosine adjustment for the LF observer.





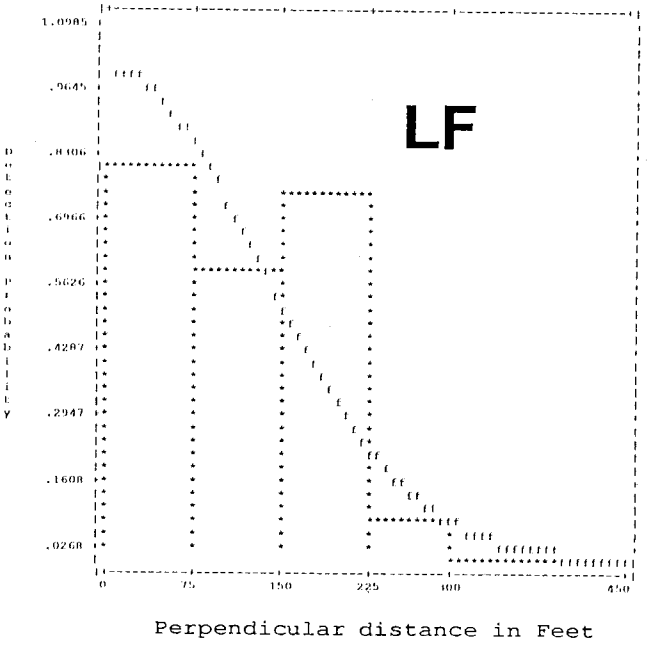


Figure 11. Distribution of indicated breeding pair (IBP) observations of wood ducks in perpendicular distance classes obtained by the left rear (LR), right rear (RR), and left front (LF) aerial observers and the fit of key function models to data generated during the aerial line transect survey at the Meredosia study site on 21 April 1997. Graphs represent the half-normal key function with cosine adjustment for each observer.

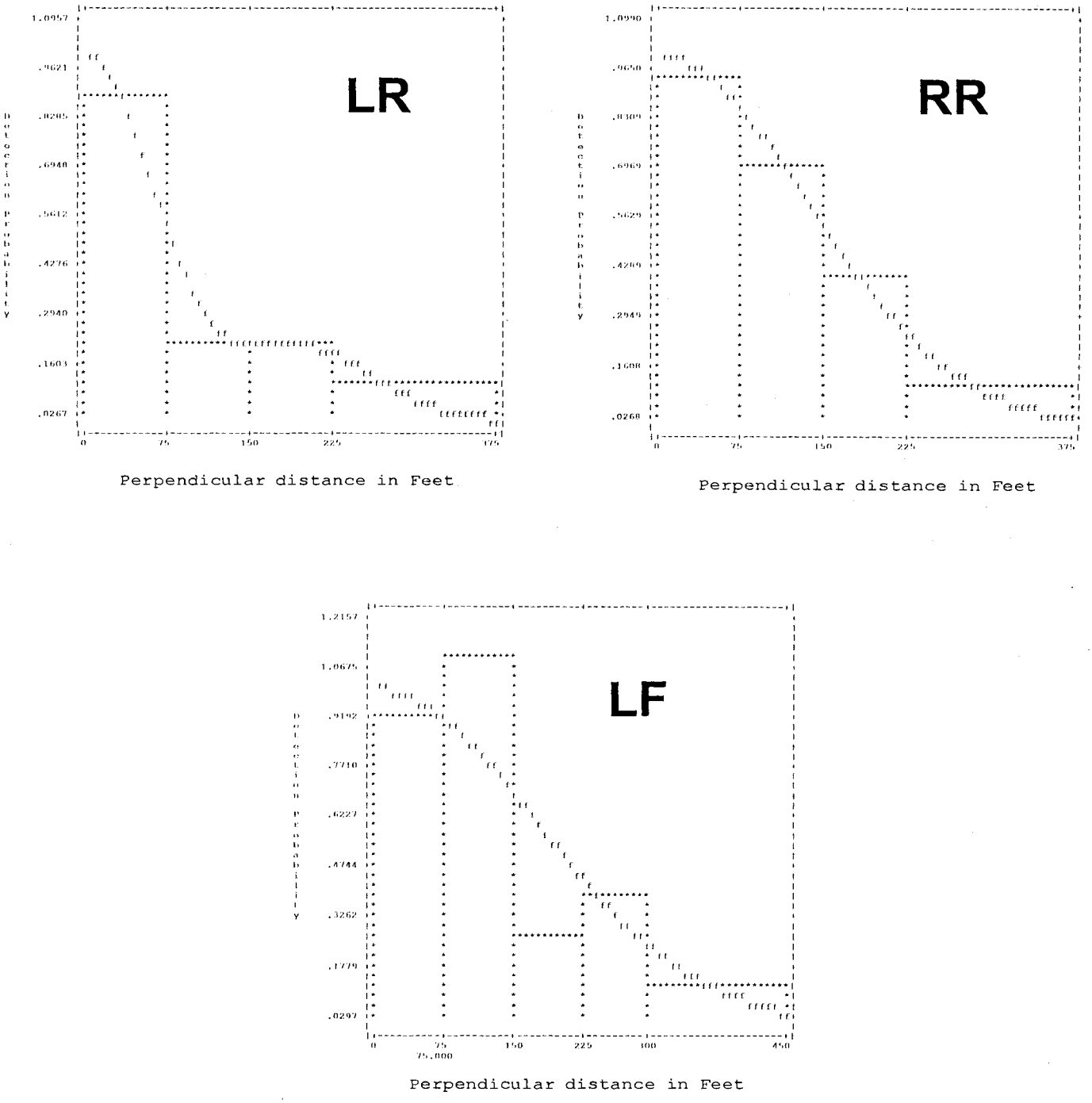
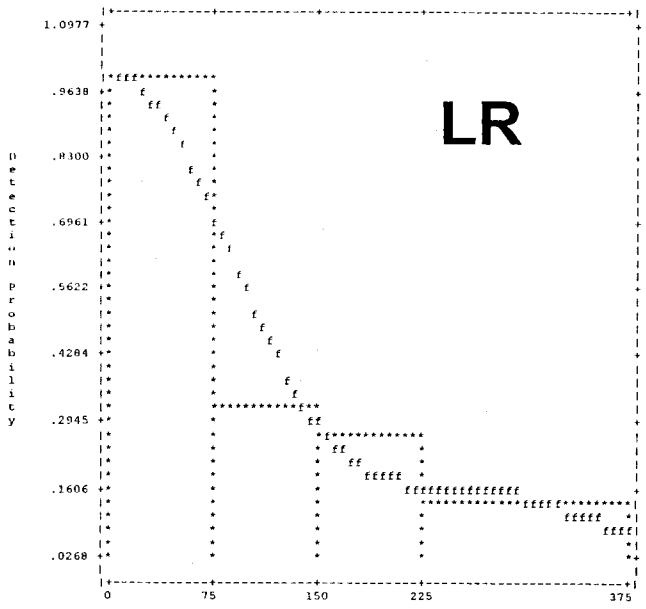
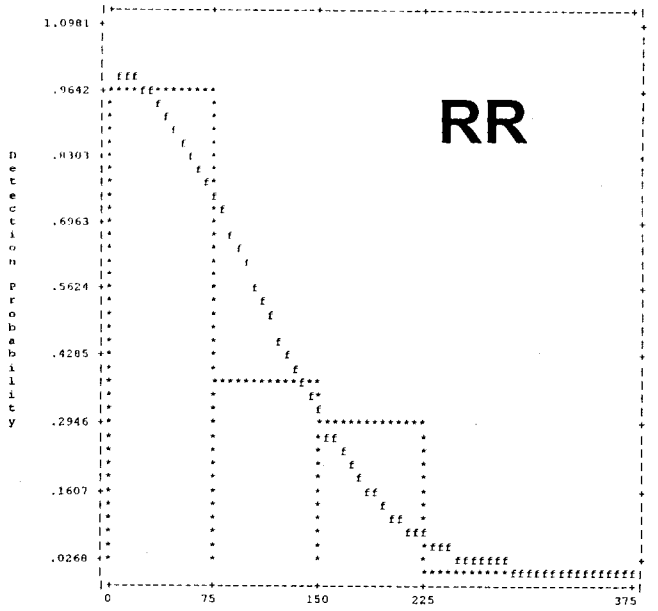


Figure 12. Distribution of indicated breeding pair (IBP) observations of wood ducks in perpendicular distance classes obtained by the left rear (LR), right rear (RR), and left front (LF) aerial observers and the fit of key function models to data generated during the aerial line transect survey at the Sanganois study site on 20-21 April 1997. Graphs represent the half-normal key function with cosine adjustment for each observer.





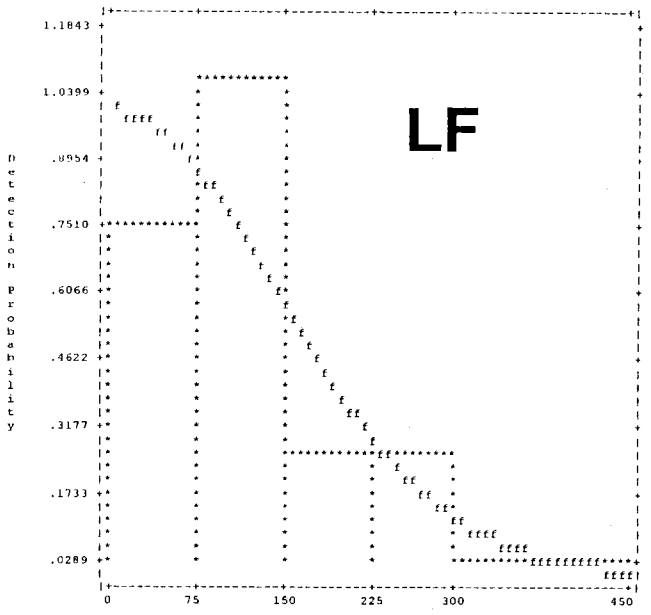
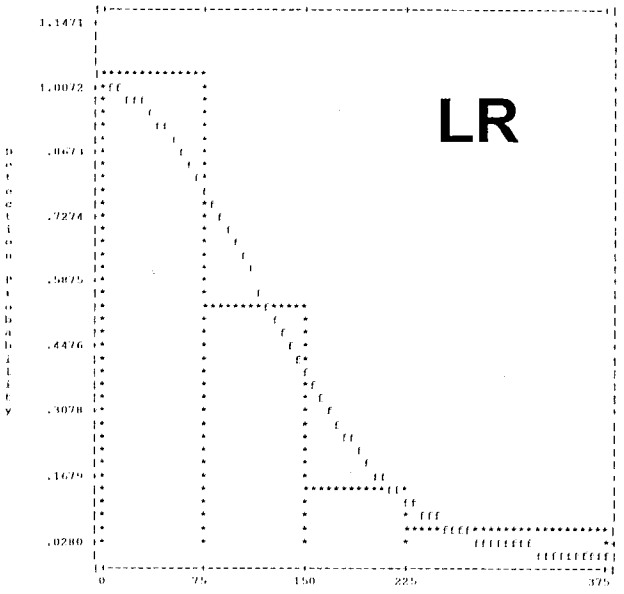
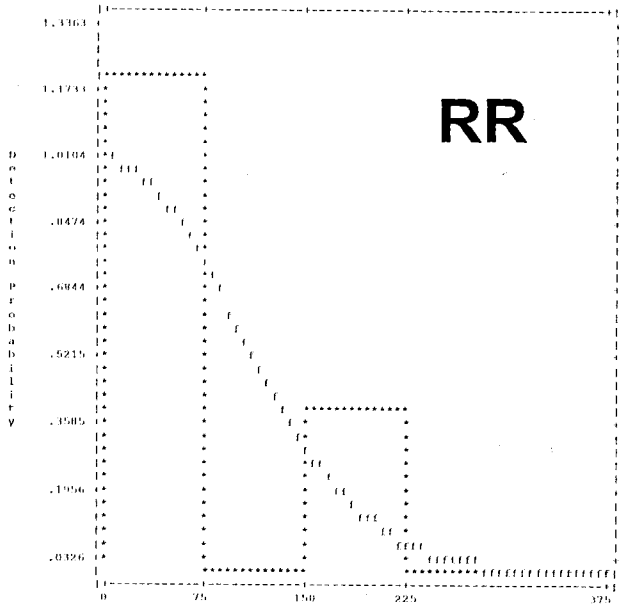


Figure 13. Distribution of indicated breeding pair (IBP) observations of wood ducks in perpendicular distance classes obtained by the left rear (LR), right rear (RR), and left front (LF) aerial observers and the fit of key function models to data generated during the aerial line transect survey at the Princeton study site on 15 April 1998. Graphs represent the half-normal key function with cosine adjustment for each observer.





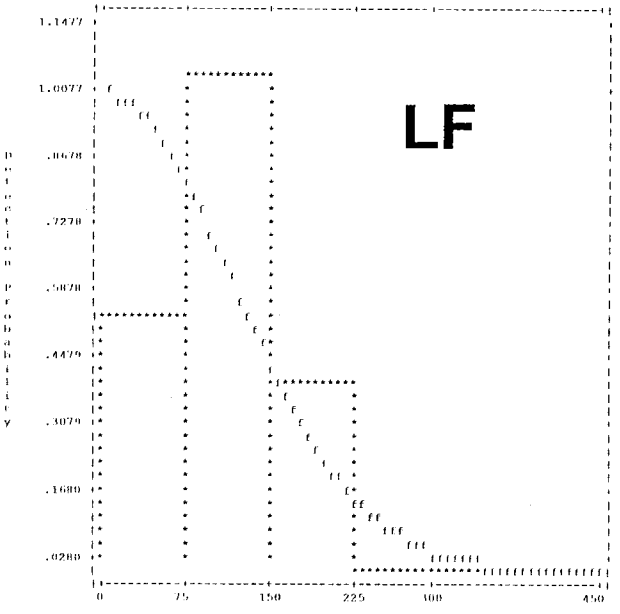
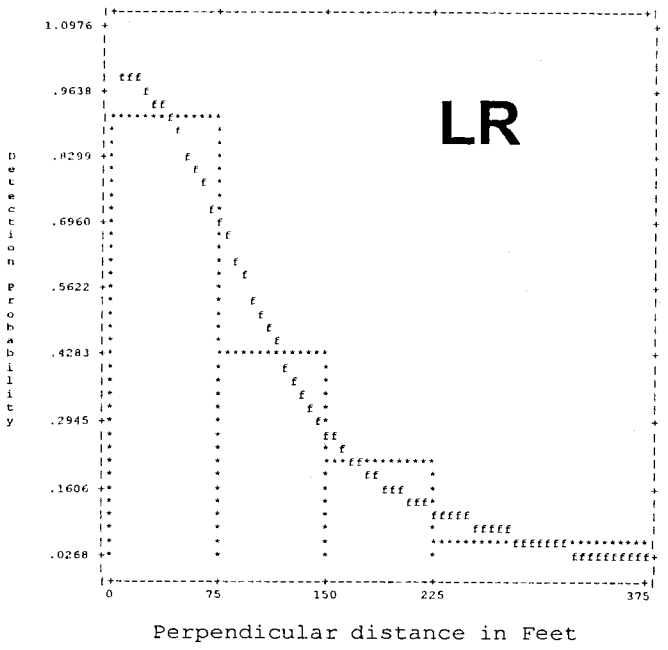
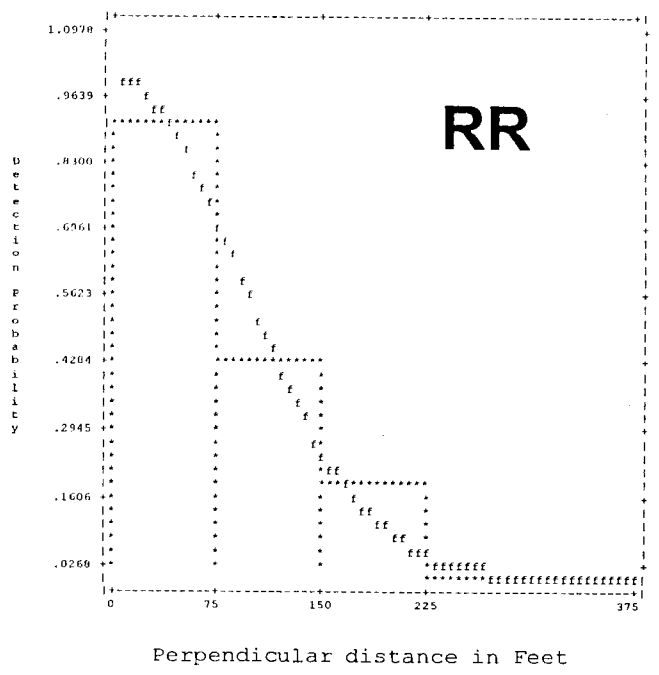


Figure 14. Distribution of indicated breeding pair (IBP) observations of wood ducks in perpendicular distance classes obtained by the left rear (LR), right rear (RR), and left front (LF) aerial observers and the fit of key function models to data generated during the aerial line transect survey at the Meredosia study site on 14 April 1998. Graphs represent the half-normal key function with cosine adjustment for each observer.





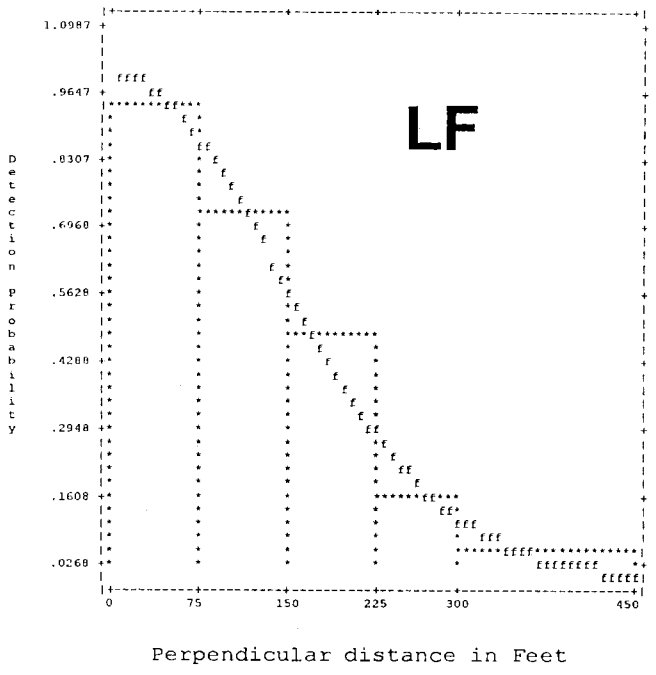


Figure 15. Distribution of indicated breeding pair (IBP) observations of wood ducks in perpendicular distance classes obtained by the left rear (LR), right rear (RR), and left front (LF) aerial observers and the fit of key function models to data generated during the aerial line transect survey at the Sanganois study site on 14 April 1998. Graphs represent the half-normal key function with cosine adjustment for each observer.

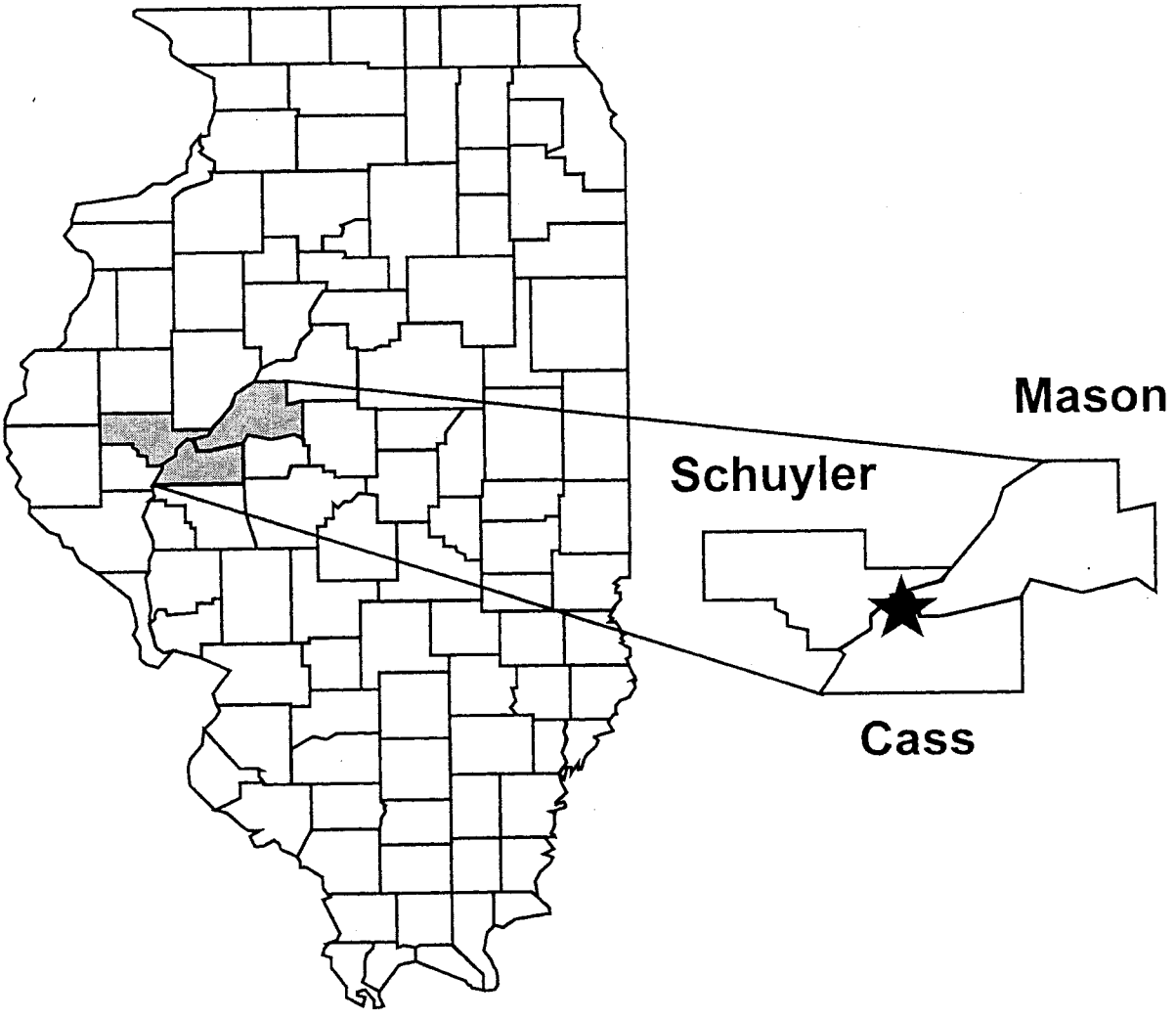


Figure 16. The Sanganois study area in Mason, Cass, and Schulyer counties in west-central Illinois.

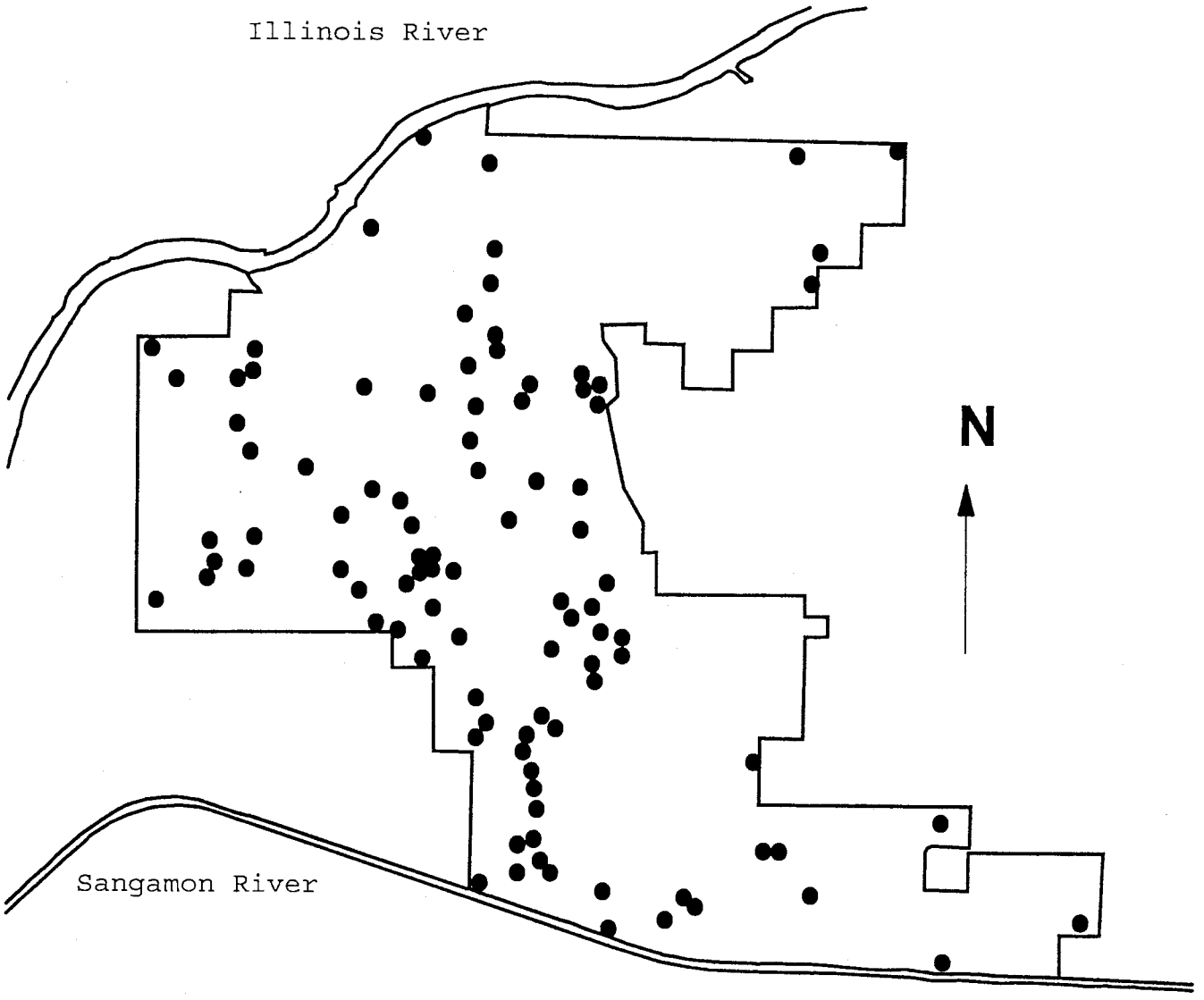


Figure 17. Distribution of 97 sample plots at the Sanganois Conservation Area for the investigation of natural cavities identified during 1992-1994.

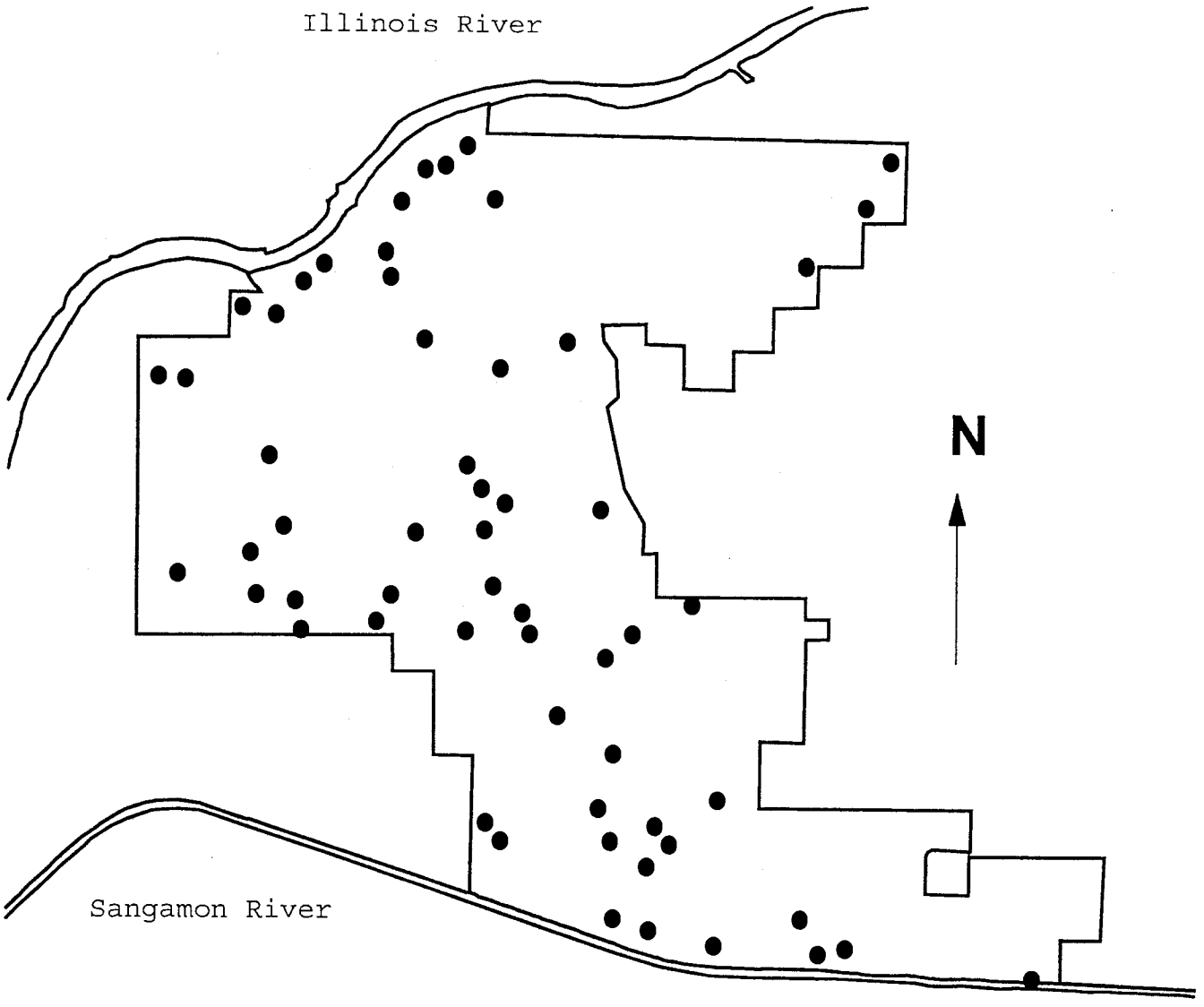


Figure 18. Distribution of 58 sample plots at the Sanganois Conservation Area for the investigation of natural cavities identified during 1996-1997.

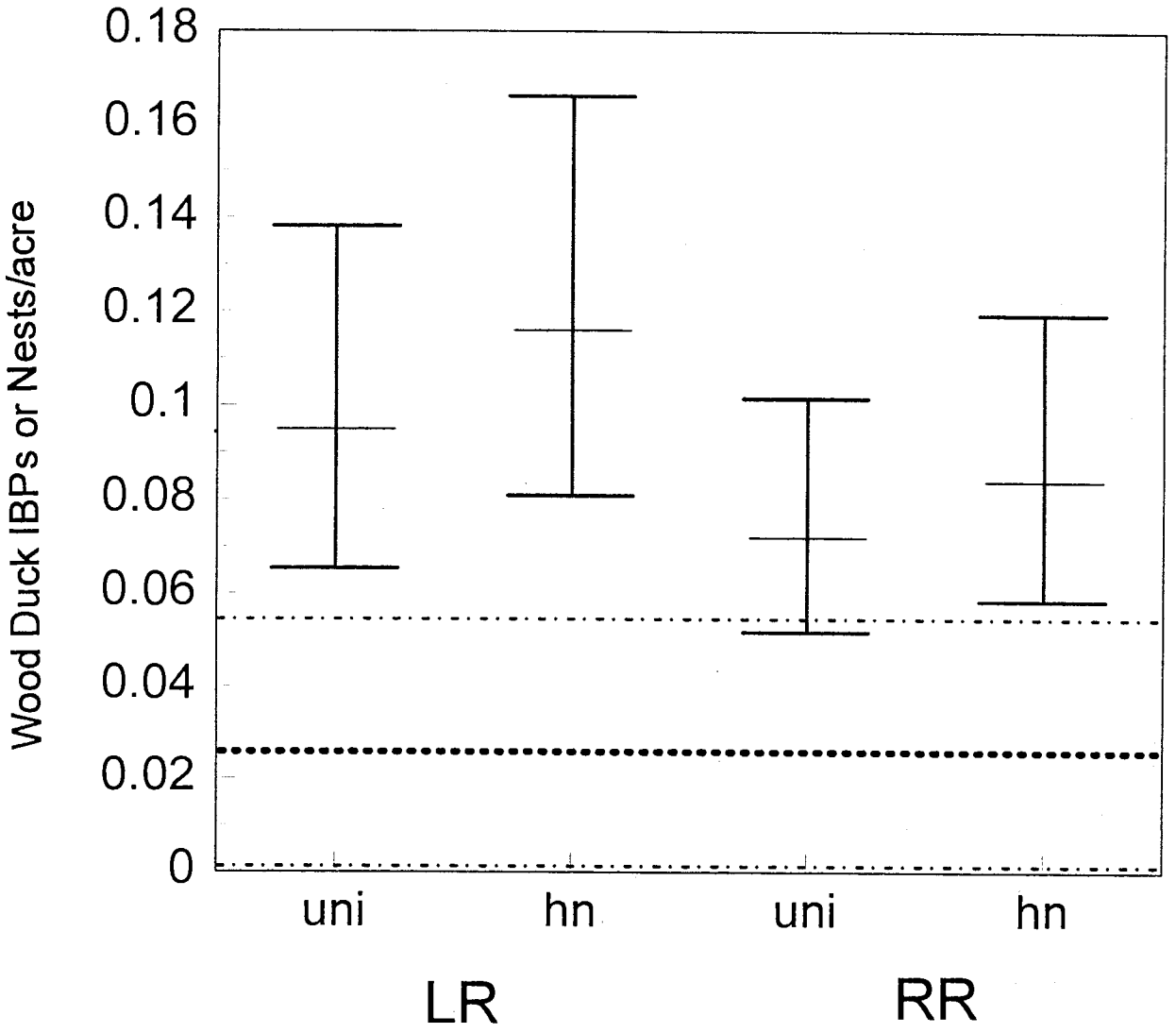


Figure 19. Estimates of wood duck nest densities at Sanganois Conservation Area from 1996 cavity inspections with 95% confidence interval (dashed lines) and indicated breeding pair (IBP) densities from aerial surveys with 95% confidence intervals (solid lines). Aerial data are presented for each observer; left rear (LR) and right rear (RR). Aerial data were collected on 22 April 1996 and evaluated using the uniform (uni) and half-normal (hn) key functions of Program DISTANCE.

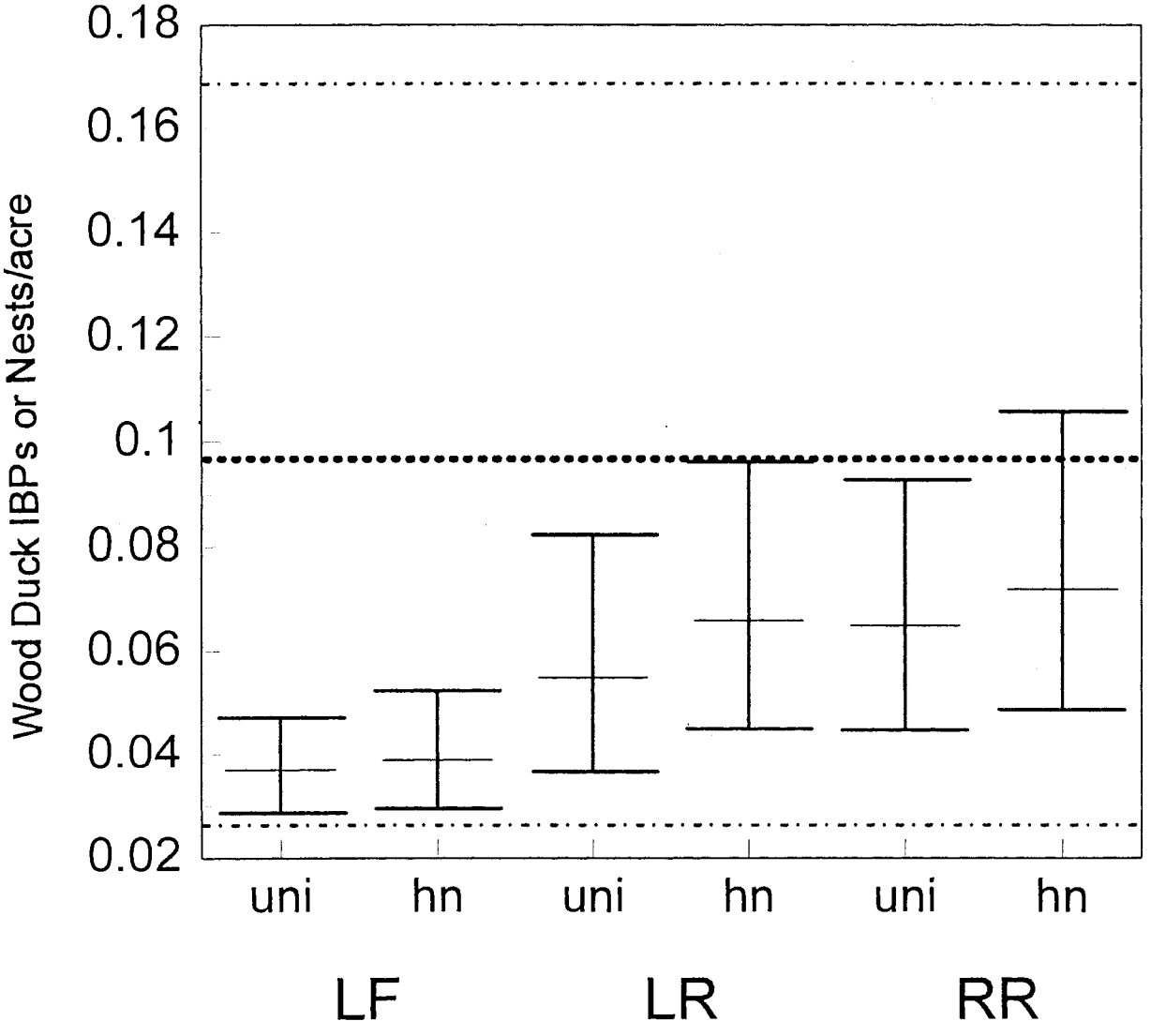


Figure 20. Estimates of wood duck nest densities at Sanganois Conservation Area from 1997 cavity inspections with 95% confidence interval (dashed lines) and indicated breeding pair (IBP) densities from aerial surveys with 95% confidence intervals (solid lines). Aerial data are presented for each observer; left front (LF), left rear (LR) and right rear (RR). Aerial data were collected on 20-21 April 1997 and evaluated using the uniform (uni) and half-normal (hn) key functions of Program DISTANCE.

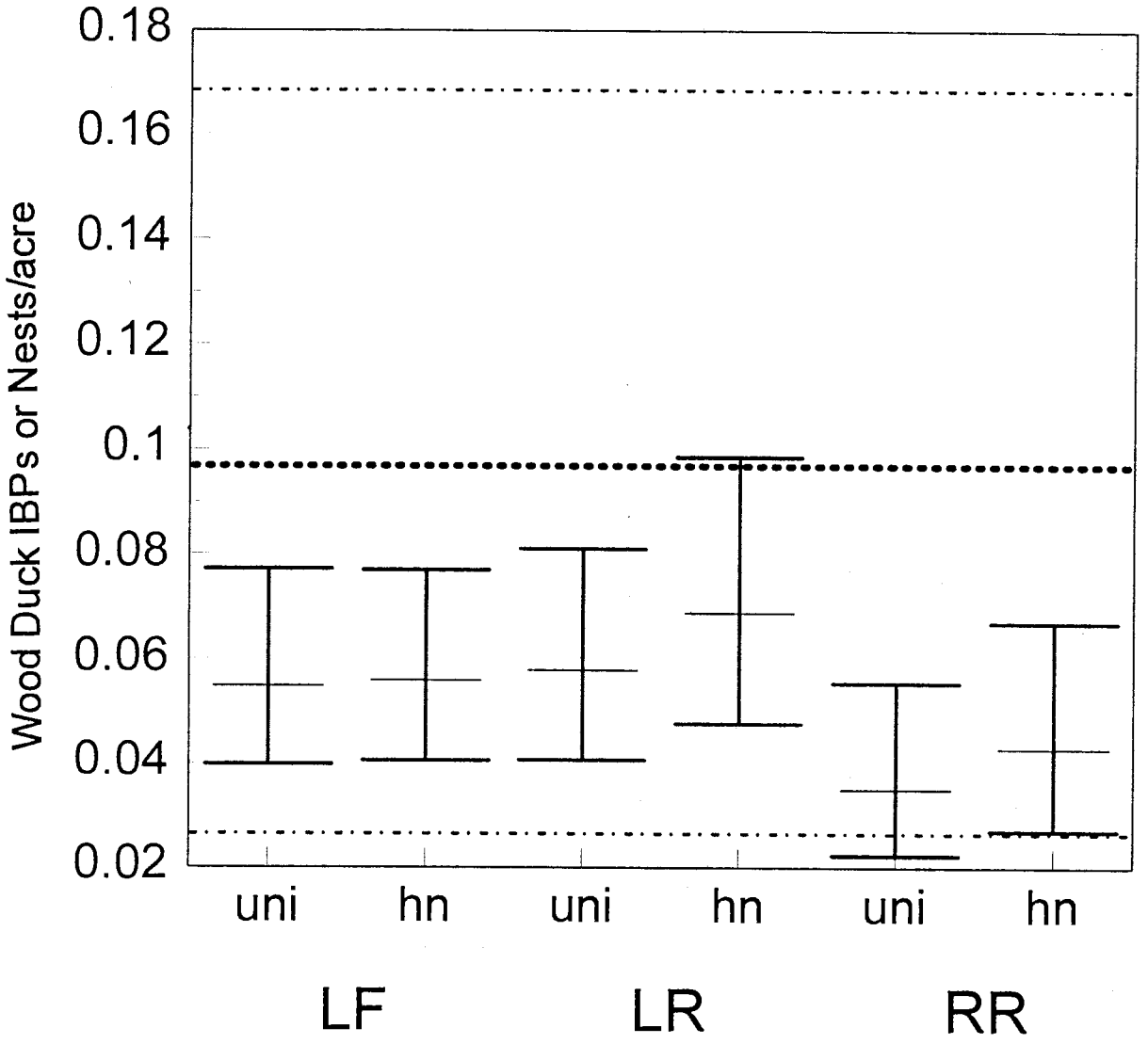


Figure 21. Estimates of wood duck nest densities at Sanganois Conservation Area from 1998 cavity inspections with 95% confidence interval (dashed lines) and indicated breeding pair (IBP) densities from aerial surveys with 95% confidence intervals (solid lines). Aerial data are presented for each observer; left front (LF), left rear (LR), and right rear (RR). Aerial data were collected on 14 April 1998 and evaluated using the uniform (uni) and half-normal (hn) key functions of Program DISTANCE.

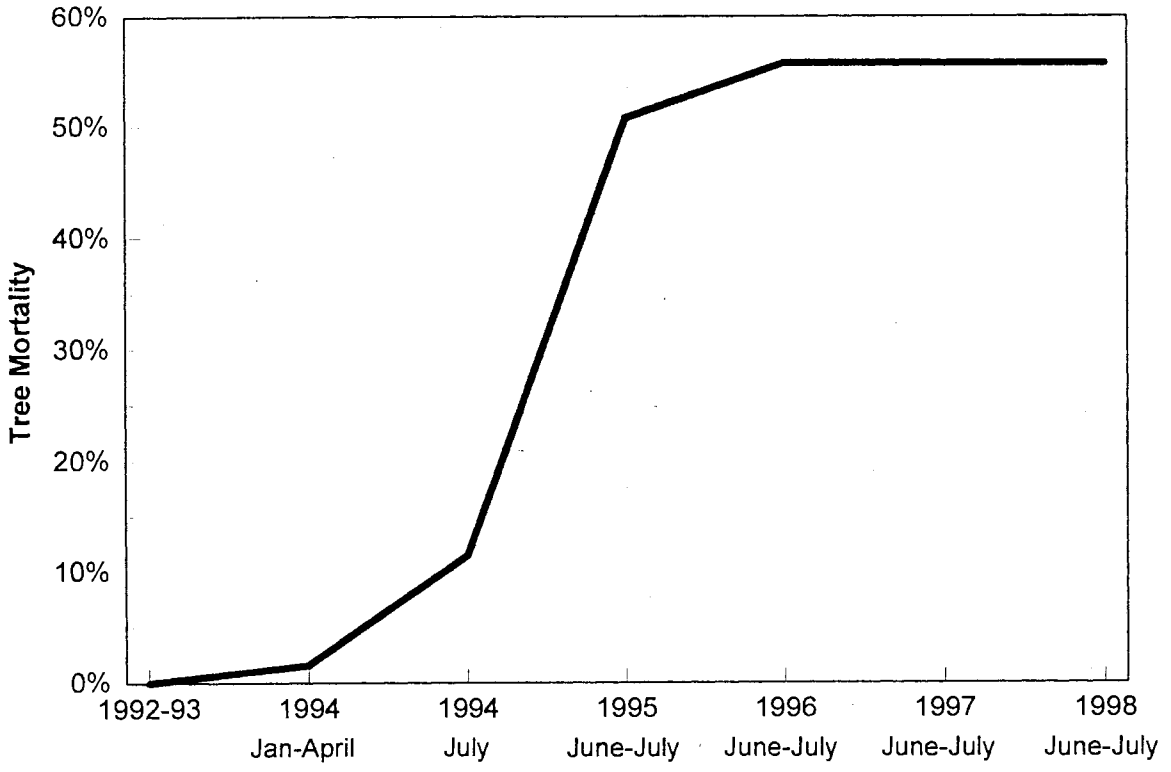


Figure 22. Mortality of 61 trees containing natural cavities potentially suitable for nesting by wood ducks at the Sanganois Conservation Area, 1992-1998.

Table 1. Date, time, number of transects, total number of wood ducks observed, and the resulting number of indicated breeding pairs (IBPs) estimated for each observer during aerial line transect surveys at the Princeton, Meredosia, and Sanganois study areas, April 1996-1998.

Study site	Date	Time	Number of transects	Observer[a]	Total observed	IBPs
1996						
Princeton	16 April	1:11pm- 1:48pm	12	LR	63	26
				RR	86	35
	27 April	11:00am-11:43am	13	LR	58	30
				RR	40	16
Meredosia	16 April	9:55am-10:50am	16	LR	38	15
				RR	41	27
	27 April	8:46am- 9:41am	18	LR	88	47
				RR	72	24
Sanganois	15 April	1:50pm- 3:11pm	15	LR	233	117
				RR	176	87
	22 April	2:05pm- 4:50pm	16	LR	181	99
				RR	257	111

Table 1. Continued.

Study site	Date	Time	Number of transects	Observer[a]	Total observed	IBPs
1997						
Princeton	14 April	11:30am-12:05pm	13	LF	44	25
				LR	33	18
				RR	54	22
	22 April	9:43am-10:25am	13	LF	39	23
				LR	32	18
				RR	28	14
Meredosia	14 April	9:06am- 9:51am	18	LF	63	24
				LR	50	16
				RR	32	17
	21 April	2:20pm- 3:06pm	18	LF	51	30
				LR	49	24
				RR	31	17
Sanganois	13 April	8:50am-10:15am	17	LF	176	97
				LR	137	66
				RR	122	63
	20 April[b]	8:56am- 9:53am	17	LF	144	74
	21 April	1:38pm- 2:02pm		LR	132	63
				RR	163	105

Table 1. Continued.

Study site	Date	Time	Number of transects	Observer[a]	Total observed	IBPs
1998						
Princeton	15 April	9:02am- 9:42am	13	LF	58	36
				LR	46	28
				RR	26	17
	23 April	9:46am-10:22am	13	LF	22	14
				LR	9	7
				RR	19	13
Meredosia	14 April	4:10pm- 4:57pm	18	LF	26	15
				LR	24	14
				RR	6	4
	22 April	9:53am-10:43am	18	LF	34	23
				LR	32	25
				RR	41	22
Sanganois	14 April	1:56pm- 3:22pm	17	LF	154	87
				LR	121	74
				RR	65	42
	22 April	11:32am-12:50pm	16	LF	132	78
				LR	91	51
				RR	68	37

[a] Left front (LF), left rear (LR), and right rear seat (RR) observers.
[b] Survey was completed the following afternoon because of mechanical difficulties.

Table 2. Indicated breeding pair (IBP) density estimates ($\hat{D}$=IBPs/acre) of wood ducks and corresponding model selection statistics from aerial line transect surveys for the Princeton study area, April 1996-1998.

Date	Observer	Key function	Adjustment	AIC[a]	$\hat{D}$	CV(%)[b]	Log based CI_{95}[c]	
1996								
16 April	left rear	uniform	cosine	59.29	0.064	36.31	0.031	0.132
		half-normal	cosine	56.85	0.069	30.95	0.037	0.130
	right rear	uniform	cosine	95.75	0.050	23.95	0.031	0.083
		half-normal	cosine	95.70	0.052	25.76	0.031	0.088
27 April	left rear	uniform	cosine	82.48	0.039	26.86	0.023	0.068
		half-normal	cosine	82.48	0.041	28.37	0.023	0.072
	right rear	uniform	cosine	43.78	0.025	26.44	0.014	0.042
		half-normal	cosine	44.41	0.025	31.40	0.013	0.047
1997								
14 April	left front	uniform	cosine	50.52	0.069	30.63	0.038	0.127
		half-normal	cosine	46.17	0.068	25.26	0.040	0.113
	left rear	uniform	cosine	37.19	0.037	36.68	0.018	0.078
		half-normal	cosine	33.68	0.049	35.52	0.024	0.100
	right rear	uniform	cosine	54.69	0.034	26.46	0.019	0.059
		half-normal	cosine	53.44	0.042	29.50	0.023	0.076
22 April	left front	uniform	cosine	74.10	0.015	17.04	0.010	0.021
		half-normal	cosine	74.90	0.019	27.38	0.011	0.033
	left rear	uniform	cosine	49.62	0.014	17.23	0.010	0.020
		half-normal	cosine	50.79	0.018	30.43	0.010	0.033
	right rear	uniform	cosine	37.34	0.021	29.92	0.011	0.038
		half-normal	cosine	36.99	0.023	33.92	0.012	0.045

Table 2. Continued.

Date	Observer	Key function	Adjustment	AIC[a]	$\hat{D}$	CV(%)[b]	Log based CI_{95}[c]	
1998								
15 April	left front	uniform	cosine	101.96	0.046	18.15	0.031	0.068
		half-normal	cosine	100.71	0.057	21.04	0.037	0.088
	left rear	uniform	cosine	73.21	0.041	24.99	0.024	0.069
		half-normal	cosine	72.24	0.058	30.00	0.032	0.106
	right rear	uniform	cosine	38.44	0.035	36.50	0.017	0.073
		half-normal	cosine	36.47	0.040	35.24	0.020	0.082
23 April	left front	uniform	cosine	34.66	0.024	33.53	0.012	0.047
		half-normal	cosine	31.77	0.031	33.62	0.016	0.062
	left rear	uniform	cosine	16.04	0.014	58.89	0.005	0.046
		half-normal	cosine	12.87	0.021	57.21	0.007	0.065
	right rear	uniform	cosine	29.33	0.027	38.52	0.012	0.058
		half-normal	cosine	27.25	0.032	36.95	0.015	0.067

[a] Akaike Information Criterion.
[b] Coefficient of variation.
[c] Confidence interval.

Table 3. Indicated breeding pair (IBP) density estimates ($\hat{D}$=IBPs/acre) of wood ducks and corresponding model selection statistics from aerial line transect surveys for the Meredosia study area, April 1996-1998.

Date	Observer	Key function	Adjustment	AIC[a]	$\hat{D}$	CV(%)[b]	Log based CI_{95}[c]	
1996								
16 April	left rear	uniform	cosine	37.92	0.022	36.07	0.010	0.045
		half-normal	cosine	37.18	0.027	39.35	0.012	0.059
	right rear	uniform	cosine	69.43	0.039	30.95	0.021	0.074
		half-normal	cosine	70.08	0.044	33.28	0.023	0.087
27 April	left rear	uniform	cosine	127.95	0.042	23.02	0.026	0.066
		half-normal	cosine	126.17	0.055	27.56	0.032	0.095
	right rear	uniform	cosine	67.65	0.026	28.87	0.015	0.046
		half-normal	cosine	67.66	0.026	30.66	0.014	0.047
1997								
14 April	left front	uniform	cosine	75.39	0.023	21.51	0.015	0.036
		half-normal	cosine	75.20	0.024	24.50	0.015	0.040
	left rear	uniform	cosine	42.05	0.021	26.17	0.013	0.036
		half-normal	cosine	42.18	0.024	30.67	0.013	0.044
	right rear	uniform	cosine	37.04	0.038	38.41	0.018	0.082
		half-normal	cosine	34.59	0.043	31.42	0.023	0.081
21 April	left front	uniform	cosine	80.98	0.045	28.56	0.025	0.079
		half-normal	cosine	80.24	0.045	28.66	0.025	0.080
	left rear	uniform	cosine	62.03	0.031	27.51	0.018	0.055
		half-normal	cosine	61.48	0.035	30.31	0.019	0.064
	right rear	uniform	cosine	34.81	0.030	39.45	0.014	0.066
		half-normal	cosine	31.25	0.040	38.33	0.019	0.087

Table 3. Continued.

Date	Observer	Key function	Adjustment	AIC[a]	$\hat{D}$	CV(%)[b]	Log based CI_{95}[c]	
1998								
14 April	left front	uniform	cosine	39.26	0.022	34.85	0.011	0.044
		half-normal	cosine	37.61	0.025	34.91	0.013	0.051
	left rear	uniform	cosine	34.39	0.019	31.47	0.010	0.035
		half-normal	cosine	32.45	0.025	35.18	0.013	0.051
	right rear	uniform	cosine	10.91	0.005	46.62	0.002	0.013
		half-normal	cosine	10.04	0.008	54.86	0.003	0.025
22 April	left front	uniform	cosine	65.81	0.025	20.83	0.017	0.039
		half-normal	cosine	64.57	0.031	24.71	0.019	0.052
	left rear	uniform	cosine	53.85	0.044	28.97	0.025	0.079
		half-normal	cosine	51.40	0.052	27.88	0.030	0.091
	right rear	uniform	cosine	52.75	0.036	26.54	0.021	0.061
		half-normal	cosine	50.99	0.050	24.40	0.030	0.081

[a] Akaike Information Criterion.
[b] Coefficient of variation.
[c] Confidence interval.

Table 4. Indicated breeding pair (IBP) density estimates ($\hat{D}$=IBPs/acre) of wood ducks and corresponding model selection statistics from aerial line transect surveys for the Sanganois study area, April 1996-1998.

Date	Observer	Key function	Adjustment	AIC[a]	$\hat{D}$	CV(%)[b]	Log based CI_{95}[c]	
1996								
15 April	left rear	uniform	cosine	297.69	0.080	15.02	0.058	0.109
		half-normal	cosine	296.92	0.087	16.18	0.062	0.121
	right rear	uniform	cosine	232.98	0.057	16.32	0.040	0.080
		half-normal	cosine	232.51	0.052	24.00	0.033	0.084
22 April	left rear	uniform	cosine	230.45	0.095	18.73	0.066	0.138
		half-normal	cosine	224.49	0.116	18.02	0.081	0.166
	right rear	uniform	cosine	276.33	0.072	16.10	0.052	0.101
		half-normal	cosine	276.87	0.084	17.17	0.059	0.119
1997								
13 April	left front	uniform	cosine	246.04	0.080	17.55	0.056	0.114
		half-normal	cosine	243.27	0.085	16.71	0.060	0.119
	left rear	uniform	cosine	172.49	0.039	14.69	0.029	0.052
		half-normal	cosine	171.76	0.042	16.50	0.030	0.058
	right rear	uniform	cosine	139.74	0.062	18.97	0.043	0.091
		half-normal	cosine	137.63	0.064	15.86	0.047	0.088
20-21 April	left front	uniform	cosine	221.62	0.037	12.18	0.029	0.047
		half-normal	cosine	220.87	0.039	14.33	0.030	0.052
	left rear	uniform	cosine	153.08	0.055	20.31	0.037	0.082
		half-normal	cosine	150.37	0.066	19.36	0.045	0.096
	right rear	uniform	cosine	264.73	0.065	17.49	0.045	0.093
		half-normal	cosine	264.20	0.072	18.58	0.049	0.106

Table 4. Continued.

Date	Observer	Key function	Adjustment	AIC[a]	$\hat{D}$	CV(%)[b]	Log based CI_{95}[c]	
1998								
14 April	left front	uniform	cosine	240.12	0.055	16.14	0.040	0.077
		half-normal	cosine	238.24	0.056	15.63	0.041	0.077
	left rear	uniform	cosine	171.22	0.058	16.88	0.041	0.081
		half-normal	cosine	169.28	0.069	17.68	0.048	0.098
	right rear	uniform	cosine	84.48	0.035	23.08	0.022	0.055
		half-normal	cosine	80.98	0.043	22.27	0.027	0.067
22 April	left front	uniform	cosine	208.90	0.055	16.12	0.040	0.076
		half-normal	cosine	206.88	0.049	22.93	0.031	0.076
	left rear	uniform	cosine	94.68	0.061	22.63	0.039	0.096
		half-normal	cosine	91.18	0.061	19.38	0.041	0.091
	right rear	uniform	cosine	80.99	0.032	21.50	0.021	0.050
		half-normal	cosine	78.66	0.035	20.52	0.023	0.054

[a] Akaike Information Criterion.
[b] Coefficient of variation.
[c] Confidence interval.

Table 5. Number of wood duck clusters (groups) and mean cluster size observed during aerial surveys at the Princeton study site, spring 1997. Cluster sizes with different letters within surveys and observers were significantly different, Tukey/Kramer post hoc multiple comparisons ($P \leq 0.05$).

Observer	Distance class	Number of clusters	Mean cluster size	SE
14 April				
Left front	1	12	2.17a	0.47
	2	8	2.00a	0.19
	3	0	0.00a	-
	4	1	2.00a	-
	5	0	0.00a	-
Left rear	1	12	1.75a	0.18
	2	4	1.50a	0.29
	3	2	2.00a	0.00
	4	0	0.00a	-
Right rear	1	7	2.57a	0.43
	2	6	3.33a	0.42
	3	2	6.00a	4.00
	4	2	2.00a	0.00
22 April				
Left front	1	8	1.50a	0.19
	2	3	1.67a	0.33
	3	2	2.00a	0.00
	4	4	1.75a	0.25
	5	5	2.20a	0.58
Left rear	1	7	1.71a	0.19
	2	2	2.00a	0.00
	3	3	1.67a	0.33
	4	5	2.20a	0.20
Right rear	1	7	2.14a	0.51
	2	5	1.60a	0.24
	3	1	1.00a	-
	4	2	2.00a	0.00

Table 6. Number of wood duck clusters (groups) and mean cluster size observed during aerial surveys at the Meredosia study site, spring 1997. Cluster sizes with different letters within surveys and observers were significantly different, Tukey/Kramer post hoc multiple comparisons ($P \leq 0.05$).

Observer	Distance class	Number of clusters	Mean cluster size	SE
14 April				
Left front	1	11	1.73a	0.14
	2	6	3.00a	1.41
	3	2	1.50a	0.50
	4	4	1.75a	0.25
	5	4	3.50a	2.17
Left rear	1	8	2.00a	0.73
	2	4	1.50a	0.29
	3	4	1.75a	0.25
	4	2	8.00a	7.00
Right rear	1	11	1.36a	0.28
	2	5	2.80a	0.92
	3	1	1.00a	-
	4	1	2.00a	-
22 April				
Left front	1	9	2.00a	0.29
	2	6	2.67a	0.88
	3	9	1.67a	0.17
	4	1	2.00a	-
	5	0	0.00a	-
Left rear	1	8	1.63a	0.18
	2	10	2.70a	0.58
	3	1	1.00a	-
	4	3	1.67a	0.33
Right rear	1	9	2.22a	0.28
	2	6	1.50a	0.22
	3	1	2.00a	-
	4	0	0.00a	-

Table 7. Number of wood duck clusters (groups) and mean cluster size observed during aerial surveys at the Sanganois study site, spring 1997. Cluster sizes with different letters within surveys and observers were significantly different, Tukey/Kramer post hoc multiple comparisons ($P \leq 0.05$).

Observer	Distance class	Number of clusters	Mean cluster size	SE
13 April				
Left front	1	42	2.19a	0.19
	2	28	1.71a	0.13
	3	7	2.00a	0.65
	4	3	2.00a	0.00
	5	7	2.29a	0.64
Left rear	1	26	1.96a	0.20
	2	18	2.17a	0.44
	3	11	1.45ab	0.16
	4	7	3.57ac	0.97
Right rear	1	34	2.06a	0.25
	2	15	2.07a	0.32
	3	7	2.14a	0.67
	4	3	2.00a	0.00
20-21 April				
Left front	1	24	1.92a	0.37
	2	25	2.08a	0.21
	3	8	2.25a	0.41
	4	10	1.60a	0.22
	5	6	1.83a	0.17
Left rear	1	34	2.00a	0.20
	2	8	2.25a	0.25
	3	9	1.56a	0.18
	4	8	1.88a	0.13
Right rear	1	38	1.58a	0.09
	2	29	1.86a	0.16
	3	16	1.63a	0.15
	4	9	1.89a	0.20

Table 8. Number of wood duck clusters (groups) and mean cluster size observed during aerial surveys at the Princeton study site, spring 1998. Cluster sizes with different letters within surveys and observers were significantly different, Tukey/Kramer post hoc multiple comparisons ($P \leq 0.05$).

Observer	Distance class	Number of clusters	Mean cluster size	SE
15 April				
Left front	1	10	1.70a	0.30
	2	16	1.56a	0.13
	3	4	1.75a	0.48
	4	4	1.75a	0.48
	5	1	2.00a	-
Left rear	1	15	1.60a	0.27
	2	5	1.80a	0.20
	3	4	1.50a	0.29
	4	3	2.33a	0.88
Right rear	1	10	1.50a	0.17
	2	4	1.50a	0.29
	3	3	1.67a	0.33
	4	0	0.00a	-
23 April				
Left front	1	6	1.50a	0.22
	2	6	1.83ab	0.17
	3	2	1.00a	0.00
	4	0	0.00ac	-
	5	0	0.00ac	-
Left rear	1	4	1.50a	0.29
	2	3	1.00a	0.00
	3	0	0.00a	-
	4	0	0.00a	-
Right rear	1	6	1.00a	0.00
	2	6	2.00b	0.00
	3	1	1.00a	-
	4	0	0.00c	-

Table 9. Number of wood duck clusters (groups) and mean cluster size observed during aerial surveys at the Meredosia study site, spring 1998. Cluster sizes with different letters within surveys and observers were significantly different, Tukey/Kramer post hoc multiple comparisons ($P \leq 0.05$).

Observer	Distance class	Number of clusters	Mean cluster size	SE
14 April				
Left front	1	4	1.75a	0.14
	2	8	1.63a	1.41
	3	3	2.00a	0.00
	4	0	0.00b	-
	5	0	0.00b	-
Left rear	1	8	1.50a	0.19
	2	4	2.00a	0.00
	3	1	2.00a	-
	4	1	2.00a	-
Right rear	1	3	1.67[c]	0.67
	2	0	0.00	-
	3	1	1.00	-
	4	0	0.00	-
22 April				
Left front	1	9	1.33a	0.17
	2	8	1.75a	0.16
	3	3	1.33a	0.33
	4	2	1.00a	0.00
	5	1	2.00a	-
Left rear	1	16	1.38a	0.15
	2	3	1.67a	0.33
	3	2	2.50a	1.50
	4	0	0.00a	-
Right rear	1	12	1.75a	0.18
	2	6	2.33a	0.33
	3	1	2.00a	-
	4	2	2.00a	0.00

[c] Post hoc multiple comparison test not possible because of small sample size.

Table 10. Number of wood duck clusters (groups) and mean cluster size observed during aerial surveys at the Sanganois study site, spring 1998. Cluster sizes with different letters within surveys and observers were significantly different, Tukey/Kramer post hoc multiple comparisons ($P \leq 0.05$).

Observer	Distance class	Number of clusters	Mean cluster size	SE
14 April				
Left front	1	34	1.88a	0.07
	2	26	1.73a	0.09
	3	16	1.81a	0.16
	4	6	1.83a	0.17
	5	3	1.67a	0.33
Left rear	1	39	1.74a	0.11
	2	18	1.83a	0.09
	3	9	1.44a	0.18
	4	5	1.40a	0.24
Right rear	1	24	1.58a	0.16
	2	12	1.67a	0.14
	3	4	1.75a	0.75
	4	0	0.00a	-
22 April				
Left front	1	19	1.26a	0.10
	2	38	1.84a	0.17
	3	10	2.40a	0.64
	4	5	2.00a	0.32
	5	2	2.00a	0.00
Left rear	1	33	1.91a	0.22
	2	10	2.00a	0.37
	3	4	1.75a	0.25
	4	1	1.00a	-
Right rear	1	19	1.84a	0.19
	2	11	2.00a	0.00
	3	4	2.25a	0.25
	4	1	2.00a	-

Table 11. Number of wood duck nests (% of boxes) and number of successful nests (% of nests) in artificial nest boxes at Sanganois Conservation Area in springs, 1996-1998.

Nest box type	n	Number of nests (%)	Number of nests hatched (%)
1996			
Plastic	55	5 (31.3)	4 (36.4)
Metal	37	10 (62.5)	6[a] (54.5)
Wooden	6	1 (6.3)	0 (0.0)
Total	98	16	11
1997			
Plastic	68	1 (14.3)	0 (0.0)
Metal	33	6 (85.7)	4 (100.0)
Wooden	6	0 (0.0)	0 (0.0)
Total	107	7	4
1998			
Plastic	78	2 (28.6)	2 (28.6)
Metal	30	5 (71.4)	5 (71.4)
Wooden	5	0 (0.0)	0 (0.0)
Total	113	7	7

[a] Does not include one hen still incubating on 27 June.

SUBMITTED BY:

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DATE: 20 November 1998