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W-121-R-6

WOOD DUCK POPULATION AND HABITAT INVESTIGATIONS

FINAL REPORT

Federal Aid Project W-121-R-6

Submitted by:

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Presented to:

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Study 2. Job 2.1

FINAL REPORT

STATE OF ILLINOIS

W-121-R-6

Project Period: 1 July 1995 through 30 June 1998

Project: Wood Duck Population and Habitat Investigations

Prepared by Robert J. Gates
Cooperative Wildlife Research Laboratory
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NEED: Research on population-habitat relationships of wood ducks in southern Illinois began in FY 93 with Illinois Federal Aid Project W-121-R. Study No. 1 (Population Monitoring and Habitat Relationships of Wood Ducks in Southern Illinois) focused on; 1) obtaining indices of breeding population densities, 2) acquiring basic data on reproductive performance, and 3) determining movement and habitat use patterns of breeding hens in the Mississippi River floodplain. Data collected in the first 2 segments of W-121-R indicated that nesting effort, reproductive performance, and possibly hen survival were influenced by habitat conditions associated with variable water levels. The study also documented that about >60% of wood ducks produced on the study area originated from natural tree cavities located in upland forest habitats. This distribution of nesting effort was hypothesized to result from high rates of hen and/or nest predation in bottomland forests. Alternative hypotheses are that; 1) hens nest above the floodplain to avoid dense aggregation that leads to nest interference (Semel and Sherman 1993), or 2) that availability and quality of suitable tree cavities are greater in upland than in lowland forests. Study No. 2 (Factors Affecting Reproduction and Survival of Wood Duck Hens in Forested Landscapes) will continue and expand upon work that began with Study No. 1. In order to test hypotheses regarding distribution of breeding effort and productivity among different forested landscapes, additional data are needed to; 1) compare reproductive success of upland and lowland nesting hens, 2) determine relative abundance of potential nest predators, and 3) to evaluate differences in availability and quality of nest sites. Monitoring of breeding population densities and reproductive performance must continue in order to develop a longerterm data base. A second study of factors affecting survival and reproduction on would provide a more complete understanding of factors that affect reproduction and survival of wood duck hens in southern Illinois. Particularly important are habitat and other factors such as predation that affect nesting productivity and survival of breeding hens.

OBJECTIVES:

1. Identify factors affecting breeding productivity and survival of hen wood ducks in different forested landscapes.
2. Relate variation in breeding population indices, reproductive performance, and hen survival to habitat conditions and landscape characteristics.
3. Provide recommendations for improved management and conservation of forested wetland habitats in the Mississippi River floodplain.

EXECUTIVE SUMMARY

Study No. 1 titled "*Population Monitoring and Habitat Relationships of Wood Ducks in Southern Illinois*" was conducted during 1993-1995 (Gates 1995) and focused primarily on indices of abundance, reproduction, movements, and distribution of breeding wood ducks (*Aix sponsa*) in southern Illinois. Three major findings from Study No. 1 formed the basis for Study No. 2 which was conducted during 1996-1998. First, radiomarked wood duck hens nested primarily (82% of nests) in upland forests at distances up to 3.2 km from suitable brood habitat within the Mississippi River floodplain (Ryan et al. 1998). Second, wood duck hens nested in more secure tree cavities (higher entrances with smaller openings) in floodplain forests compared to upland forests. Nest success did not differ between forest types (Ryan et al. 1998), but sample sizes were too small for a conclusive statistical comparison. Third, only 56% of resident radiomarked hens nested each year and nesting effort seemed to vary with the timing and magnitude of spring flooding. Furthermore, there was very little evidence of renesting, and annual nesting effort seemed to vary inversely with intraspecific nest parasitism rates (Ryan et al.

1998). Study No. 2 was initiated to test 2 general hypotheses developed to explain the patterns of nest distribution and nesting effort observed during Study No. 1.

Wood ducks are typically thought to nest mostly in tree cavities or nest boxes located close to water, primarily within lowland habitats. Earlier studies documented wood ducks nesting in upland forests, but the importance and ecological implications of upland forests as a source of wood duck production was unknown before Study No. 1. Ryan et al. (1998) hypothesized that the high proportion of hens that nested in upland forest was due to limited availability of suitable tree cavities that were sufficiently secure from predation to sustain a tradition of nesting in floodplain forest. Alternatively, wood duck hens may simply disperse their nests across all suitable habitats and nest distribution may reflect the relative area of floodplain and upland forests available that are equally suitable nesting habitats.

Prior to Study No. 1, it was also widely believed that all wood duck hens attempt to nest each year, and those hens that parasitize nests eventually incubate their own clutches (Bellrose and Holm 1994). The second general hypothesis that Study No. 2 was designed to test is that dry conditions or sudden changes in water levels during prenesting and egg-laying may affect the ability of breeding hens to secure nutritional resources (i.e., forest invertebrates) needed to produce and incubate their own clutches. Consequently, lower nesting effort and higher nest parasitism rates should occur during dry years or when large sudden changes in water levels occur before most hens begin incubating, compared to wet years and when water levels change more gradually throughout the nesting season. Ryan et al. (1998) proposed that intraspecific nest parasitism is a normal feature of wood duck nesting biology in natural tree cavities that is associated with nesting effort. Thus, intraspecific nest parasitism may be a breeding strategy that affords reproductive opportunity for some wood duck hens that would otherwise not nest when habitat conditions are not conducive to successful breeding. Alternatively, capture, handling, and radiomarking of wood duck hens may have inhibited or interfered with nesting activity.

Furthermore, some nesting attempts may have been missed if they failed early in the nesting cycle.

This final project report is comprised of 2 Master's theses (Selle 1998, Zwicker 1999) and one doctoral dissertation (Kawula 1998) that are appended to the report. The Master's theses include summaries, analyses, and interpretations of data collected during Study Nos. 1 and 2. The doctoral dissertation reports data collected during Study No. 1, but analyses and writing were completed during Study No. 2. The dissertation also bears directly on the nesting effort hypothesis we tested during Study No. 2. The narrative under Job 2 presents analyses of nesting and other population data that were collected in the final project segment of Study No. 2, but do not appear in any of the aforementioned theses or dissertation. These data and analyses form the basis for a second doctoral dissertation that is still in progress. The following segment of this Executive Summary describes the work that was accomplished under Study No. 2 and where the results of such work are reported in the theses and dissertation appended to this report.

As in 1993-1995, we continued during Study No. 2 to radiomark wood duck hens, follow radiomarked hens to nest sites, and climb nest trees used by radiomarked hens to determine clutch sizes and nest success. We also continued to inspect a cumulative sample of known nest cavities used in preceding years, followed radiomarked broods to determine distances traveled after hatching, and conducted brood surveys to estimate juvenile mortality through fledging. We discontinued work at Oakwood Bottoms Greentree Reservoir (GTR), but we continued to use LaRue-Pine Hills Research Natural Area (RNA) as a secondary study site, while Union County Conservation Area (CA) remained the primary study site.

Visual and auditory detections of wood ducks during road-side survey routes conducted at Oakwood Bottoms GTR, LaRue-Pine Hills RNA, and Union County CA mostly reflected seasonal and annual variation in the distribution of surface water and migration and nesting chronologies during 1993-1996. We found no strong evidence of relationships between numbers of wood ducks detected and annual variation in proportions of hens that nested or nesting productivity. Consequently, we discontinued the road-side surveys after spring 1996. We instead focused on annual variation in proportions of radiomarked hens that nested, emigrated, or remained resident on the study area without nesting as the primary index of breeding populations on our study areas.

Three major components were added to the investigation during Study No. 2. We sampled 300 400-m^2 plots randomly located in floodplain and upland forests to estimate densities of tree cavities suitable for nesting wood ducks during 1996-1998. These plots were used to compare densities of suitable wood duck nest sites between floodplain and upland forests at Union County and LaRue-Pine Hills RNA. Physical characteristics of suitable nest cavities found during random plot surveys were compared with those of known nest sites to determine whether wood ducks used cavities randomly with respect to their availability in floodplain and upland forests. Nest site selection also was investigated by comparing the distribution of nests among different forest ages, stand types, and tree species, and by comparing forest composition and topography between areas surrounding nests and random sample points. The thesis titled "*Availability and use of tree cavities by wood ducks nesting in upland and floodplain forests of southern Illinois*," by Edward H. Zwicker reports the methods, results, analyses, and comparisons of forest composition and nest site availability between upland and floodplain forests at Union County and LaRue-Pine Hills RNA during 1997-1998.

Random plot surveys provided suitable nest cavities for a simulated nest study that was the second new component implemented during Study No. 2. We placed 4 call duck (*Anas platyrhynchos*) or domestic chicken eggs in suitable nest cavities in upland and floodplain forests for 2-week exposure periods. We determined survival of each nest after the 2-week exposure period for 28 simulated nests distributed nearly evenly between upland and floodplain forests at Union County during spring 1997. We determined survival of 60 simulated nests distributed equally among upland and floodplain forests at both Union County and LaRue-Pine Hills RNA during 1998. Results were used to compare potential predation rates between study sites, forest types, and among tree cavities with different physical characteristics. Comparisons of survival rates of simulated nests and nest success of radiomarked hens provided 2 sources of data with which to determine the role of predation as a factor affecting nest distribution and nest site selection by breeding wood ducks. We also developed deterministic recruitment models for wood ducks that nested in upland and floodplain habitats. These recruitment models were based on adult and juvenile survival rates from this and other studies, and from estimates of nesting productivity obtained solely from this study. Results of the simulated nest study, nesting productivity, adult survival during the breeding season, and juvenile survival through fledging are reported in the narrative included under Job 2.1 of this report. A doctoral dissertation authored by R. G. Anderson is in progress, and will be based on the data reported under Job 2.1. Mr. Anderson's dissertation will provide a general synthesis of nesting productivity and population data that will more completely answer hypotheses regarding the distribution of wood duck nests between upland and floodplain forests in southern Illinois. Mr. Anderson's dissertation is not expected before 1 year after the end date of Study No. 2.

Daily movements, home ranges, and habitat use patterns of wood duck hens were intensively monitored during Study No. 1. A dissertation titled "*Breeding season movements and resource selection of female wood ducks in southern Illinois*" authored by R. J. Kawula based on these data was completed during Study No. 2 and is appended to this report. Mr. Kawula's dissertation compares home range sizes, habitat use patterns, and movements between: (1) nesting and non-nesting hens, (2) years (1994-1995) with different habitat conditions, and (3) hens that nested in upland and floodplain forests. Seasonal range fidelity to wetland habitat patches and microhabitat characteristics surrounding locations of radiomarked hens under varying habitat conditions also are reported in Mr. Kawula's dissertation. Results and conclusions presented therein are relevant to understanding how breeding hens respond to seasonal changes in water levels, and possible effects of habitat conditions on nesting effort and breeding productivity.

We did not intensively monitor or analyze home range and habitat use patterns during Study No. 2 as we did during Study No. 1. Nevertheless, we continued to determine nesting effort and productivity throughout 1996-1998. This enabled us to examine annual variation in adult survival, nesting effort, nesting chronology, clutch sizes, nest success, and juvenile survival over 5 breeding seasons (1994-1998). A thesis titled "*Annual variation in breeding productivity of natural cavity nesting wood ducks in southern Illinois*" authored by Andrew T. Selle presents data collected during 1994-1997 and is appended to this report. We measured seasonal changes in water depths in 20 selected forested wetland feeding sites used by breeding wood ducks during 1996 and 1997. A predictive model was developed to relate water depths in forested wetlands to local precipitation and stage levels of the Mississippi and Big Muddy rivers near Union County and LaRue-Pine Hills RNA. The predictive models were used to estimate seasonal changes in water levels in forested wetlands during 1994 and 1995 when direct measurements were not recorded. With such estimates, we were able to investigate relationships between the timing and magnitude of spring flood pulses and annual differences in nesting effort and nest parasitism rates. Mr. Selle's research project was concluded after the 1997 breeding season, but we continued to collect nesting data (reported under Job 2.1 of this report) during 1998. We will combine data from 1994-1998 in a manuscript submitted for publication in a peer-reviewed journal. The manuscript will address annual variation in nesting effort and nest parasitism rates in relation to differences in the timing and duration of spring flood pulses.

The data contained within the 2 M.S. theses and the Ph.D. dissertation appended to this report, in combination with the narrative under Job 2.1, constitute completed summaries and/or analyses of all data collected during Study No. 2, combined with relevant data that was collected under Study No. 1. Descriptions of how project objectives were addressed within the separate theses and dissertations appended to the report appear in the Introduction sections of Jobs 2.1 and 2.2. Specific management implications and recommendations appear in the theses and dissertation and also under Job 2.3.

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LITERATURE CITED

Bellrose, F. C., and D. J. Holm. 1994. Ecology and Management of the Wood Duck. Stackpole Books, Mechanicsburg, Pennsylvania, USA.

Gates, R. J. 1995. Wood duck population and habitat investigations. Final Report, Federal Aid Project W-121-R. Illinois Department of Natural Resources.

Kawula, R. J. 1998. Breeding season movements and resource selection of female wood ducks in southern Illinois. Dissertation, Southern Illinois University at Carbondale, Carbondale, Illinois, USA.

Ryan, D. C., R. J. Kawula, and R. J. Gates. 1998. Breeding biology of wood ducks using natural cavities in southern Illinois. Journal of Wildlife Management 62:112-123.

Selle, A. T. 1998. Annual variation in breeding productivity of natural cavity nesting wood ducks in southern Illinois. M.S. Thesis, Southern Illinois University at Carbondale, Carbondale, Illinois, USA.

Semel, B., and P. W. Sherman. 1993. Answering basic questions to address management needs: case studies of wood duck nest box programs. Transactions North American Wildlife Natural Resource Conference 58:537-550.

Zwicker, E. H. 1999. Availability and use of tree cavities by wood ducks nesting in upland and floodplain forests of southern Illinois. Draft M.S. Thesis, Southern Illinois University at Carbondale, Carbondale, Illinois, USA.

STUDY 2. FACTORS AFFECTING REPRODUCTION AND SURVIVAL OF WOOD DUCK HENS IN FORESTED LANDSCAPES

JOB 2.1. BREEDING PRODUCTIVITY AND HEN SURVIVAL

Objective: Identify factors affecting breeding productivity and survival of hen wood ducks in different forested landscapes.

INTRODUCTION

The objective under this job was met primarily by determining nesting effort, clutch sizes, nest success, and breeding season survival of radiomarked hens during 1994-1998. These data are reported by year, and across years (1994-1997) in the thesis authored by Mr. Andrew Selle that is appended to this report. Mr. Selle compared nesting effort, nest parasitism, and nest success rates among years with different habitat conditions. Comparisons of nesting effort, body masses, and breeding season survival also were made between adult and juvenile hens, and between nesting and non-nesting hens. Additional analyses were conducted to determine whether estimates of nesting effort were biased by capture, handling, and radiomarking hens. Updated comparisons that include data collected during 1998 appear in the narrative below.

This objective also was addressed through comparisons of nesting productivity and population recruitment based on deterministic population models that also are presented in the narrative that follows. We also determined the potential influence of nest predation on breeding productivity with results from the simulated nest study that is reported in the narrative presented under this job.

STUDY AREA

Study area boundaries were determined by daily and seasonal movements of radio-marked hens from capture sites at Union County CA, LaRue Swamp-Pine Hills RNA, and Oakwood Bottoms GTR. The general study area encompassed the Illinois portion of the Mississippi River floodplain from the Oakwood and Big Muddy River Bottoms in southwestern Jackson County, to Union County CA in southwestern Union County, IL. Study sites encompassed a diverse array of habitats including bottomland forest, cropland, and shallow emergent wetlands within Union County CA, and larger contiguous tracts of forested bottomland and swamps associated with LaRue Swamp and Oakwood/Big Muddy River bottoms (Gates 1995). Adjacent forested upland tracts in the Shawnee National Forest (SNF) east of the Mississippi River floodplain also were part of the general study area. Oakwood Bottoms GTR, LaRue-Pine Hills RNA, and Union County CA differed greatly with respect to type and spatial configuration of forested wetland and other habitats, and land management practices. LaRue Swamp was an area of contiguous swamp and forested bottomland that was essentially unmanaged. Oakwood Bottoms was a contiguous tract of forested wetland that was artificially flooded and de-watered by the U.S. Forest Service. Union County CA was a fragmented bottomland with interspersed cropland, forested wetland, and shallow lakes and ponds.

METHODS

This report summarizes data collected on wood duck hens captured and radiomarked during 1993-1998 in southern Illinois. Additional hens were captured but not radiomarked during the study. These hens were not included in analysis or discussion in this report.

Radio-telemetry

Wood duck hens (n = 244) were captured with floating bait- traps, floating Y-traps, swim-in traps, and rocket nests during springs 1993-1998. The hen capture period (first to last hen capture) varied annually but ranged from 25 February to 13 May (Table 1). Reproductive condition (laying or not laying) was determined by cloacal examination. Age was determined from shape and color intensity of the greater and middle secondary wing coverts (Harvey et al. 1989, Carney 1992), and by measuring the white patch posterior to the eye (Bellrose and Holm 1994). Adult (171) and juvenile (73) hens were fitted with 7.5-10.0 g necklace type radiotransmitters mounted on Herculite (Herculite Products, Inc.) fabric bibs. Birds also were marked with serially numbered No. 5 U.S. Fish and Wildlife Service aluminum leg bands.

Radiomarked hens were tracked throughout the breeding season or until transmitters expired (Table 1). Most birds were located daily or every other day during the nesting season to determine survival and nesting activity. Birds were located 2-3 times/week after early May when it appeared that most nesting activity had ceased. Resident hens were located by triangulation or homing to strongest signal (Mech 1983) with hand-held yagi antennas. Aerial searches were conducted when contact with radiomarked birds was lost. Birds not found after repeated aerial (>3) or ground searches were assumed to have emigrated from the study area or to have transmitters that failed. Visual contact was re-established when hens remained in the same location for >4 days. These birds were then flushed, tracked to nest trees, or their radios were recovered. Cause of death was determined by inspecting carcass remains, radio condition, and other field signs present at recovery sites. The tight fit of radio packages under breast and back feathers made it unlikely that radios were lost during the tracking period. Therefore, radios recovered without carcasses were assumed to indicate death of the hen.

Nesting Activity

Survival.—The Kaplan-Meier procedure (Pollock et al. 1989) was used to estimate weekly survival probabilities of radiomarked hens during the breeding season (25 February - 26 July). All years were pooled to meet sample size (>40, Pollock et al. 1989) requirements for good precision.

Productivity.—Wood duck nests were found by following radiomarked hens to nest sites, inspecting nest trees used in previous years, and discovered incidentally during other aspects of field work. Hereafter, these nests will be known as radiomarked, reclimb, and incidental nests, respectively.

Nesting effort was defined as the proportion of hens remaining on the study areas that nested during a year. Only radiomarked nests were used for calculating nesting effort. Nest success was calculated from all nests found during the study if the clutch was accessible to determine fate of the nest attempt. Clutch size calculations were made from all incubated nests and clutch size was determined by the number of eggs or egg membranes found. Nests were considered parasitized if there were > 14 eggs in the clutch. Egg hatchability was the percent of eggs hatching from successful clutches. Mean brood size at hatch was the average number of eggs that hatched in all initiated nests.

Brood Surveys.—Brood surveys were conducted opportunistically based on daily water conditions. Broods were observed during evening (commencing at 1900) or morning (commencing before 0700) at Union County CA, LaRue Swamp RNA, Oakwood Bottoms GTR, and from incidental sightings of broods concurrent with other field activities. Minimum brood size, duckling age-class (Gollop and Marshall 1954), and habitats where broods were observed were recorded. The wood duck hen-brood bond is not as strong as in most waterfowl and often dissolves < 5 weeks after hatching (McGilvrey 1969, Beard 1964, Ball et al. 1975). Dissolution of family units could cause misinterpretations of brood sizes because of brood splitting or amalgamation when broods reach age-class IIB. Therefore, comparisons of brood sizes among age-classes will be conducted only on broods younger than class IIB.

Simulated Nests

Simulated nest trials were conducted from March to June 1997 and 1998. Union County was used during 1997 and 1998 but LaRue-Pine Hills RNA was used only during 1998. Ninety nests were placed in randomly located natural cavities in each of upland (n = 45) and floodplain (n = 45) habitats at Union County (n = 60) and LaRue-Pine Hills RNA (n = 30). Three nests, consisting of 4 domestic call duck or Bantam chicken eggs, were placed weekly at each study site over the 10 week trial period. Eggs were placed in cavities with no attempt to create a nest bowl. All simulated nests were then exposed for 2-weeks and then checked for signs of disturbance. Two floodplain nests were censored in 1997 because of improper exposure period.

Population Model

A deterministic wood duck population model was created based on Cowardin and Johnson's (1979) mallard population model. The base model,

$$C_h = S_a + R_h S_{jn} , \tag{1}$$

estimates the proportional change in the population within each habitat (C_h). The proportional population change in a habitat was calculated from adult hen survival (S_a), recruitment of juvenile females to the fall population within a habitat (R_h), and survival of the juvenile females (S_{jn}) during the nonbreeding season (from fall to the following spring). The value for adult hen survival was a published annual survival estimate (Kelly 1997). Recruitment within a habitat was estimated as,

$$R_h = ½ C_h E_h N_h F . \tag{2}$$

Where recruitment from a habitat is half (only females are included) the product of clutch size (C_h), egg hatchability (E_h), nest success (N_h), and fledgling survival (F). Estimates of clutch size, egg hatchability, and nest success were from this study and were calculated for upland and floodplain habitats. Fledgling survival estimates could not be made for each habitat and therefore this estimate was assumed similar between habitats. The estimate of S_{jn} were derived from juvenile annual survival (S_j) which was represented as,

$$S_j = S_b S_h S_w , \tag{3}$$

where S_j was a product of breeding season survival (S_b), hunting season survival (S_j), and overwinter survival (S_w). Juvenile nonbreeding season survival (S_{jn} from equation 1) is equal to survival estimates during the nonbreeding period ($S_h S_w$ from equation 3) and can be substituted into equation 3 so that,

$$S_{jn} = S_j / S_b . \tag{4}$$

The estimate for S_{jn} was substituted into equation 1 and C_h was estimated as,

$$C_h = S_a + R_h S_j / S_b . \tag{5}$$

The value for S_j was a published estimate (Kelly 1997), whereas, S_b was estimated from hens radiomarked during this study.

Equation 5 was used to estimate C for each habitat. The interpretation of C is that populations are considered stable when $C = 1$, increasing when $C > 1$, and decreasing when $C < 1$.

DATA ANALYSIS

Data were combined between Union County and LaRue-Pine Hills for analyses unless otherwise noted. Most statistical analyses were conducted using S-Plus 4.0 (MathSoft 1997) and Statistix (Analytical Software 1996). Differences were considered significant at $P < 0.05$.

Non-normally distributed nesting data such as, clutch sizes, brood size at hatch, brood sizes, and egg success were compared using Kruskall-Wallis tests (Sokal and Rohlf 1995). Egg hatchability and nest success were compared between upland and floodplain habitats and among years with *G*-tests of independence (Sokal and Rohlf 1995). Mean brood sizes were compared among age classes (IA, IB, IC, and IIA) with the Kruskal-Wallis tests and the mean ranks option.

G-tests of independence were used to compare age composition and proportions of nesting, nonnesting, and parasitizing hens within and among years. *G*-goodness of fit tests (Sokal and Rohlf 1995) were used to compare age ratios between all radiomarked hens and resident hens. Data from 1993 was censored from analysis of nesting effort among years because of low sample size. Log-rank tests (Pollock et al. 1989) were used for survival comparison between adult and juvenile hens and nesting and nonnesting hens.

Logistic regression was used to predict survival of simulated nests placed in upland and floodplain habitats. Predictive logistic models were created for both upland and floodplain forests. Model parameters correlated (Spearman's rank correlation) $r > |0.15|$ were included in logistic regression models. The most parsimonious model was chosen using Akaike's Information Criterion (AIC)(Akaike 1974). The AIC selects models based on the trade-off between explained variance and number of parameters being estimated. Model selection was done using the "drop 1" procedure in S-plus 4.0. The AIC for the full model was first calculated, then AIC values were calculated for all other possible models after dropping one variable. If the

AIC for a reduced model was lower than the preceding model, then the reduced model was considered more parsimonious. This procedure continued until removal of variables from the model did not produce a reduced model AIC lower than the previous model.

RESULTS

Nesting Effort and Survival

Two-hundred-forty-four hens were radiomarked at Union County CA (203), LaRue Swamp RNA (19), and Oakwood Bottoms GTR (22) during 1993-1998 (Table 2). Union County and LaRue-Pine Hills RNA were the primary study areas. Because no hens nested in Oakwood Bottoms GTR during 1993-1996 the area was not used in the 1997 and 1998 study seasons. Seventy percent of captured hens were adults and 30% were juveniles. Proportions of adult and juvenile hens radiomarked each year were similar ($G = 2.22$, df = 4, $P > 0.05$) during 1994-1998 (Table 3).

During the 6 years of the study, 179 (73%) of the 244 hens that were radiomarked remained on the study areas (hereafter resident hens) and were included in analysis of nesting effort. Age ratios of resident hens were similar ($G = 6.34$, df = 4, $P > 0.05$) among all years (Table 4). Age ratios (adult:juvenile) were similar ($G = 0.006$, df = 1, $P > 0.05$) between all radiomarked hens (2.51:1) and resident radiomarked hens (2.56:1). Seventy-seven of 104 (74%) nests of radiomarked hens were initiated by adults and 27 (26%) by juveniles. Proportions of adults and juveniles that initiated nests were similar ($G = 6.34$, df = 4, $P > 0.05$) among years (Table 5). Fifty-eight percent of resident hens nested during the 6 year study. No difference in nesting effort ($G = 5.01$, df = 4, $P > 0.05$) was detected among years (Table 6). More radiomarked hens nested in the upland forests (66%) than in the floodplain forests (34%). Variation in nest distribution between habitats occurred among years but overall there were no differences ($G = 5.99$, df = 5, $P > 0.05$) in nest distribution among years (Table 7).

Thirty-two (15%) of 208 radiomarked hens used for the survival analyses died during the 6 seasons of tracking. Seven (12%) of 60 juveniles and 25 (17%) of 148 adults died during the study. Kaplan-Meier survival estimates were similar (X^2 = 0.739, df = 1, P > 0.05) between adult (0.7834) and juvenile (0.8364) hens (Figure 1). No differences (X^2 = 0.481, df = 1, P > 0.05) were found between survival estimates of nesting hens (0.7701) and nonnesting (0.8235) hens (Figure 1). Therefore, the survival estimate (0.7984) which includes all radiomarked hens, regardless of nesting status or age, probably best represents survival of the southern Illinois wood duck population during the breeding season.

Nesting Productivity

One-hundred-sixty-three wood duck nesting attempts were located during 1993-1998 in southern Illinois. Most (64%) nesting attempts were located by following radiomarked hens to nest sites but 48 (29%) additional nests were discovered by reclimbing previously used trees and 11 (7%) nests were found incidentally during other phases of the study.

Mean (SE) incubated clutch size of all nests was 12.2 eggs (0.4, n = 67). Normal clutches (≤ 14 eggs) had mean size of 10.9 eggs (0.3, n = 55) while parasitized clutches (≥ 15 eggs) were larger (X^2 = 29.73, df = 1, P < 0.001) with a mean of 18.2 eggs (0.8, n = 12). Clutch sizes of normal nests differed (X^2 = 9.925, df = 4, P = 0.042) between years with clutches in 1997 being larger (Z = 2.81, df = 4, P < 0.05) and clutches in 1996 being smaller than other years (Table 8).

No differences (G = 1.876, P > 0.05) in nest success (49% vs. 61%) were detected between reclimbed nests and radiomarked nests (Table 9). Similarly, nest success was not different between habitats for either reclimb nests (G = 2.01, P > 0.05) or nests of radiomarked hens (G = 0.4652, P > 0.05). Combining radiomarked, reclimb, and incidental nests, there was no difference (G = 2.73, P > 0.05) between floodplain (49%) and upland nest success (63%).

Mean incubated clutch size of normal nests was similar (X^2 = 0.095, P = 0.758) between Union County (10.8 ± 0.3, n = 48) and LaRue-Pine Hills RNA (11.0 ± 0.6, n = 6). With study areas pooled, no differences in incubated clutch sizes were found (X^2 = 0.033, P = 0.857) between upland (11.0 ± 0.3, n = 36) and floodplain (10.6 ± 0.6, n = 19) forests. Successful nests had similar egg hatch rates (G = 2.16, P > 0.05) in floodplain (93%, n = 13) and upland (88%, n

= 35) habitats. Egg hatch rates were similar ($G = 0.05$, $P > 0.05$) between habitats for normal nests. However, parasitized nests in the floodplain (93%, $n = 3$) had higher ($G = 6.67$, $P < 0.05$) egg hatch rates than parasitized nests in the upland (78%, $n = 6$). Mean brood size at hatch also did not differ for normal nests ($X^2 = 1.44$, $P = 0.229$) between upland (8.6 ± 0.7, $n = 34$) and floodplain nests (5.4 ± 1.3, $n = 19$).

No differences were detected in clutch size ($X^2 = 2.94$, $P = 0.086$) between reclimb nests or nests located by following radiomarked hens. However, there were differences ($X^2 = 4.40$, $P = 0.036$) in mean brood size at hatch between radiomarked (7.4 ± 0.9, $n = 43$) and reclimb (10.3 ± 1.2, $n = 19$) nests. In the upland forests, clutch size was similar ($X^2 = 0.304$, $P = 0.581$) between radiomarked and reclimb nests but mean brood at hatch differed ($X^2 = 6.14$, $P = 0.013$) between radiomarked (7.4 ± 1.0, $n = 27$) and reclimb (12.0 ± 0.9, $n = 13$) nests. In the floodplain forests there were differences ($X^2 = 4.03$, $P = 0.045$) in clutch size between radiomarked (11.4 ± 1.0, $n = 16$) and reclimb (14.0 ± 0.9, $n = 6$) nests but not in mean brood at hatch ($X^2 = 0.036$, $P = 0.848$).

Nest Occupancy

During the 5 (1994-1998) years of reclimb nest inspections, 81 nest sites were identified as potentially suitable for reclimb effort. Sixty-three of these 81 trees were located and safe to climb in years subsequent to initial nest cavity discovery. Nests were discovered in 52 (35%) of 147 reclimb inspections. No differences were found in occupancy rates of reclimbed nest trees between upland (33%) and floodplain (40%) habitats ($G = 0.70$, $P > 0.05$).

Brood Survival

Four-hundred-seventy-two broods were observed at Union County CA, LaRue Swamp RNA, and Oakwood Bottoms GTR during 1993-1998. Brood class size was similar ($X^2 < 10.76$, $P > 0.056$) among years (Table 10). After removing broods older than class IIB, brood size differed ($X^2 = 13.57$, $P = 0.004$) among age-classes.

Simulated Nests

Forty-three (49%) of 88 simulated nests were depredated during the 2 year study (Table 11). More floodplain nests (65%, $n = 43$) were depredated than upland nests (33%, $n = 45$)($G = 8.9$, $P < 0.05$). There were no differences ($X^2 < 1.14$, $P > 0.297$) in cavity entrance heights, depths, or entrance areas of artificial nest cavities between upland and floodplain habitats (Table 12). However, mean distance from simulated nests to habitat edge was greater ($X^2 = 47.61$, $P < 0.001$) in the upland forest than in the floodplain forest.

For the upland simulated nests, 3 variables (date of nest placement, distance to habitat edge, and study area) were included in the model selection procedures. The full 3-variable model was most parsimonious. The predictive equation for simulated nest fate in the upland forest was:

$$Pr[Survival_U] = \frac{\exp[-4.066+0.002(distance)+0.024(date)+1.310(study)]}{1+\exp[-4.066+0.002(distance)+0.024(date)+1.310(study)]} \quad (6)$$

By creating probability functions for each study site the positive effect of date of nest placement and distance from habitat edge (0-600 m) on survival of upland simulated nests can be observed at both Union County (Figure 2) and LaRue-Pine Hills RNA (Figure 3). Simulated nests placed in the Union County upland forest were about 20% more likely to survive (73% vs. 53%) than nests placed in the LaRue-Pine Hills RNA upland forests. The effect of this increase in survival is apparent by comparing the predictive model outputs for both areas.

Four variables (date of nest placement, study area, cavity depth, and cavity height above ground) were correlated with simulated nest fate and included in the predictive models of simulated nest fate in the floodplain forests. The most parsimonious floodplain model was the 3-variable model:

$$Pr[Survival_F] = \frac{\exp[-4.427-1.457(study)+0.029(date)+0.1154(height)]}{1+\exp[-4.427-1.457(study)+0.029(date)+0.1154(height)]} \quad (7)$$

The floodplain model was similar to the upland model except that cavity height above ground replaced distance from simulated nest to habitat edge in the predictive equation. Using equation 7, probability functions were created for simulated nests in the floodplain forests at LaRue-Pine Hills RNA (Figure 4) and Union County (Figure 5). Similar to the upland model the positive relationship between date of nest placement and nest survival can be recognized at both LaRue-Pine Hills RNA and Union County. Cavity height above ground (5-20 m) also shows a positive relationships with probability of survival in both areas. Comparing the 2 study areas, poor survival (25% vs. 53%) of simulated nests at Union County lowers the predicted survival estimates below those for LaRue-Pine Hills RNA.

Population Model

Estimates of adult annual survival (0.5112), annual juvenile survival (0.4179), and fledgling survival (0.4225) were used in both the upland and floodplain model for the proportional change in the population (C_h). Using mean values for clutch size (12.27), egg hatchability (0.8558), and nest success (0.625) estimated from upland nesting hens, C_U was estimated to be 1.236. Similarly, using clutch size (11.96), egg hatchability (0.9281), and nest success (0.4225) estimates for the floodplain nesting hens, the estimate of C_F was 1.114.

DISCUSSION

Breeding Productivity

Most of our radiomarked hens nested in upland forest, many at considerable distances from floodplain forests that are generally considered to be the preferred nesting habitat for wood ducks. Although clutch sizes, egg hatchability, nest success, and brood size at hatch varied among breeding seasons, we found no differences between floodplain and upland habitats. Long brood movements after hatching should reduce fitness of upland nesting hens if overland movement increases early brood mortality. We were unable to directly compare juvenile survival to fledging of brood hatched from upland versus floodplain nests. However, total brood losses through 5 weeks after hatching was similar between upland- and floodplain-hatched broods with years combined. Thus, we found no apparent fitness cost associated with nesting in upland forest.

Simulated Nests

The simulated nest study demonstrated that in the absence of active nest site selection by wood ducks, nest predation rates were higher in floodplain than in upland forest habitats. Survival probabilities of simulated nests placed in upland and floodplain forests were related to date of nest placement and study area. Survival probability increased substantially between early and late stages of the nesting season at both study sites and forest types. Visual obstruction of cavities caused by leaf emergence or the appearance of alternate prey sources may have changed the behavior of nest predators. Survival probabilities of simulated nests were higher within the contiguous floodplain forest of LaRue-Pine Hills, compared to the smaller isolated floodplain forest tracts at Union County. Survival probabilities of simulated nests placed in floodplain tree cavities increased with cavity height above ground, while survival probabilities of simulated nests in upland tree cavities increased with distance from the floodplain. These findings point directly toward nest predation being a predominant factor that influenced nest distribution on our study areas.

Zwicker's (1999) finding that wood ducks nested in tree cavities that were higher above ground and with smaller openings than were available in floodplain forest corroborated the conclusion that differences in predation pressure between floodplain and upland habitats affected nest distribution. By nesting in more secure tree cavities, floodplain-nesting hens attained similar rates of nest success compared to upland-nesting hens that were non-selective in their use of tree cavities. We believe that wood duck hens enhanced their reproductive fitness by seeking upland nest sites that were distant from floodplain forest where potential predation rates were high. Those hens that nested successfully in the floodplain did so by selecting more physically secure tree cavities that allowed sufficiently high rates of nest success to maintain a tradition of nesting in floodplain forest.

Recruitment

Zwicker (1999) determined that relative densities of nests were higher in floodplain than in upland forest habitats. This might suggest that floodplain habitats are more suitable nesting habitats but the high proportion of upland nests resulted from limited availability of forested wetlands. However, fitness measures (e.g., recruitment) are often better measures of habitat quality than relative abundance or population densities of terrestrial vertebrates (Van Horne 1983). Using simple deterministic population recruitment models, we determined that upland and floodplain forests were nearly equally suitable as nesting habitats for breeding wood ducks. Recruitment of juvenile hens to breeding populations in spring must offset annual mortality if upland and floodplain forests are not population sinks for breeding wood ducks. We determined that nesting productivity and juvenile survival to fledging were sufficiently high for recruitment from both upland and floodplain nests to offset annual mortality of adult hens.

We conclude that wood ducks maintained a tradition of nesting in floodplain forests by selecting more physically secure nest sites, despite higher potential predation rates, compared to upland habitats. However, this conclusion assumes that newly recruited hens all home to natal or previously used breeding sites (i.e., Union County, LaRue-Pine Hills), nesting habitats (i.e forest vs. upland forests) and, more precisely to similar types of tree cavities (i.e., high above ground and with small entrances in floodplain forest) to those where they were hatched. Relatively low occupancy rates of known nest cavities, and observations of a few individual hens that we radiomarked in multiple years suggests that wood ducks did not home precisely to specific nest trees or cavities.

LITERATURE CITED

Akaike, H. 1974. A new look at the statistical model identification. IEEE Transactions on Automatic Control 19:716-723.

Analytical Software. 1996. Statistix for Windows user's manual. Analytical Software, Tallahassee, Florida, USA.

Ball, I. J., Jr., D. S. Gilmer, L. M. Coward in, and J. H. Riechman. 1975. Survival of wood duck and mallard broods in north-central Minnesota. Journal Wildlife Management 39:776-780.

Beard, E. B. 1964. Duck brood behavior at the Seney National Wildlife Refuge. Journal Wildlife Management 17:492-521.

Bellrose, F. C., and D. J. Holm. 1994. Ecology and management of the wood duck. Stackpole Books, Mechanicsburg, Pennsylvania, USA.

Carney, S. M. 1992. Species, age, and sex identification of ducks using wing plumage. U.S. Department of Interior, Fish and Wildlife Service Washington, D.C., USA.

Cowardin, L. M., and D. H. Johnson. 1979. Mathematics and mallard management. Journal Wildlife Management 43:18-35.

Gates, R. J. 1995. Wood duck population and habitat investigations study no.1: population monitoring and habitat relationships of wood ducks in southern Illinois. Final Report, Project W-121-R. Illinois Department Conservation.

Gollop, J. B., and W. H. Marshall. 1954. A guide for aging duck broods in the field. Mississippi Flyway Council Technical Section.

Harvey, W. F., IV, G. R. Hepp, and R. A. Kennamer. 1989. Body mass dynamics of wood ducks during incubation: individual variation. Canadian Journal Zoology 67:570-574.

Kelly, J. R., Jr. 1997. Wood duck population monitoring initiative: final report. Atlantic Flyway Council, Mississippi Flyway Council, and U.S. Fish and Wildlife Service. Administrative Report, Laurel, Maryland, USA.

MathSoft. 1997. S-PLUS 4 Guide to Statistics. Data Analysis Products Division. MathSoft, Seattle, Washington, USA.

Mech, L. D. 1983. Handbook of animal radio-tracking. University Minnesota Press, Minneapolis, Minnesota, USA.

McGilvery, F. B. 1969. Survival in wood duck broods. Journal Wildlife Management 33:73-76.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. Journal Wildlife Management 53:7-15.

Sokal, R. R. and F. J. Rohlf. 1995. Biometry. 3rd ed. W. Freeman and Co., San Francisco, California, USA.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. Journal Wildlife Management 47:893-901.

Zwicker, E. H. 1999. Availability and use of tree cavities by wood ducks nesting in upland and floodplain forests of southern Illinois. Draft M.S. Thesis, Southern Illinois University at Carbondale, Carbondale, Illinois, USA.

Table 1. Annual capture and telemetry periods (day of year / Gregorian) for wood ducks in southern Illinois during 1993-1996.

Year	First Capture	Last Capture	Final Location
1993	94 / 4 April	132 / 13 May	184 / 3 July
1994	68 / 9 March	129 / 9 May	186 / 5 July
1995	79 / 20 March	125 / 5 May	204 / 23 July
1996	70 / 11 March	132 / 12 May	196 / 15 July
1997	56 / 25 February	118 / 28 April	144 / 24 May
1998	77 / 18 March	119 / 29 April	203 / 22 July

Table 2. Distribution among Union County Conservation Area (CA), LaRue-Pine Hills Research Natural Area (RNA), Oakwood Bottoms Greentree Reservoir (GTR) of wood duck hens captured and radiomarked in southern Illinois during 1993-1998.

Year	Union County CA	LaRue-Pine Hills RNA	Oakwood Bottoms GTR	Total
1993	8	0	0	8
1994	29	4	9	42
1995	41	4	7	52
1996	35	4	6	45
1997	45	6	N/A	51
1998	45	1	N/A	46
Total	203	19	22	244

Table 3. Ages of wood duck hens captured and radiomarked in southern Illinois during 1993-1998.

Year	Adult	Juvenile	Total
1993	8	0	8
1994	30	12	42
1995	41	11	52
1996	29	16	45
1997	35	16	51
1998	28	18	46
Total	171	73	244

Table 4. Ages of radiomarked wood duck hens remaining during the nesting seasons in southern Illinois during 1993-1998.

Year	Adult	Juvenile	Total
1993	8	0	8
1994	18	7	25
1995	32	8	40
1996	23	10	33
1997	24	9	33
1998	23	17	40
Total	128	51	179

Table 5. Ages of radiomarked wood duck hens nesting in southern Illinois during 1993-1998.

Year	Adult	Juvenile	Total
1993	8	0	8
1994	6	6	12
1995	20	4	24
1996	12	2	14
1997	15	8	23
1998	16	7	23
Total	77	27	104

Table 6. Nesting status of radiomarked wood duck hens in southern Illinois during 1993-1998.

Year	Nesting	Nonnesting	Total
1993	8	0	8
1994	18	7	25
1995	32	8	40
1996	23	10	33
1997	24	9	33
1998	23	17	40
Total	128	51	179

Table 7. Nest distribution of radiomarked wood duck hens between upland and floodplain forests in southern Illinois during 1993-1998.

Year	Upland	Floodplain	Total
1993	5	3	8
1994	10	2	12
1995	21	3	24
1996	7	7	14
1997	10	13	23
1998	16	7	23
Total	69	35	104

Table 8. Mean (SE, *n*) clutch sizes of wood ducks nesting in southern Illinois during 1994-1998.

Year	All clutches	Normal	Parasitized
1994	15.7 (2.2, 7)	11.3 (0.8, 4)	21.7 (1.2, 3)
1995	12.1 (0.8, 16)	10.9 (0.5, 13)	17.7 (1.2, 3)
1996	11.0 (1.0, 10)	9.6 (0.4, 8)	16.5 (0.5, 2)
1997	12.3 (0.4, 12)	12.0 (0.3, 11)	15.0 (N/A, 1)
1998	11.5 (0.7, 22)	10.6 (0.6, 19)	17.3 (1.5, 3)
Total	12.2 (0.4, 67)	10.9 (0.3, 55)	18.2 (0.8, 12)

Table 9. Fate of wood duck nests located by following radiomarked hens (radio), climbing trees used in previous years (reclimb), and found incidentally (incidental) in southern Illinois during 1993-1998.

Habitat	Fate	Radio (n = 95)	Reclimb (n = 47)	Incidental (n = 10)	Total (n = 152)
Upland (n = 97)	Success	40	17	4	61
	Fail	23	13	0	36
Floodplain (n = 55)	Success	18	6	3	27
	Fail	14	11	3	28
Both (n = 152)	Success	58	23	7	88
	Fail	37	24	3	64

Table 10. Mean (SE, *n*) size of wood duck broods observed in southern Illinois during 1993-1998.

	Age class						
Year	IA	IB	IC	IIA	IIB	IIC	III
1993	8.6 (0.6, 14)	9.9 (1.0, 11)	8.0 (1.0, 3)	7.8 (1.7, 6)	7.5 (0.5, 2)	11.0 (2.0, 3)	N/A
1994	6.8 (0.9, 20)	5.5 (0.9, 11)	6.9 (1.0, 10)	5.3 (1.0, 7)	7.3 (1.9, 4)	7.0 (0.9, 7)	N/A
1995	6.6 (1.0, 13)	6.7 (0.7, 24)	8.5 (1.1, 10)	6.0 (0.9, 7)	6.3 (0.8, 6)	5.7 (2.9, 3)	5.6 (0.5, 7)
1996	6.5 (0.3, 8)	5.6 (1.1, 13)	5.6 (0.6, 14)	6.4 (0.7, 15)	7.5 (0.6, 19)	5.7 (1.1, 13)	7.9 (1.0, 10)
1997	8.0 (1.3, 8)	7.0 (0.5, 24)	6.2 (0.6, 17)	4.5 (0.6, 17)	5.1 (0.6, 18)	6.0 (0.9, 10)	3.7 (0.5, 9)
1998	9.3 (1.2, 12)	7.1 (0.5, 24)	6.0 (0.5, 22)	5.3 (0.6, 17)	5.6 (0.9, 15)	5.5 (1.2, 11)	N/A
Total	7.6 (0.4, 75)	6.9 (0.3, 114)	6.5 (0.3, 76)	5.6 (0.3, 69)	6.3 (0.4, 64)	6.2 (0.5, 47)	5.8 (0.5, 26)

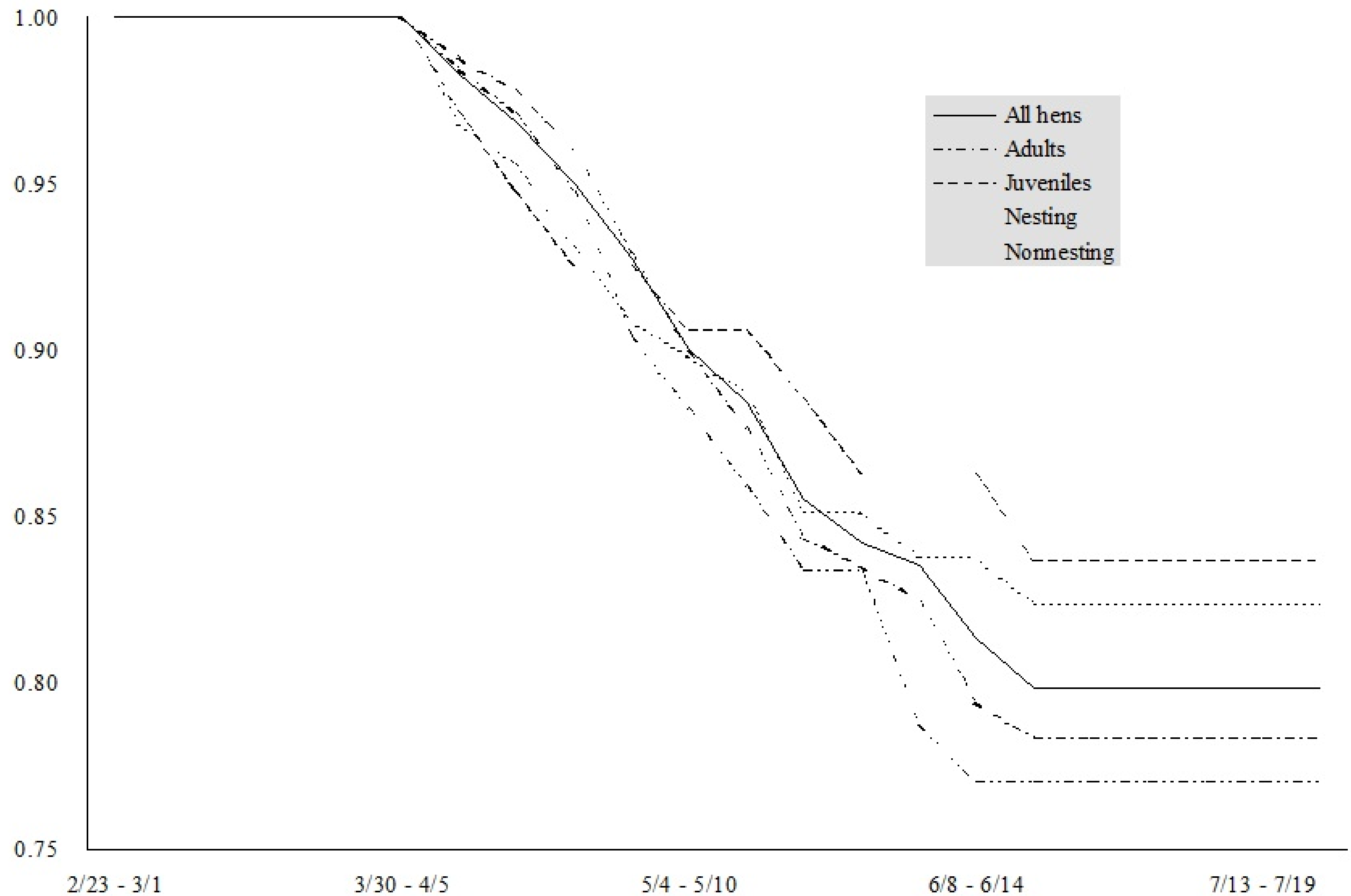
Table 11. Fate of simulated wood duck nests placed in natural cavities in southern Illinois during 1997 and 1998.

Study site	Habitat	Survived	Disturbed	Total
Union County Conservation Area	Upland	22	8	30
	Floodplain	7	21	28
LaRue-Pine Hills Research Natural Area	Upland	8	7	15
	Floodplain	8	7	15
Total		45	43	88

Table 12. Mean physical characteristics (SE) of natural cavities used for placement of simulated wood duck nests at Union County Conservation Area and LaRue-Pine Hills Research Natural Area during 1997 and 1998.

Characteristic	Floodplain (n = 43)	Upland (n = 45)	P-value
Bole diameter (cm)	39.3 (1.8)	44.0 (2.1)	0.163
Diameter at breast height (cm)	55.2 (2.6)	59.6 (2.4)	0.119
Cavity depth (cm)	30.7 (6.9)	31.4 (6.5)	0.854
Cavity entrance area (cm^2)	103.2 (22.9)	113.6 (16.3)	0.356
Cavity height above ground (m)	9.9 (0.6)	10.7 (0.7)	0.658
Distance to habitat edge (m)	84.6 (18.6)	535.8 (59.1)	<0.001

Figure 1. Survival curves for wood duck hens radiomarked in southern Illinois during 1993-1998.



1.00
0.95
0.90
0.85
0.80
0.75
2/23 - 3/1
3/30 - 4/5
5/4 - 5/10
6/8 - 6/14
7/13 - 7/19
All hens
Adults
Juveniles
Nesting
Nonnesting

Figure 2. Survival probabilities for simulated nests in the upland forests of Union County Conservation Area.

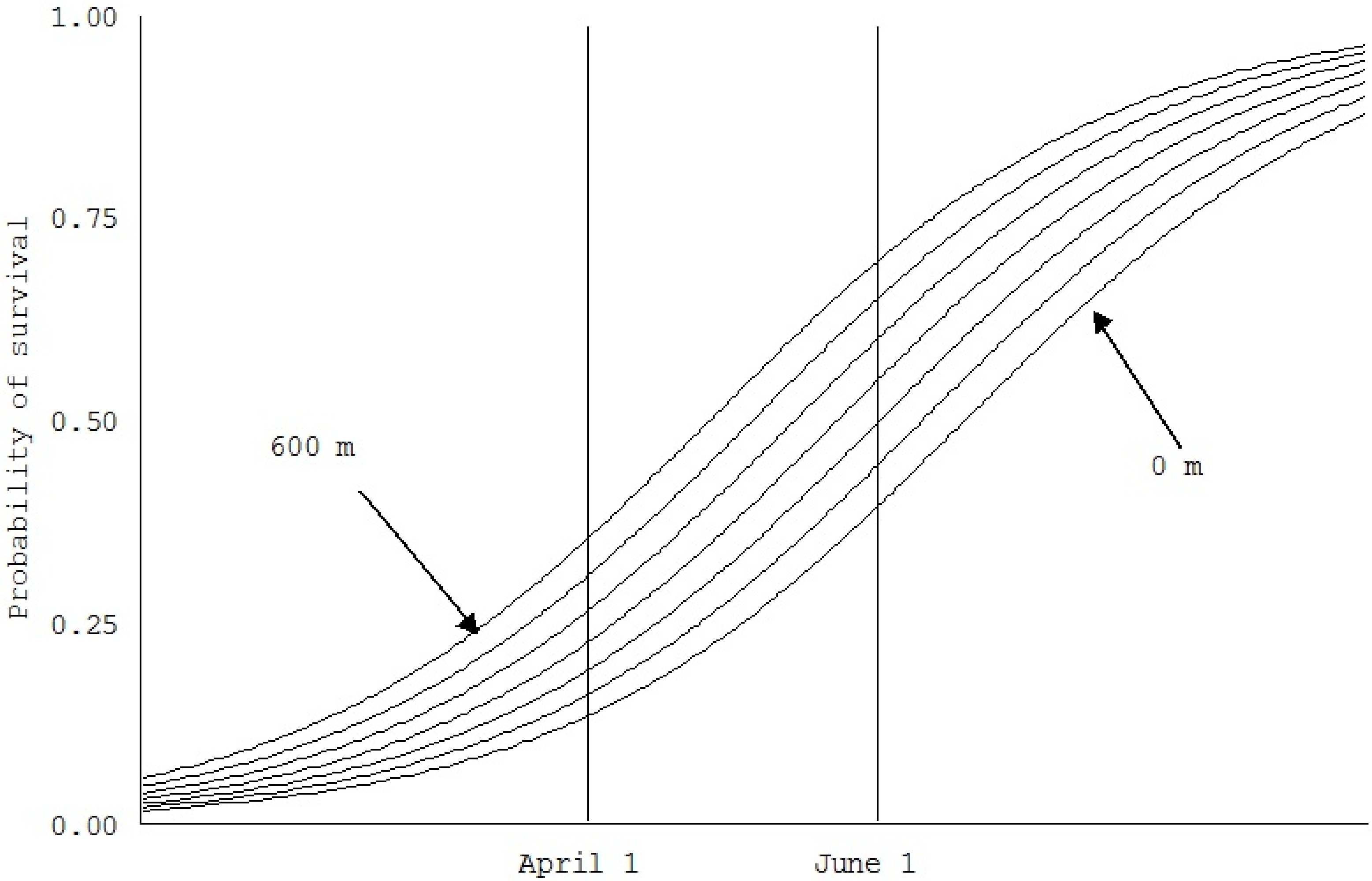
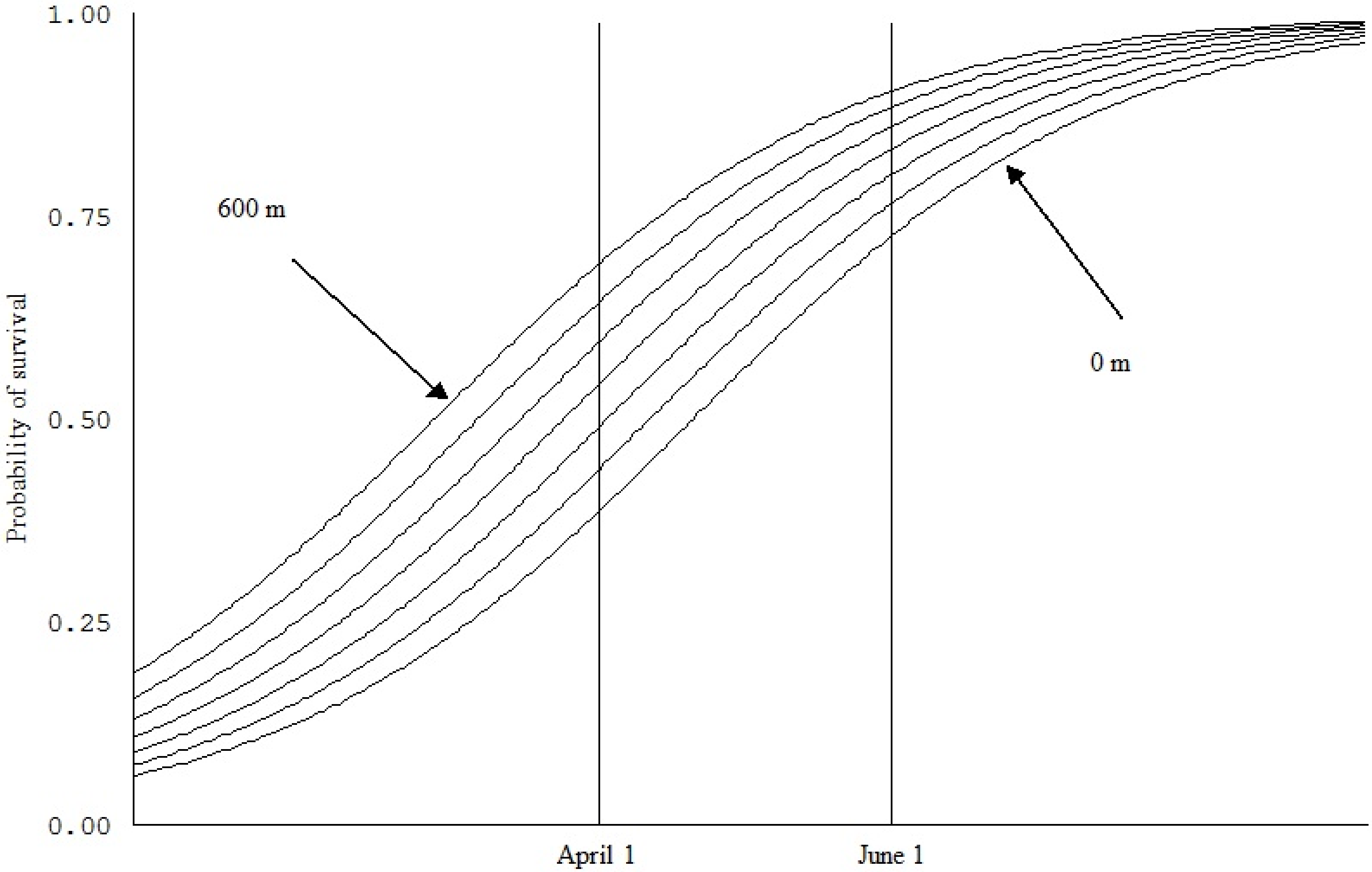
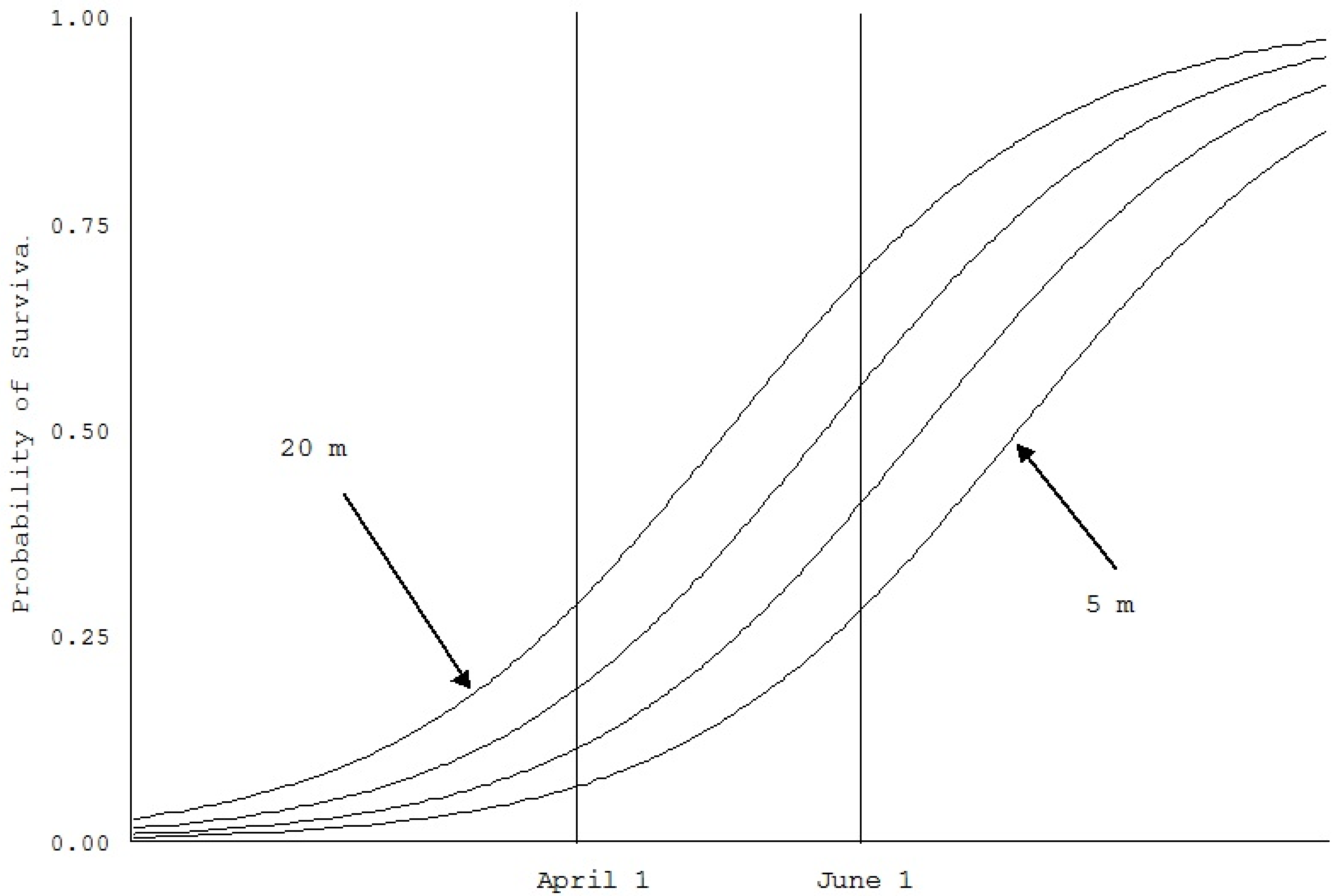

1.00
0.75
0.50
0.25
0.00
Probability of survival
600 m
0 m
April 1
June 1

Figure 3. Survival probabilities for simulated nests in the upland forests of LaRue-Pine Hills Research Natural Area.



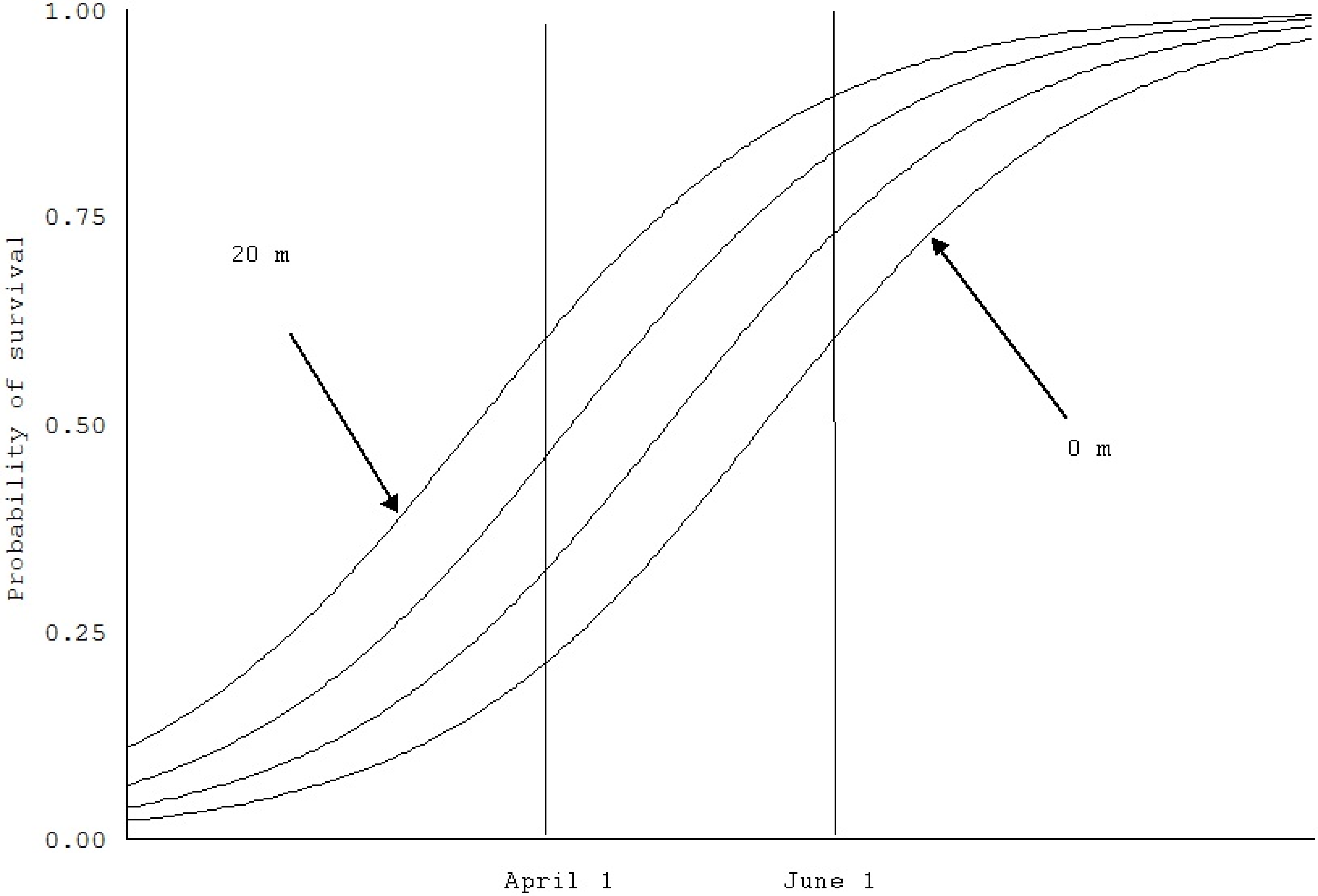
1.00
0.75
0.50
0.25
0.00
Probability of survival
600 m
0 m
April 1
June 1

Figure 4. Survival probabilities for simulated nests in the floodplain forests of Union County Conservation Area.



1.00
0.75
0.50
0.25
0.00
Probability of Surviva.
20 m
5 m
April 1
June 1

Figure 5. Survival probabilities for simulated nests in the upland forests of LaRue-Pine Hills Research Natural Area.


1.00
0.75
0.50
0.25
0.00
Probability of survival
20 m
0 m
April 1
June 1

JOB 2.2. HABITAT CONDITIONS AND LANDSCAPE CHARACTERISTICS

Objective: Relate variation in breeding population indices, reproductive performance, and predation on hens and nests to habitat conditions and landscape characteristics.

The objective under this job was met primarily by comparing forest composition and availability of nest sites between upland and floodplain landscapes. We also investigated factors that affect nest site selection by breeding wood ducks at multiple spatial scales including landscape (upland vs. floodplain), forest stand (tree species composition, stand age), nest site (tree species and surrounding topography), and nest cavity (physical characteristics) levels of resolution. These results are reported in Mr. Edward Zwicker's (1999) M.S. thesis that is appended to this report.

Measurements and predictive modeling of seasonal changes in water levels within forested wetlands reported in Mr. Selle's (1998) M.S. thesis that is appended to this report also partially met the objective of this job. The primary purpose of Mr. Selle's thesis was to determine how habitat conditions, principally water levels, influence nesting effort, reproductive performance, and survival of breeding hens. The Ph.D. dissertation authored by Mr. Robert Kawula (1998) also contains comparisons of daily and seasonal movements, home ranges, and habitat use patterns under varying environmental conditions that are relevant to the objective of Job 2.2. Mr. Kawula's dissertation contains additional analyses of landscape and microhabitat characteristics of habitat patches used by breeding wood ducks. Results and conclusions presented in Mr. Kawula's dissertation are relevant to understanding how wood duck hens responded behaviorally to seasonal and annual changes in habitat conditions.

LITERATURE CITED

Kawula, R. J. 1998. Breeding season movements and resource selection of female wood ducks in southern Illinois. Dissertation, Southern Illinois University at Carbondale, Carbondale, Illinois, USA.

Selle, A. T. 1998. Annual variation in breeding productivity of natural cavity nesting wood ducks in southern Illinois. M.S. Thesis, Southern Illinois University at Carbondale, Carbondale, Illinois, USA.

Zwicker, E. H. 1999. Availability and use of tree cavities by wood ducks nesting in upland and floodplain forests of southern Illinois. Draft M.S. Thesis, Southern Illinois University at Carbondale, Carbondale, Illinois, USA.

JOB 2.3. ANALYSIS AND REPORT

Objective: Provide recommendations for improved management and conservation of forested wetland habitats in the Mississippi River floodplain.

The objective of this job was met by management implications and recommendations that appear in Chapter 5 of Mr. Zwicker's (1999) M.S. thesis. A major objective of Mr. Zwicker's thesis was to examine forest stand ages and species composition to make recommendations for management of nesting habitat for wood ducks. Because upland forests were an important source of nesting habitat for wood ducks, Mr. Zwicker made recommendations for management and conservation of upland forest in addition to wetland habitats. Results and conclusions presented in Mr. Selle's (1998) M.S. thesis and Mr. Kawula's (1998) dissertation were the foundation of some of the management recommendations and implications presented below. We summarize specific implications and recommendations for management that were derived from all components of Study No. 2 as follows:

1. Use of upland forest habitats by nesting wood ducks that also depend on bottomland forest and other wetland habitats for feeding, nesting, and brood-rearing illustrate an important functional connection between upland forests within the Shawnee National Forest and bottomland habitats contained within the Mississippi River floodplain. Other species similarly depend on both upland and floodplain habitats, and interdependencies with upland forests should be considered in managing and conserving forested wetland habitats. Floodplain areas such as Union County CA and LaRue Swamp in southern Illinois should be managed as a habitat complex coordinated with management and conservation of nearby upland forests.

2. Wood ducks exhibited considerable flexibility in their use of nest sites that appears to have allowed them to adapt to high predation rates in floodplain forests. Other cavity nesting species that are less adaptable or more dependent on forested wetlands may be more adversely affected by loss and fragmentation of forested wetlands in southern Illinois.

3. We believe that the most important findings from this study are the result of human-induced hydrological changes and losses of forested wetland habitats within the Mississippi River floodplain. Low nesting effort appeared to be related to suboptimal habitat conditions that were caused by habitat conditions that were either too dry, or by extreme flooding events. We attributed the high proportion of wood duck nests that were located in upland forest to potentially high rates of nest predation in the floodplain, and to limited availability of suitable floodplain forest nesting habitat.

4. Implementation of nest box programs in Mississippi River floodplain habitats would not be cost-effective, nor substantially improve breeding productivity of wood ducks in the Mississippi River floodplain of southern Illinois. Improved management for breeding wood ducks can be best achieved in southern Illinois by restoring floodplain forests, controlling extreme fluctuations in water levels, controlling mammalian nest predator populations, and managing upland and floodplain forests to ensure adequate densities of trees of suitable ages that produce secure nest cavities.

5. Emphasis should be placed on restoring floodplain forests where it is ecologically feasible and consistent with other management objectives. Floodplain forest restoration would increase the amount of nesting and feeding habitats available to wood ducks in southern Illinois, particularly where there is suitable brood habitat but alternative nesting

habitat (i.e., upland forest) is unavailable within 5 km. Early succession tree species such as sycamores (*Platanus occidentalis*), cottonwoods (*Populus deltoides*), and sweet gums (*Liquidambar styraciflua*) are needed to provide an early source of nest cavities, while later succession forests consisting of bottomland oaks (*Quercus spp.*), hickories (*Carya spp.*), and pecans *(Carya illinoensis*) would provide sources of hard mast and substrates for invertebrates that are important nutritional resources for breeding wood ducks. Restoration of bottomland forests to flood-prone agricultural lands would improve feeding conditions for wood ducks during extreme flood events.

6. Natural hydrologic regimes that are altered by levee and drainage systems likely increase the magnitude and unpredictability of spring flood events that may disrupt feeding patterns of wood duck hens during critical stages of the nesting cycle. Water levels should be managed or natural flooding regimes restored to avoid extreme fluctuations in water levels where wood ducks breed. The feasibility of developing water delivery and drainage systems on Union County CA should be investigated. As a minimum, water level management plans should be developed in coordination with drainage and levee districts to moderate extreme fluctuations in water levels that sometimes occur on Union County CA.

7. Nest predator populations should be controlled by promoting legal harvest of furbearers (principally raccoons [*Procyon lotor*]), and by restoring large tracts of forested wetland habitats. Additional research is needed to compare predator populations between upland and floodplain forests. However, it appears from this study that the interspersion of agricultural and forested lands in the Mississippi River floodplain, combined with the absence of legal furbearer harvest on publicly-owned lands has led to high densities of raccoons and other mammalian nest predators in the Mississippi River floodplain.

8. Uneven-aged sylvicultural management to ensure continued availability of mature (> 65 years) forest stands in upland forest habitats is necessary to sustain densities of tree cavities suitable for nesting wood ducks. This recommendation is not incompatible with a rotational system of harvesting mature timber if such activity enhances tree species diversity and mature age-classes of cavity-producing species are maintained. Non-merchantable species that account for a high proportion of suitable tree cavities (i.e.,, American beech (*Fagus grandifolia*), black gum *(Nyssa sylvatica*), and sycamore) should not be disturbed.

LITERATURE CITED

Kawula, R. J. 1998. Breeding season movements and resource selection of female wood ducks in southern Illinois. Dissertation, Southern Illinois University at Carbondale, Carbondale, Illinois, USA.

Selle, A. T. 1998. Annual variation in breeding productivity of natural cavity nesting wood ducks in southern Illinois. M.S. Thesis, Southern Illinois University at Carbondale, Carbondale, Illinois, USA.

Zwicker, E. H. 1999. Availability and use of tree cavities by wood ducks nesting in upland and floodplain forests of southern Illinois. Draft M.S. Thesis, Southern Illinois University at Carbondale, Carbondale, Illinois, USA.

Kawula, R. J. 1998. Breeding season movements and resource selection of female wood ducks in southern Illinois. Dissertation, Southern Illinois University at Carbondale, Carbondale Illinois, USA.

Selle, A. T. 1998. Annual variation in breeding productivity of natural cavity nesting wood ducks in southern Illinois. M.S. Thesis, Southern Illinois University at Carbondale, Carbondale, Illinois, USA.

Zwicker, E. H. 1999. Availability and use of tree cavities by wood ducks nesting in upland and floodplain forests of southern Illinois. Draft M.S. Thesis, Southern Illinois University at Carbondale, Carbondale, Illinois, USA.