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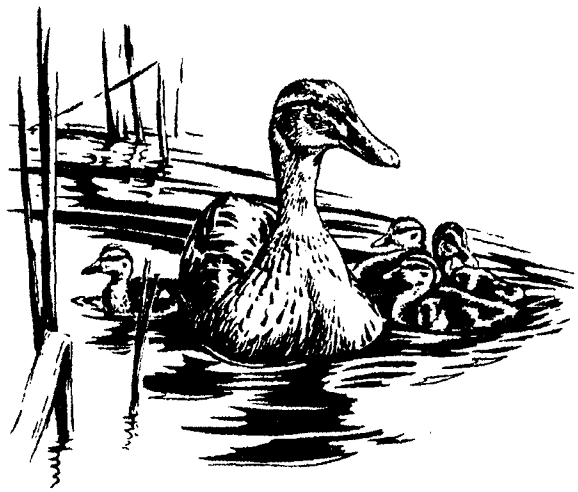

Mallard Investigations

W-130-R-1-2-3

Final Report
To
Illinois Department of Natural Resources

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EXECUTIVE SUMMARY

The nesting biology of mallards (Anas platyrhynchos) was studied in central Illinois from March to August, 1998-2000. The objectives were to develop a data set of mallard nesting information in Illinois and evaluate recruitment. To achieve these objectives, 119 female mallards were live trapped (Sharp and Lokemoen 1987, Ringelman 1990) during spring and fitted with radio transmitters (Pietz et al. 1995). Radio-marked females were located daily throughout the nesting seasons, and broods were located daily for 20 days posthatch (Orthmeyer and Ball 1990).

Mallard hens were in better physiological condition (mass/wing chord) in spring 1998 than during the springs of 1999 and 2000. The mallard nesting seasons ranged from 89-103 days. First nests were initiated on 4, 6, and 12 April 1998-2000, respectively. The number of nest attempts per female varied from 1.12 ± 0.08 nests/yearling hen in 1999 to 1.74 ± 0.17 nests/hen with age classes combined in 1998. The mean nest initiation date for first nest attempts was later in 1999 (6 May) than 1998 (22 April); for spring 2000, it was 29 April, similar to both 1998 and 1999.

Mean incubated clutch sizes for first nest attempts were 9.4 ± 0.3 eggs/clutch, and the clutch size for all nests did not appear to decline with the advancement of the nesting season. Incubation periods were constant during the study and averaged 26.7 ± 0.4 days; 94.7 percent of all eggs laid in successful nests hatched. Seventy-five percent of all mallard nests were initiated by 20 May each spring, and the projected hatch date for 75 percent of the nests was 25 June. The mallard nesting season in central Illinois was completed each summer by 3 August. Renesting effort of mallard hens was 87.5 percent, 52.4 percent, and 73.7 percent in 1998-2000, respectively. Renesting effort was significantly reduced in 1999 from that observed in 1998.

Coyotes (Canis latrans) and raccoons (Procyon lotor) were identified as the major nest predators; however, the cause of nest failure was not determined for 51 out of 140 nests (36.4%). Simple estimates of nest success were 23.3 percent in 1998, followed by 15.2 percent in 1999 and 8.9 percent in 2000. Nest success was highest in idle grasslands (22.1%) where nearly 65 percent of all nests were located, and nest success was not influenced by the distance from a wetland. Hen success rates were high in 1998 - 37.0 percent, but declined to 21.2 percent in 1999, and to a dismal 15.4 percent in 2000. The initial brood size for 21 successful nests during 1998-2000 averaged 8.5 ± 0.5 ducklings; however, brood size declined to an average of 3.2 ± 0.8 ducklings by the 17th day posthatch.

Kaplan-Meier survival estimates were determined for nests, broods, ducklings, and hens each year. Nest survival ranged from a low of 6.4 percent for all hens in 2000 to 36.5 percent for adult hens in 1998. Brood survival was high in all three years and averaged 77.8 percent. Duckling survival was moderate and ranged from 38.8 percent in 1999 to 50.0 percent in 1998. Twenty-three of 97 resident mallard hens (23.7%) were killed during the 3-year study, and survival ranged from 60 to 80 percent. Hen survival during the nesting and brooding period was 65.3% for all years.

Mallard production exceeded hen mortality during the 1998 nesting season. Recruitment was estimated at 0.76 females fledged/hen in the spring population resulting in a proportional increase of 11 percent in the 1999 spring mallard population. However, production was not adequate to compensate for hen mortality in 1999 when recruitment was estimated at 0.34. As a result, the spring 2000 mallard population declined 19 percent from the 1999 population. Similarly, mallard production in spring 2000 was dismal, and recruitment fell to 0.29. The spring 2001 mallard population, like that of spring 2000, will likely decrease by about 22 percent.

This Project (W-130-R-1-3) was extended for three years into Segments 4-5-6. A detailed discussion of all results will be incorporated into the Final Report of August 2003.

SUMMARY OF ACCOMPLISHMENTS

STUDY I: THE NESTING BIOLOGY OF MALLARDS IN ILLINOIS

JOB I-1. Nesting History and Reproductive Success of Mallards in Illinois.

We examined the nesting ecology of mallards in central Illinois using radio telemetry during spring/summer 1998-2000. The mallard nesting season was defined each spring, and basic nesting parameters were described including nest attempts/hen, nest success, egg hatchability, incubated clutch size, incubation period, and brood size. We identified the major predators of mallard nests. Survival estimates of nests, ducklings, broods, and hens were also determined.

JOB I-2. Assessment of Mallard Recruitment.

We estimated mallard recruitment each year, 1998-2000. Recruitment was defined as the number of hens added to the fall population per hen in that year's spring population. Additionally, the proportional change in the mallard population size was estimated each spring and derived from various nesting parameters and survival estimates from JOB I-1.

FINAL REPORT
Mallard Investigations
Federal Aid in Wildlife Restoration W-130-R-1-2-3
1 July 1998 through 30 June 2000

STUDY I: THE NESTING BIOLOGY OF MALLARDS IN ILLINOIS

INTRODUCTION

The mallard is the most abundant duck migrating through Illinois. During the 1993-1996 fall migrations, mallards represented 77.5 percent of the total duck use-days on the Illinois River from Spring Valley to Grafton and 58.0 percent of the total duck use-days on the Mississippi River from Rock Island to Grafton (Havera 1999:246-247). The mallard was also the most numerous species in the duck harvest in Illinois, the Mississippi Flyway, and the United States (Martin and Padding 2000, Peterson 2000).

Besides its importance as a migrant, the mallard has become a common summer resident as well and is one of the most abundant duck species nesting in Illinois. Yetter (1992) estimated that mallards represented 61.4 percent of the breeding waterfowl population in northeastern Illinois. Historically, however, nesting mallards were not as abundant in Illinois. In a database compiled by the Illinois Natural History Survey (INHS), only 15 records of nesting mallards were documented in Illinois before 1930 (Havera 1999). From 1863 to 1929, nesting mallards were identified in only in 9 of 102 Illinois counties. Since 1930, mallards have expanded their range in Illinois and now nest in all 102 counties. Information from the Breeding Bird Survey data compiled by the United States Fish and Wildlife Service (USFWS) showed that mallards in Illinois increased 5.4 percent annually and 214 percent from 1966 to 1989 (Droege and Sauer 1990, Havera 1999).

In the 1980's, the number of mallards breeding in Illinois soared. The cause of this population expansion is unknown although possible reasons include: increased nesting habitats under the 1985 Conservation Reserve Program (CRP), deployment of artificial nesting structures, release of game-farm mallards by private citizens, and pioneering of mallards from the traditional breeding areas of the northern prairies to nontraditional areas (i.e., Illinois, Wisconsin, Michigan, and Ohio) due to the severe droughts of the 1980's (Havera 1999).

While the traditional breeding grounds of prairie Canada and the northcentral United States far surpass nontraditional areas in attracting numbers of breeding mallards (USFWS 2000), mallard populations in nontraditional areas are expanding. Two decades ago the number of mallards breeding in Wisconsin, Michigan, and Ohio was estimated at 225,000 birds. In 1999, this population was approaching one million in number (Petrie 1999). More stable breeding environments resulting in greater breeding success may have been the reason for this population growth. Wetlands in nontraditional nesting areas are more stable and do not undergo the severe drought cycles of the prairie wetlands (Petrie 1999).

The mallard population expansion has translated into a shift in the harvest derivation. Breeding reference areas (Fig. 1) defined by Anderson and Henny (1972) and Pospahala et al. (1974) were used to examine the mallard harvest. From 1961-1975, the majority of mallards harvested in Illinois were produced in prairie Canada and the northcentral United States (Munro and Kimball 1982; Fig. 2). During this time, only 8.7 percent of the mallards harvested in Illinois were produced in the Great Lakes states; however, preliminary evidence suggests that the number harvested from this region increased to 28.2 percent in the 1990's (Zuwerink and Gates 1999; Fig. 2). The apparent decline in Illinois' harvest of mallards produced in prairie Canada has resulted from the increased harvest of mallards produced in the Great Lakes states.

In spite of the mallard's importance in the Illinois waterfowl harvest and its population expansion in the Great Lakes states including Illinois, little has been done to investigate the nesting ecology of the mallard in this state. Yetter (1992) estimated mallard breeding populations in northeastern Illinois and collected some corollary nesting information. Louis (1999) examined some nesting parameters of the mallard in eastcentral Illinois. Other than these two studies, there have been no recent investigations of the nesting biology of mallards in Illinois. Therefore, this study was designed to develop a data set of basic nesting information on mallards in Illinois and evaluate if mallard recruitment was meaningful.

ACKNOWLEDGMENTS

Project W-130-R was supported by Federal Aid in Wildlife Restoration Act (Pittman - Robertson), with funds administered by the USFWS and the Illinois Department of Natural Resources (IDNR). The staff at the Metropolitan Water Reclamation District of Greater Chicago's Prairie Plan site and the IDNR Banner Marsh State Fish and Wildlife Area permitted access to their properties and contributed advice and assistance during this investigation. The following INHS staff helped with the project: P. White, L. Anderson, J. Steckel, and R. Hillemeyer provided field assistance; J. Levengood assisted data analysis; and K. Roat supplied technical assistance. R. Yetter, D.V.M., demonstrated and instructed INHS staff on procedures for radio transmitter attachment. J. Havera helped with trapping and attachment of radio transmitters. Illinois Department of Transportation (IDOT), Division of Aeronautics, Springfield, IL, and Phil Mankin, University of Illinois (UIUC), Department of Forestry, Urbana, IL, furnished aerial support for the project. Game-farm hen mallards used during decoy trapping were purchased from Whistling Wings, Inc., Hanover, IL.

STUDY AREA

Two study areas were selected for mallard investigations in central Illinois: 1) the Banner Marsh State Fish and Wildlife Area (Banner), and 2) the Prairie Plan site of the Metropolitan Water Reclamation District of Greater Chicago (MSD) (Fig. 3). MSD is located approximately nine miles west of Banner. Habitat structure in Fulton Co., IL as determined from the Illinois Geographic Information System, Illinois Department of Natural Resources, Springfield, Illinois, consisted of approximately 40 percent row crop agriculture; 29 percent grassland, pasture, and hayland; 23 percent forest; 6 percent wetland and deepwater habitats; and 1 percent urban/suburban.

Banner was located on the Illinois River in Fulton and Peoria counties from river mile 138 to 144 between the towns of Banner and Kingston Mines. Banner was isolated from the Illinois River for agricultural purposes by the Banner Special Drainage and Levee District between 1910 and 1917 (USACOE 1995). In 1958, the United Electrical Coal Companies, Inc. purchased the drainage and levee district and subsequently surface mined coal until 1974. The State of Illinois acquired the property in the 1980's, and it was managed for outdoor recreation and fish and wildlife habitats. Banner was isolated from the Illinois River by a 50-yr flood event levee and consisted of 5,524 ac of non-forested wetlands, upland forests, grasslands, pastures, old fields, and row crops. Upland nesting cover at Banner was comprised of idle grasses including smooth brome (Bromus inermis) and switch grass (Panicum virgatum), forbes (i.e., goldenrod (Solidago spp.), and muliflora rose (Rosa multiflora).

MSD was located in Fulton County between Cuba and Canton and owned by the City of Chicago. The property consisted of 15,249 ac of reclaimed surface-mined lands (Lawrence 1987, Prairie Plan 1998). MSD was managed as a disposal site for biosolids (sludge) received from Chicago. Biosolids were transported from Chicago in dry form and spread over agricultural fields where they were incorporated into the soil. Major land categories at MSD included hay and pasture, idle grassland, row crop agriculture, upland forest, and a variety of wetland and deepwater habitats ranging from large final-cut lakes to small ponds and marshes. Upland nesting cover at MSD included smooth brome, switch, and orchard grasses (Dactylis glomerata), timothy (Phleum pratense), alfalfa (Medicago sativa), red clover (Trifolium pratense), crown vetch (Coronilla varia), goldenrod, and multiflora rose.

To consolidate work effort, the Banner study site was eliminated during springs 1999 and 2000. Difficulties encountered at Banner with water-level fluctuations and public use during 1998 convinced us to concentrate our efforts at MSD allowing for more efficient monitoring of mallard hens.

JOB NO. I.1. Nesting History and Reproductive Success of Mallards in Illinois.

OBJECTIVES:

To determine nesting effort of female mallards.

To determine nest success of female mallards.

To collect corollary nesting information for female mallards, such as clutch size, egg hatchability, nest chronology, type of predation, and brood size at hatching.

To monitor brood survival for those females with successful nests.

To monitor duckling survival for females that successfully nested.

METHODS

Trapping and Transmitter Attachment

Prenesting mallards were captured using decoy traps (Sharp and Lokemoen 1987, Ringelman 1990). Wetlands were searched daily for resident pairs. When isolated or territorial pairs were recorded on a wetland for multiple days, they were considered residents and trapped. Traps were checked multiple times each day while other potential trap sites were continually monitored. Once a female was captured and fitted with a radio transmitter, the trap was moved to another location to avoid recapture.

When captured, mallards were banded using USFWS No. 7 leg bands and weighed with a Pesola scale (± 20 g). Morphological measurements included bill length at two points (culmen1 and culmen2), bill width, tarsus length, tarsus width, and total tarsus (± 0.1 mm) (Byers and Cary 1991), and wing chord length (± 1 mm) (IWWR 1996). Hen mallards were aged (adult or yearling) according to Krapu et al. (1979).

Female mallards were fitted with a prong and suture radio transmitter (Model 2354) designed by Advanced Telemetry Systems, Inc. (ATS), Isanti, Minnesota (Mauser and Jarvis 1991, Pietz et al. 1995). Radio transmitters were equipped with 70-day (1998) and 90-day batteries (1999-2000) and 8-hr mortality switches assisted detection of predatory events. The entire transmitter weighed 10 - 12 g, or about 1 percent of the body weight of a hen mallard. Transmitters were attached mid-dorsally just above the shoulder joints using three sutures and a wire prong inserted subcutaneously (Mauser and Jarvis 1991, Pietz et al. 1995). The procedure was done under local anesthetic (Lidocaine) and was approved by the University of Illinois at Urbana-Champaign, Laboratory Animal Care Advisory Committee (LACAC), Office of Laboratory Animal Resources (OLAR) (Protocol # N7C100).

Radio Telemetry

Radio-marked hens were located by triangulation (White and Garrott 1990, Samuel and Fuller 1996) using vehicle-mounted null-array antenna systems (ATS, Inc., Isanti, Minnesota). Tracking began the day following capture and transmitter attachment. Most hens were found twice daily ($\geq$ 6 days/week) between 0600 h and 1300 h, which is the period when laying hens were most likely to be on their nests (Gloutney et al. 1993). Daily locations were marked on aerial photos. Hens found in potential nesting cover were triangulated by vehicle or on foot using the hand-held Yagi antennas. Nest searching ensued when the female was located away from the nest site (Paquette et al. 1997). If a female was absent from her nest for two consecutive locations, nests were inspected to learn their fate (active, abandoned, destroyed, or hatched; Klett et al. 1986, Sovada et al. 1996, Hernandez et al. 1997). Nest initiation dates were determined by subtracting the number of eggs in a nest when found from the date when the nest was located (Paquette et al. 1997). We assumed an egg laying interval of one egg/day and that incubation began when the last egg was laid. Incubation periods were calculated as (((HATCH DATE−NEST INITIATION DATE)-CLUTCH SIZE)+1). On approximately the 18th day of incubation, nests were visited despite the hen's presence to determine the incubated clutch size (we assumed partial nest depredation had not occurred), egg dimensions ($\pm$ 0.1 mm), and incubation stage (Hanson 1954, Weller 1956). Egg hatchability was determined from the presence of whole eggs and membranes at the nest site. We classified a successful nest as hatching $\geq$ 1 egg (Klett et al. 1986), and hen success was defined as the probability of a hen having a successful nest in one or more nest attempts (Cowardin et al. 1985). Successful females and their broods were located daily for 20 days posthatch, and attempts were made to count ducklings multiple times each week to ascertain brood and duckling survival (Orthmeyer and Ball 1990). Renesting effort was determined for those hens that were unsuccessful in their first nest attempts.

Data Analysis

Mallard hens were classified as central Illinois residents if they attempted to nest or remained on the study areas during the nesting season. Data analysis was conducted using the Statistical Analysis System (SAS Institute 1996). Significance levels were set at $\underline{P} \leq 0.05$, and we report means as ± standard error. Nesting season length was defined as the first egg laid to the last egg hatched or destroyed. The mean number of nest attempts per resident hen, nest initiation dates for first nest attempts, and body condition indices (body mass [g]/wing chord [mm]; Ringelman and Szymczak 1985, Hine et al. 1996) were compared between age classes, study sites, and years using Tukey-Kramer post hoc multiple comparison tests (Proc GLM, SAS Institute 1996). Incubated clutch size, incubation period, and brood size comparisons were made using Wilcoxon two sample $\underline{t}$-tests and Kruskal-Wallis (χ^2) tests (Proc NPAR1WAY, SAS Institute 1996). Linear regression was used to examine the relationship of clutch size on Julian date of nest initiation (Proc REG, SAS Institute 1996). A weighted mean was used to summarize egg dimensions (Zar 1996). Nest success and hen success were expressed as a simple percentage and comparisons were made between the age classes, study sites, and years using G-tests (Sokal and Rohlf 1995:731). Distances of mallard nests to the nearest wetland were measured using the Illinois Geographic Information System (IGIS; IDNR, Springfield, Illinois). Distance classes were defined as $\leq$ 100 yds and more than 100 yds and comparisons were made using G-tests. Nest success was also calculated using the daily survival rate (DSR) according to the Mayfield method (Mayfield 1975) as modified by Johnson (1979). To determine the Julian date at which most of the mallard nests were completed, we estimated a nest's hatch date by adding the mean incubation period and clutch size observed during this study to the nest initiation date. The 75th percentile of the estimated hatch date was calculated using Proc UNIVARIATE (SAS Institute 1996).

The Kaplan-Meier product-limit estimator modified for staggered entry (Kaplan and Meier 1958, Pollock et al. 1989, White and Garrott 1990) was used to calculate mallard hen survival encompassing the prenesting, nesting, and brooding periods. For determining survival, hens were censored the day following the last radio contact, the day following loss of a transmitter, the day of brood loss, or the 20th day posthatch (Paquette et al. 1997).

Brood, duckling, and nest survival rates were calculated using the Kaplan-Meier product-limit estimator (Proc LIFETEST, SAS Institute 1996). Broods and ducklings were censored in the same manner as hen mallards. Survival of broods and ducklings was estimated to 20 days posthatch (Orthmeyer and Ball 1990). A brood was considered to have survived if ≥ 1 duckling lived for 20 days. Duckling survival may not have been independent among brood mates, which is an assumption for using the Kaplan-Meier survival estimate. However, Pollock et al. (1989) stated that violation of this assumption does not bias the survival estimate but decreases the variance and hence the 95 percent confidence interval.

Mallard hen, nest, brood, and duckling survival estimates were compared between the hen age classes, study sites, and years using log-rank (χ^2) tests (White and Garrott 1990:241).

RESULTS

Trapping

Mallards were decoy trapped from 17 March to 11 April in both 1998 and 1999 and from 16 March to 15 April 2000. Over the 3-yr period, 238 mallards were captured (Table 1). The first hen mallards were trapped on 23, 18, and 24 March 1998-2000, respectively. In 1999, two females and one male were recaptured that were originally banded in spring 1998. In 2000, four hens were recaptured that wore transmitters in 1999 but none from 1998. We also recaptured two drake mallards in spring 2000 banded at MSD in 1998, but none were retrapped from the 1999 season. From our marked sample of females, 28, 37, and 32 were considered to be resident hens during the 1998, 1999, and 2000 nesting seasons, respectively. Age structure of resident hens was 9 yearlings and 19 adults (0.47:1 yearling/adult) in 1998, 20 yearlings and 17 adults (1.18:1) in 1999, and 8 yearlings and 24 adults (0.33:1) in 2000. Due to uncontrollable circumstances, sample sizes differ throughout the text. For example, a radio-marked hen in 1998 nested unsuccessfully before her transmitter fell off (Table 1). Data from this hen was used to determine the mean nest initiation date of first nest attempts and nest success estimates, but this female was excluded from hen success calculations because of her incomplete nesting record.

Three (1 male and 2 female) mallards banded in central Illinois were recovered by waterfowl hunters during the 1998 and 1999 hunting seasons. One drake banded in 1998 and paired with a resident hen at MSD was harvested near Minneapolis, MN, during the 1998 duck season. Two resident hens banded in 1999 that nested unsuccessfully at MSD were recovered the following hunting season. One hen was harvested near Cuba, IL, within five miles of her nest site. The other hen was last located on 28 June at MSD and was recovered in North Dakota in October. Both mallards harvested northwest of Illinois presumably departed on a molt migration during summer.

Morphological Measurements and Body Condition Indices

Various measurements were taken from resident mallards upon capture (Table 2). Only those males we determined to be paired with resident hens were used in calculations. As expected, males had larger bills, legs, wings and body mass than females in all years ($\underline{P} < 0.001$). To determine the physiological condition of mallards at the time of capture, we used a body condition index calculated by dividing the mass of the bird by its wing chord length. Body condition indices were similar among the age classes each spring ($\underline{P} \geq 0.05$); therefore, age classes were pooled. Hen mallards were in better physiological condition ($F_{2,94} = 8.10$, $\underline{P} < 0.001$) during spring 1998 (4.18 ± 0.06 g/mm) than in 1999 (3.93 ± 0.04 g/mm) and 2000 (3.95 ± 0.05 g/mm). Likewise, drakes captured in 1998 (4.23 ± 0.09 g/mm) and 2000 (4.30 ± 0.08 g/mm) had better condition indices ($F_{2,32} = 5.92$, $\underline{P} < 0.007$) than drakes in 1999 (3.98 ± 0.06 g/mm).

Nesting Season and Nesting Effort

The mallard nesting season ranged from 89 to 103 days during spring/summer 1998-2000. The first nests were initiated on 4 and 6 April in 1998 and 1999, respectively. In 2000, the first nest was initiated on 12 April. The last mallard nest was destroyed on 1 July in 1998, and the last nests hatched on 17 and 20 July 1999 and 2000, respectively.

Mallard hens initiated 140 nests over the 3-yr period (Table 3). Twenty-seven hens (18 adults and 9 yearlings) initiated 1.74 ± 0.17 nests/hen in 1998 with no differences between the age classes and study sites ($\underline{P} > 0.05$). In 1999 adult hens initiated more nests (1.63 ± 0.18 nests/hen) than yearlings (1.12 ± 0.08 nests/hen) ($F_{1,31} = 6.91$, $\underline{P} = 0.013$). No differences were detected between the age classes during spring/summer 2000 ($F_{1,22} = 1.11$, $\underline{P} = 0.303$) when hens initiated 1.67 ± 0.13 nests/hen. Mallard nest initiation dates for first nests were similar between the study sites and age classes within years ($\underline{P} > 0.05$). Mean nest initiation dates for first nests were 22 April 1998 ($\underline{n} = 25$), 6 May 1999 ($\underline{n} = 33$), and 29 April 2000 ($\underline{n} = 25$) . Analysis of variance ($F_{2,80} = 9.34$, $\underline{P} < 0.001$) identified differences in the mean nest initiation date each spring, and post hoc comparisons showed that 1999 was a later spring than 1998.

Eggs measurements were taken from 34 nests. Egg width was 41.2 ± 0.2 mm and lengths were 57.3 ± 0.3 mm. The incubated clutch size was determined for 42 first nest attempts, and no differences were detected in age and year-wise comparisons ($P \geq 0.197$). The incubated clutch size was 9.4 ± 0.3 eggs/clutch. The clutch size of all nests was regressed on the Julian date of nest initiation and years were pooled because no year effect was identified. There was no age or age * Julian date interaction ($P \geq 0.565$) so these variables were deleted from the model. The regression equation had a negative slope (Fig. 4), which indicated a declining trend in clutch size with the advancement of the nesting season, but the model was not significant ($F_{1, 54} = 1.95$, $P = 0.168$).

Incubation and Egg Hatchability

Over the course of study, 21 nests hatched (Table 3). However, one hen's radio failed during incubation, so the incubation period was unknown. During the 2000 nesting season, one hen was omitted because she took a 6-day hiatus from the nest during the laying period. She subsequently returned to the nest to lay four additional eggs and hatch the nest. This nest survived 47 days from nest initiation to hatch. We detected no evidence of an age ($P \geq 0.085$) or year ($P = 0.418$) effect in the incubation period, and samples were pooled. Incubation lasted 26.7 ± 0.4 days and ranged from 24 to 31 days.

The percentage of mallard eggs that hatched in successful nests was high in central Illinois. In 1998, 84 eggs were laid in successful nests and only two failed to hatch (97.6%). Fifty-eight of 62 eggs (93.5%) hatched in 1999, and 38 of 42 eggs (90.5%) hatched in 2000. Egg hatchability was 94.7 percent (178 of 188 eggs hatched) with years combined.

Projected Hatch

To define the advancement of the mallard nesting season in central Illinois, the percentage of nests initiated for a given year was plotted against the Julian date (Fig. 5). Seventy-five percent of all nests were initiated by 20 May in both 1998 and 2000 and by 19 May in 1999. The last nests were initiated on the 28th, 22nd, and 15th of June in 1998, 1999, and 2000, respectively (Fig. 5). The projected date at which 75 percent of all nests would have hatched over the 3-yr period was 25 June, and the nesting season was effectively completed (100% of all nests hatched) after 3 August.

Renesting Effort and Nest Success

Fifty-six hens that were unsuccessful in their first nest attempt were used to determine the renesting effort by hen mallards in central Illinois. Renesting effort did not differ ($G_1 = 0.15$, $\underline{P} = 0.700$) between the study sites in 1998. However, the renesting effort was much smaller in 1999 when only 11 of 21 hens (52.4%) renested compared with 14 of 16 hens (87.5%) in 1998 ($G_1 = 5.51$, $\underline{P} = 0.019$). Fourteen of 19 hens (73.7%) renested during spring/summer 2000 which was similar to that observed in both 1998 and 1999 ($\underline{P} > 0.05$).

Nest success was greatest in 1998 when 10 of 43 nests (23.3%) were successful (Table 3). In 1999, seven of 46 nests hatched (15.2%), and nest success was dismal during 2000 when only four of 45 nests (8.9%) hatched. There were no indications that nest success differed between the study sites and age and year classes ($\underline{P} \geq 0.135$). Combined nest success in central Illinois during spring/summer 1998-2000 was 15.7 percent (21 of 134 nests hatched). Major nest predators were coyotes and raccoons. Minks (Mustela vison), striped skunks (Mephitis mephitis), opossums (Didelphis virginiana), and snakes were other known nest predators (Table 3). One nest was also indirectly destroyed when a turtle killed an incubating hen while she was at recess from the nest. Four nests were mowed, and another was destroyed when a field was cut for hay. Six hens abandoned their nests due to researcher influence, and another was abandoned for unknown reasons.

Habitats near nest sites were classified as grassland, pasture, hayfield, scrub-shrub, wetland, wooded, and cropland. One hundred thirty-three nests were used to determine the relationship of nest success with habitat type. Nest success was highest in grasslands (22.1%, $\underline{n}$ = 86) where 64.7 percent of all nests occurred. Nest success in pasture ($\underline{n}$ = 11) was 9.1 percent and 4.3 percent in hayfields ($\underline{n}$ = 23). All nests ($\underline{n}$ = 13) were unsuccessful in the remaining four habitat types.

To compare our results with that of previous studies, Mayfield nest success estimates were calculated according to Johnson (1979) using the daily survival rate (DSR). The DSR was raised to the 36th power (mean clutch size + incubation period). In 1998, the Mayfield nest survival rate was 24.8 percent (CI_{95} = 0.145, 0.418). Nest survival was lower in 1999 at 19.0 percent (CI_{95} = 0.109, 0.326) and in 2000 at 16.6 percent (CI_{95} = 0.090, 0.303). The Mayfield nest survival estimate was elevated during spring/summer 2000 when compared to the simple estimate of nest success (8.9%) because many nests were destroyed late in incubation thereby increasing the DSR and inflating the nest survival estimate.

We also examined the relationship between nest success and the juxtaposition of a nest to a wetland. Nests ($\underline{n}$ = 33) within 100 yds of a wetland in 1998 were more successful (30.3%; G_1 = 5.62, $\underline{P}$ = 0.018) than nests ($\underline{n}$ = 9, 0.0%) further from wetlands. In 1999, nest success rates did not differ (close, $\underline{n}$ = 34, 14.7%; far, $\underline{n}$ = 12, 16.7%) in relation to the proximity of a wetland to the nest site (G_1 = 0.03, $\underline{P}$ = 0.872). Although sample sizes of successful nests in 2000 were extremely small, nests farther than 100 yds from a wetland tended to be more successful (20.0%, $\underline{n}$ = 15) than nests closer to wetlands (3.3%, $\underline{n}$ = 30), although not significantly (G_1 = 3.22, $\underline{P}$ = 0.073). When nests were pooled across years, nests within 100 yds (16.5%) had similar nest success rates as nests at greater distances (13.9%) (G_1 = 0.14, $\underline{P}$ = 0.711).

Hen Success

Hen success estimates could be calculated for 86 hens during the study. There was no evidence that hen success differed by study site or age classes ($\underline{P} \geq 0.392$). Ten of 27 hens hatched a nest in 1998 for a hen success rate of 37.0 percent. Seven hens were successful in 1999 yielding a 21.2 percent hen success rate. In 2000, only four hens hatched a nest, and hen success plummeted to a low of 15.4 percent. Year-wise comparisons identified no differences between the percentage of successful hens each year ($G_2 = 3.583$, $\underline{P} = 0.167$); thus, hen success was 24.4 percent for all years. Although the hen success rate in 1998 (37.0%) was 140 percent higher than that observed in 2000 (15.4%), the difference was not significant ($G_1 = 3.280$, $\underline{P} = 0.070$).

Brood Size

The brood size at hatch was determined for 21 successful nests during 1998-2000. Mean brood sizes in 1998 ($\bar{x} = 8.2 \pm 0.9$ ducklings, $\underline{n} = 10$), 1999 ($\bar{x} = 8.3 \pm 0.6$ ducklings, $\underline{n} = 7$), and 2000 ($\bar{x} = 9.5 \pm 0.9$ ducklings, $\underline{n} = 4$) were similar ($\chi^2_1 = 1.56$, $\underline{P} = 0.459$). The overall brood size at hatch was 8.5 ± 0.5 ducklings ($\underline{n} = 21$). Brood size was determined for 14 brood hens where data was available to 17 days posthatch. This estimate, including four hens that suffered total brood loss, was 3.2 ± 0.8 ducklings and was only 37.6 percent of the initial brood size at hatch.

Survival

Nests: Mallard nests were subjected to a Kaplan-Meier survival analysis (Table 4). Nest survival was similar at Banner and MSD in 1998 ($\chi^2_1 = 2.08$, $\underline{P} = 0.150$) which allowed pooling of the study sites. Forty-three nests (28 adult and 15 yearling) were monitored in 1998, and adult nest survival ($\hat{s} = 0.365 \pm 0.101$) was more than double the yearling survival rate ($\hat{s} = 0.143 \pm 0.094$) ($\chi^2_1 = 4.98$, $\underline{P} = 0.026$). Nest survival of adult hens in 1998 was the highest observed during this study. Adult nest survival was lower than that of yearlings in 1999 although not significantly so ($\chi^2_1 = 1.32$, $\underline{P} = 0.251$), and when combined, the survival rate was $\hat{s} = 0.156 \pm 0.055$. Nest survival in 2000 was the lowest observed during this study. Age-wise differences again were not significant ($\chi^2_1 = 0.070$, $\underline{P} = 0.792$), and overall nest survival rate for 2000 declined to $\hat{s} = 0.064 \pm 0.053$.

Broods: Due to limited samples of broods, comparisons were only made between years. Brood survival was high for all years and was $\hat{s} = 0.788 \pm 0.134$ in 1998, $\hat{s} = 0.857 \pm 0.132$ in 1999, and $\hat{s} = 0.667 \pm 0.272$ in 2000. Estimates were similar between the years ($\chi^2_2 = 0.183$, $\underline{P} = 0.912$), and the pooled 1998-2000 survival rate was $\hat{s} = 0.778 \pm 0.101$. Four of 15 hens (26.7%) lost their entire brood, and brood data for six hens was incomplete due to transmitter failure.

Ducklings: One hundred seventy-eight ducklings hatched from 21 successful nests. Duckling survival at Banner and MSD was similar in 1998 ($\chi^2_1 = 0.00$, $\underline{P} = 0.950$). Duckling survival was greater in 1998 ($\hat{s} = 0.500 \pm 0.064$) than in 1999 ($\hat{s} = 0.388 \pm 0.071$) ($\chi^2_1 = 4.41$, $\underline{P} = 0.036$) (Table 5). Duckling survival during 2000 ($\hat{s} = 0.401 \pm 0.093$) was similar to estimates in both 1998 and 1999 ($\underline{P} \geq 0.228$). Survival data for 29 ducklings (3 brood hens) was lost due to transmitter failure. Of the 149 ducklings monitored, 37 (24.8%) died within their first 3 days of life. Survival curves reveal that most mallard duckling mortality (~ 48%) occurs within the first 12 days.

Hens: Hen survival was determined only for resident females because migrant hens were not considered to have undergone the same risks (Table 6). Although not significant ($\underline{P} > 0.05$), yearling survival was higher than adult survival in 1998 and 2000. Yearling survival was lowest in 1999 ($\hat{s} = 0.546 \pm 0.112$) when the age class comparisons were nearly significant ($\chi^2_1 = 3.80$, $\underline{P} =$

0.051). Log-rank tests showed no age or year-wise differences in the hen survival estimates. Twenty-three of 97 hens (23.7%) perished over the period of study and survival was $\hat{s} = 0.653 \pm 0.084$ (Table 6).

JOB NO. I.2. Assessment of Mallard Recruitment.

OBJECTIVE:

To assess the recruitment of mallards nesting in Fulton County, Illinois.

METHODS

We compared the number of ducklings produced by our marked sample of hens each year with the number of hens killed during the nesting season. This comparison provided a simple estimate of mallard production each year without considering the annual survival of hens.

Recruitment (R) was defined as the number of females recruited into the fall population per hen in that year's spring population (Cowardin et al. 1985). We estimated recruitment ($R=HGS_d/2$) according to the Mauser and Jarvis (1994) modification to equation 5 of Cowardin and Johnson (1979:23), where H = hen success (the probability that a hen will have one successful nest in one or more attempts (Cowardin et al. 1985)), G = mean brood size at hatch, and S_d = duckling survival from hatch to 20 days. We assumed a 50:50 sex ratio for the 20-day survival data, hence the division of HGS_d by two. We only collected duckling survival data to 20 days because most mallard duckling mortality occurs within this period (Orthmeyer and Ball 1990, Mauser et al. 1994).

We used equation 4 (Cowardin and Johnson 1979:23) after Mauser and Jarvis (1994) to determine the proportional change in population size (C) where $C=S(1+DR/S_b)$, S was defined as the annual survival of adult females (0.57 ± 0.01, Smith and Reynolds 1992:311), D was the ratio of the annual survival of yearlings to adults [annual yearling female mallard survival was estimated at 0.59 ± 0.02 (Smith and Reynolds 1992:311)], and S_b was defined as the summer survival of yearling and adult female mallards, which was assumed to be equal, and estimated at 0.83 (Anderson 1975:23).

RESULTS

Recruitment 1998

Six mallard hens were killed during the 1998 nesting season (Table 6), and 82 ducklings were produced by the marked sample of hens (Table 5). Duckling survival to 20 days posthatch in 1998 was $\hat{s}$=0.500; therefore, 41 ducklings survived the period. Assuming a 50:50 sex ratio and that duckling survival to 20 days did not vary by sex, 20.5 female ducklings survived. Upon preliminary examination, 3.4 female ducklings were produced for every hen lost during the nesting season. Production exceeded hen mortality during the 1998 nesting season; therefore, the spring 1999 mallard population likely increased over the spring 1998 breeding population.

Mallard recruitment (R) in 1998 was estimated at 0.76 females per hen in the spring population that translated to a proportional increase of 11 percent (C = 1.11) in the mallard breeding population from 1998 to 1999 (Table 7). The high hen success and duckling survival rates encountered in 1998 along with high hen survival ($\hat{s}$=0.672) during the nesting and brooding season resulted in an increase in the mallard breeding population in central Illinois during 1998.

Recruitment 1999

Twelve mallard hens were killed during the 1999 nesting season when only 58 ducklings hatched (Tables 5-6). Duckling survival in 1999 to 20 days posthatch was $\hat{s}$=0.388; therefore, 22.5 ducklings or 11.3 female ducklings survived the period. Upon preliminary examination, 0.9

female ducklings were produced for every hen lost during the nesting season. Since less than one female mallard was produced for every hen lost during the nesting season, the population probably declined from spring 1999 to spring 2000.

During the 1999 nesting season, hen success and duckling survival were low at 21.2 percent and $\hat{s}$=0.388, respectively (Table 7). Subsequently, R was 0.34 females per hen in the spring population, yielding a 19 percent decline in the spring 2000 resident mallard population from the 1999 breeding population. The lower hen survival rate ($\hat{s}$=0.599) and low R of mallards during the 1999 nesting and brooding seasons both suggested a decline in the spring 2000 breeding population. The proportional change in the population was C = 0.81.

Recruitment 2000

Five hens were killed during the 2000 nesting season when only 38 ducklings hatched (Tables 5-6). Duckling survival to 20 days posthatch was $\hat{s}$=0.401 in 2000. This equated to 15.2 ducklings or 7.6 female ducklings surviving. Upon preliminary examination, 1.5 female ducklings were produced for every hen lost during the nesting season. Despite the low hen and nest success rates, production surpassed hen mortality during the nesting season in 2000; however, the sample used to determine duckling survival was small.

Hen success (15%) during the 2000 season was the lowest observed during the 3-yr study (Table 7). The subsequent values for recruitment (R=0.29) and proportional change in the population (C=0.78) were also low. Duckling survival in 2000 ($\hat{s}$=0.401) was similar to that observed in 1999 ($\hat{s}$=0.388). The small number of ducklings produced in 2000 was not enough to compensate for hen mortality throughout the year despite the increased hen survival ($\hat{s}$=0.800) during the 2000 nesting and brooding seasons. The spring 2001 breeding mallard population, like that of spring 2000, should again experience a decline over the preceding year.

DISCUSSION

The fluctuating resident mallard populations in central Illinois during the 1998-2000 nesting seasons may reflect mallard population cycles in nontraditional breeding areas. Petrie (1999) suggested that the wetlands of nontraditional breeding areas were more stable which allowed for more consistent population growth. The apparent decline in recruitment during the 1999 and 2000 breeding seasons suggested that the mallard breeding population in central Illinois was decreasing. Further monitoring of nesting mallards during springs 2001-2003 (PR Project W-130-4-5-6) will allow for a more detailed look at the nesting ecology of mallards in central Illinois.

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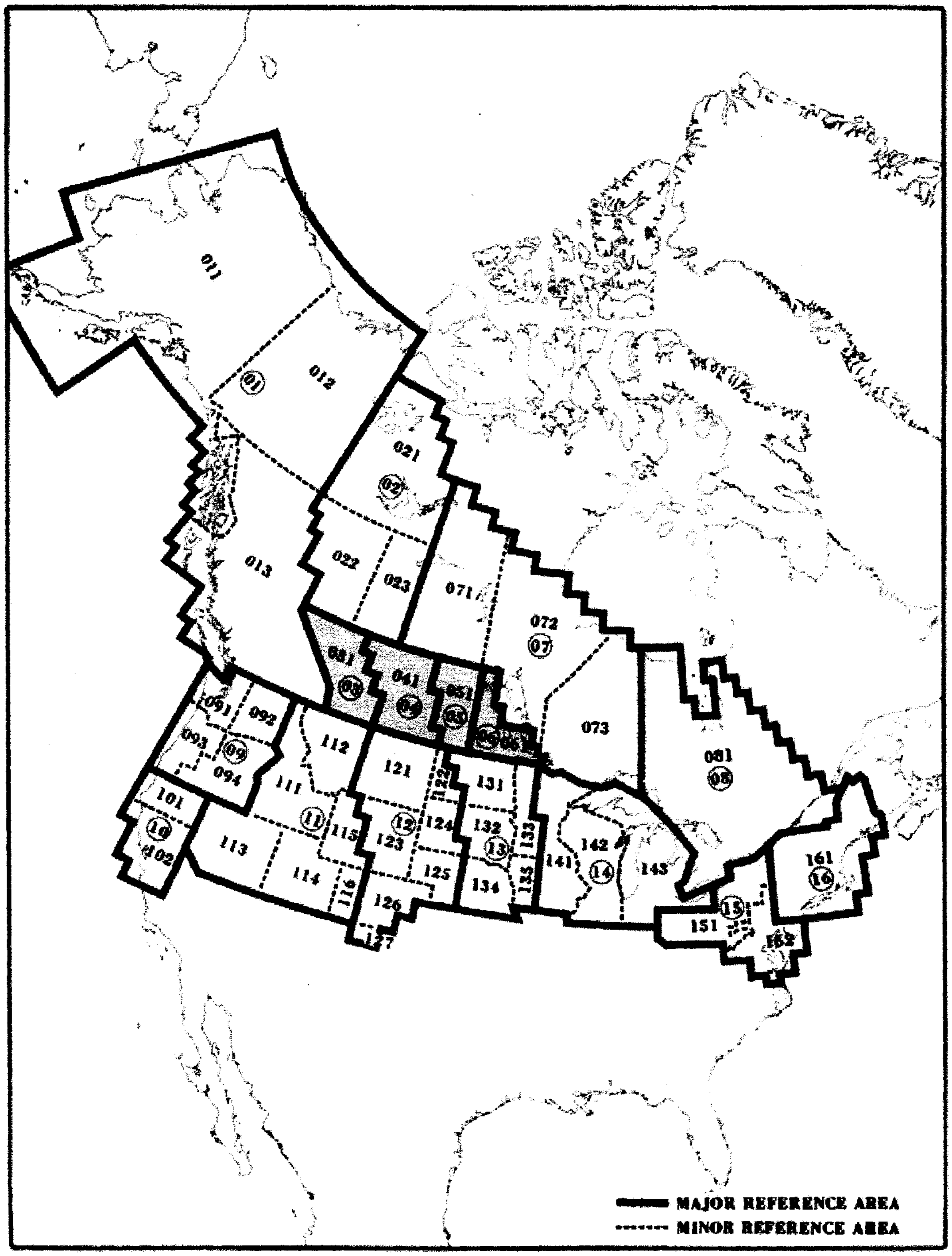

Figure 1. Breeding mallard reference areas in North America. Encircled numbers represent major reference areas (Anderson and Henny 1972, Pospahala et al. 1974).

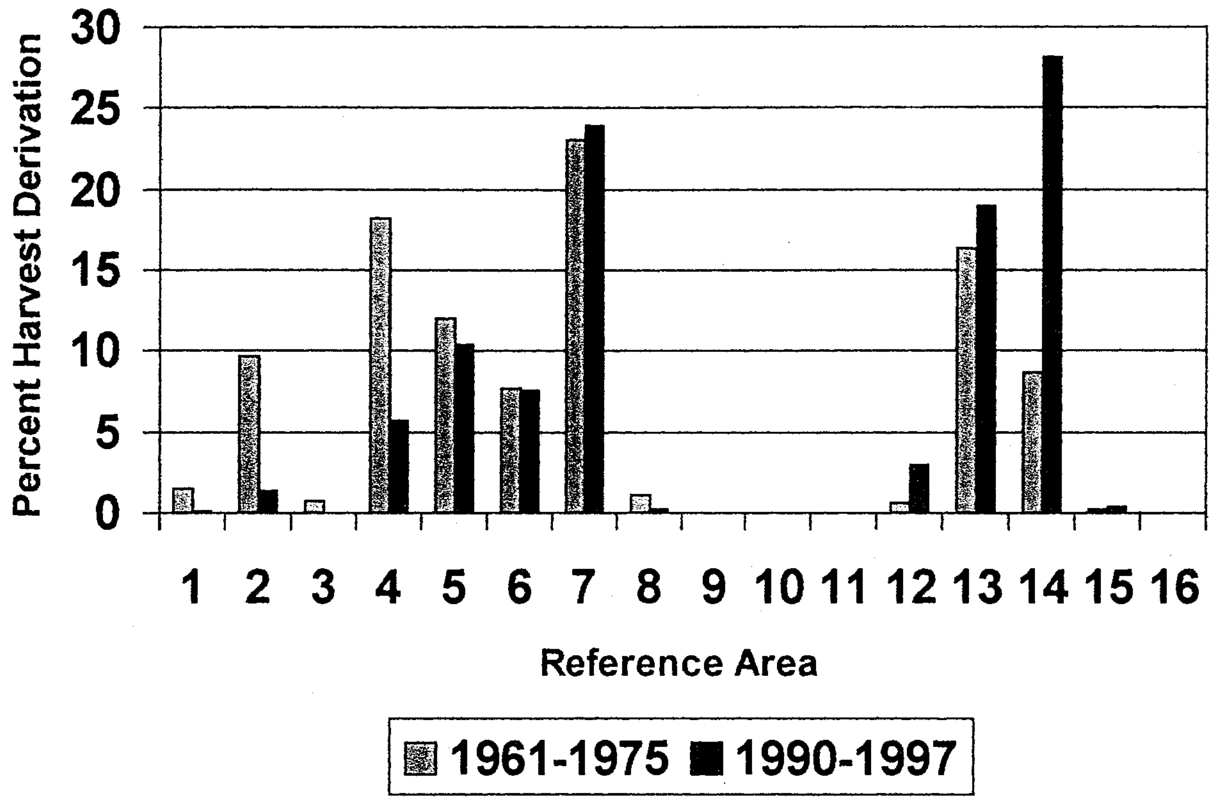

Figure 2. Percent derivation of the Illinois mallard harvest by major reference area (Anderson and Henny 1972, Pospahala et al. 1974; Figure 1). Sources of mallard harvest data were Munro and Kimball (1982) and Zuwerink and Gates (1999).

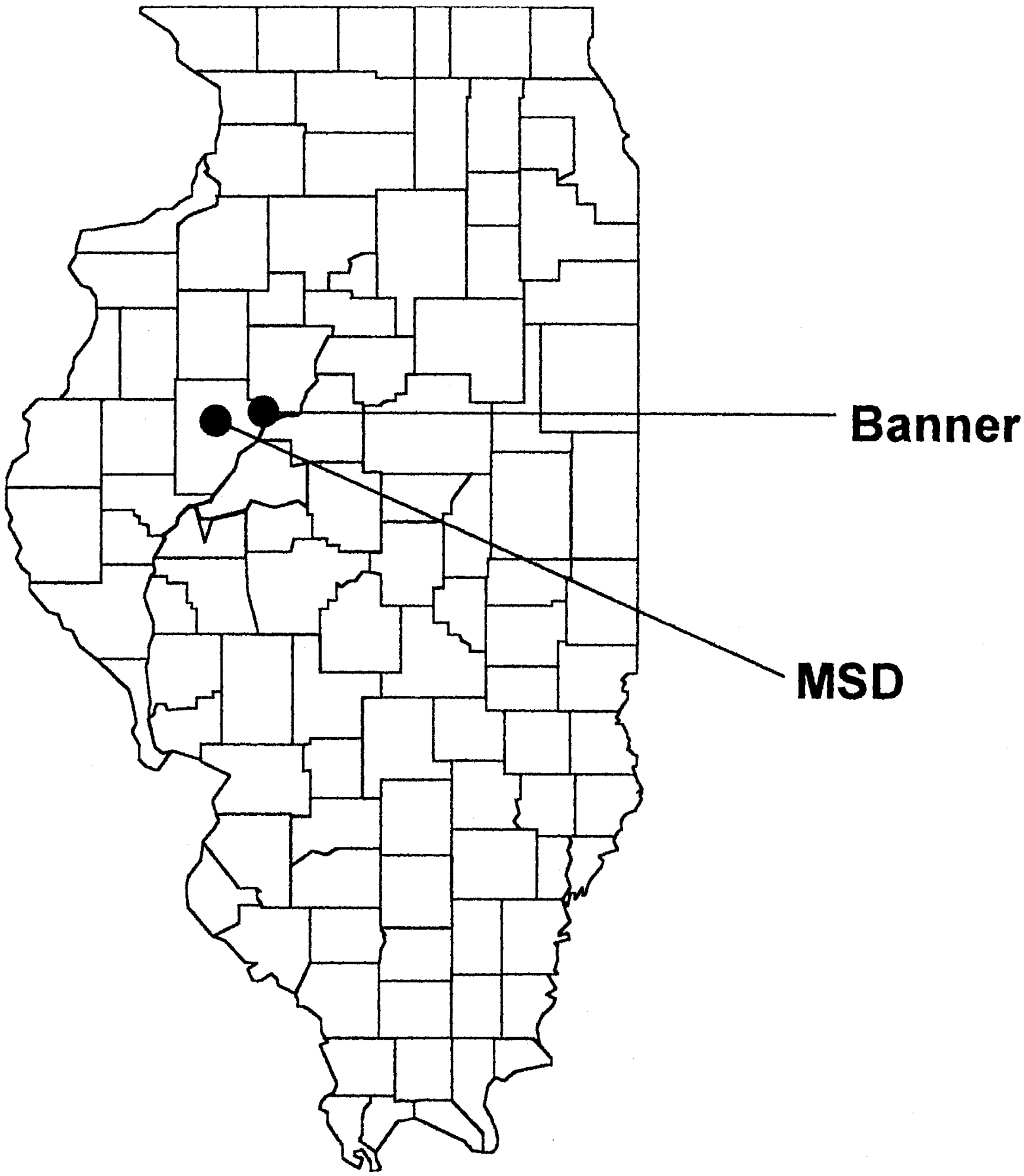

Figure 3. The nesting ecology of mallards was investigated at the Banner Marsh State Fish and Wildlife Area (Banner) and the Prairie Plan Site of the Metropolitan Water Reclamation District of Greater Chicago (MSD) in central Illinois during spring/summer, 1998-2000.

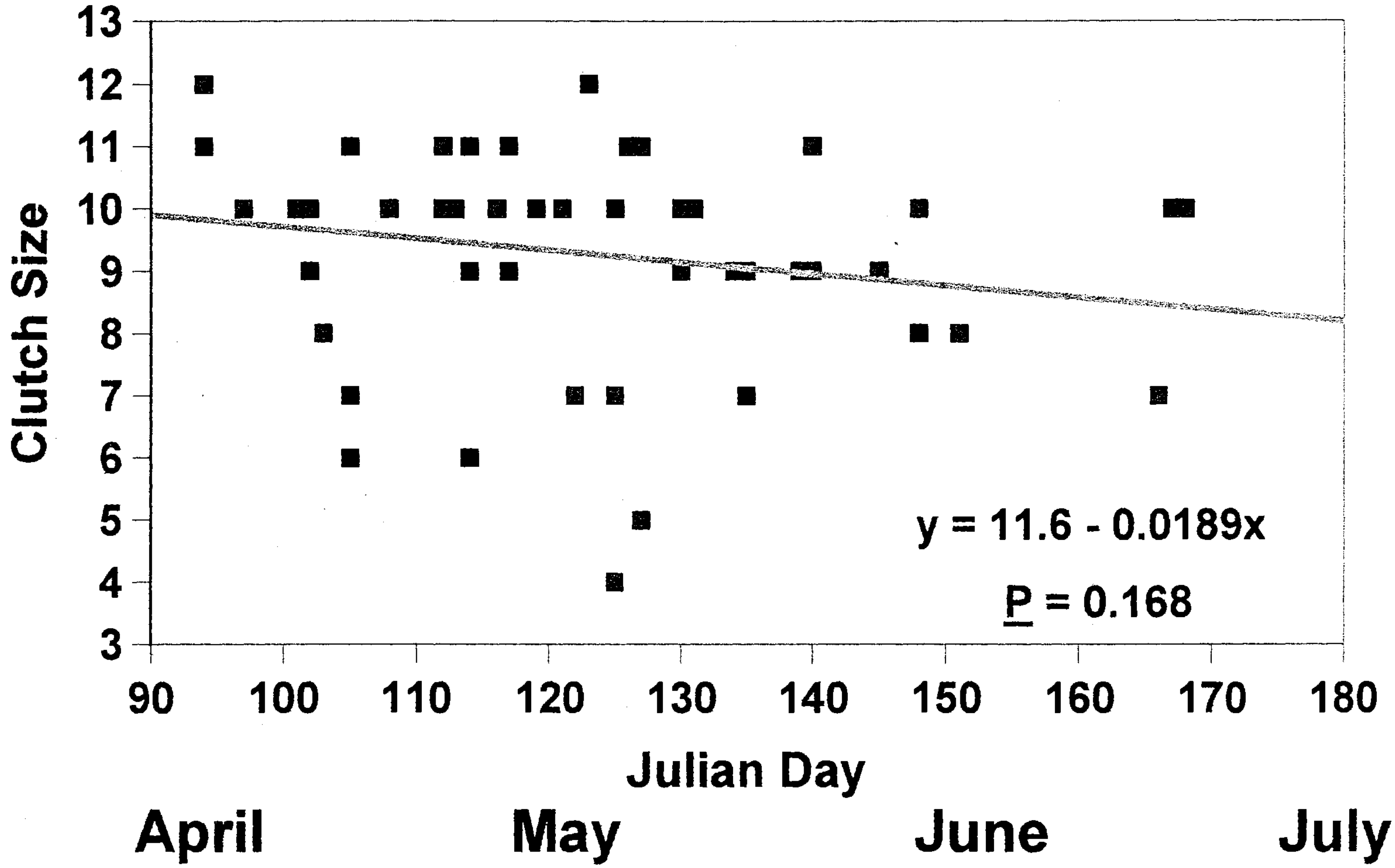

Figure 4. Regression of clutch size on date of nest initiation by mallard hens equipped with radio transmitters in central Illinois during spring/summer, 1998-2000.

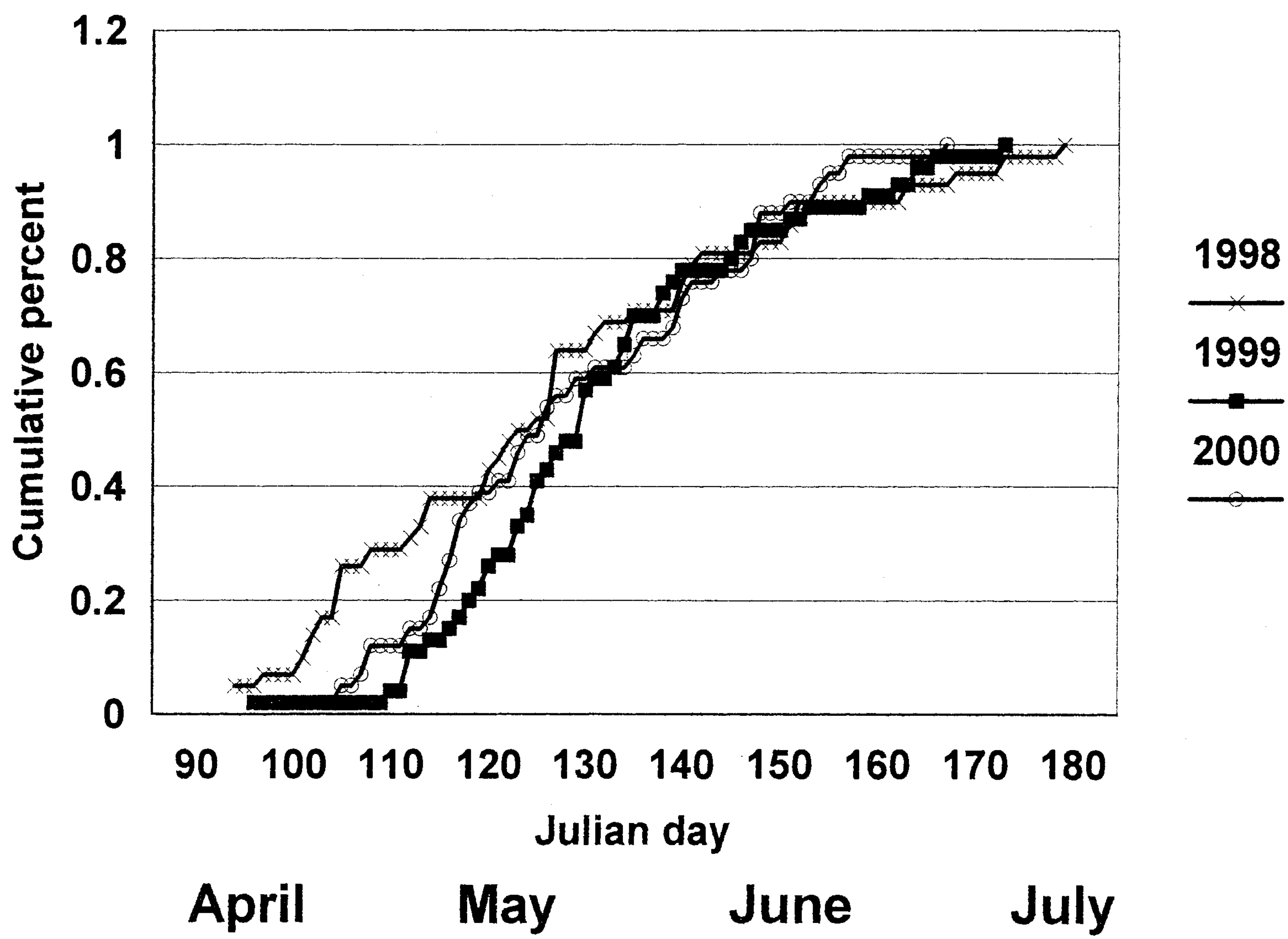

Figure 5. Percentage of mallard nests initiated by Julian day in central Illinois during spring/summer, 1998-2000.

Table 1. Number of mallards decoy trapped and hen mallards equipped with radio transmitters during March-April 1998-2000 in central Illinois.

Sex Status	Number of mallards 1998	 1999	 2000
Female	38	43	38
Nested and tracked successfully	27	33	24
Migrants	10	5	6
Did not nest	0	1	1
Killed before nesting	0	3[a]	1
Radio fell off/failed	1	1	4
Nested but unsuccessfully tracked	0	0	2
Male	50	33	36

[a] One hen in 1999 was killed within two days of transmitter attachment and was excluded from data analysis.

Table 2. Mean (± SE) morphological measurements and body condition indices of resident mallards in central Illinois, 1998-2000.

	1998		1999		2000	
Measurement[a]	Male (n=10)	Female (n=28)	Male (n=16)	Female (n=37)	Male (n=9)	Female (n=32)
Bill width (mm)	24.2 (0.2)	22.8 (0.2)	23.9 (0.2)	23.1 (0.1)	24.0 (0.2)	23.0 (0.1)
Culmen 1 (mm)	55.1 (0.8)	51.9 (0.5)	56.3 (0.8)	52.3 (0.3)	54.7 (1.0)	51.4 (0.4)
Culmen 2 (mm)	63.9 (0.9)	59.5 (0.4)	64.0 (0.8)	59.0 (0.4)	63.6 (1.2)	58.6 (0.4)
Tarsus width (mm)	5.3 (0.1)	5.2 (0.1)	5.2 (0.1)	5.0 (0.0)	5.4 (0.2)	5.1 (0.1)
Tarsus length (mm)	47.6 (1.0)	47.4 (0.4)	52.0 (0.5)	48.9 (0.3)	51.7 (1.0)	48.7 (0.4)
Total tarsus (mm)	55.3 (0.8)	53.6 (0.3)	56.4 (0.4)	53.6 (0.3)	57.1 (0.7)	54.1 (0.4)
Mass (g)	1,223.5 (26.9)	1,121.4 (15.9)	1,155.6 (18.5)	1,062.7 (13.3)	1,242.2 (17.7)	1,075.0 (13.5)
Wing chord (mm)	289.0 (2.9)	267.6 (1.3)	290.2 (2.1)	270.2 (1.2)	289.3 (1.9)	272.5 (1.1)
Body condition[b]	4.23 (0.09)	4.19 (0.06)	3.98 (0.06)	3.93 (0.04)	4.30 (0.08)	3.95 (0.05)

[a] Bill and leg measurements described by Byers and Cary (1991).
[b] Mass (g)/wing chord (mm).

Table 3. Number and fate of mallard nests from radio-equipped hens in central Illinois during spring/summer, 1998-2000.

Nest fate	Year		
	1998	1999	2000
Hatched	10	7	4
Coyote (Canis latrans)	15	10	7
Raccoon (Procyon lotor)	8	3	5
Mink (Mustela vison)	0	0	1
Snake	1	3	1
Striped skunk (Mephitis mephitis)	0	0	1
Opossum (Didelphis virginiana)	0	0	1
Turtle	0	1	0
Unknown mammal	4	12	8
Unknown	3	7	17
Abandoned[a]	6	1	0
Mowed/hayed	1	3	0
Total	48	47	45

[a] Five nests were abandoned due to researcher influence in 1998 and one in 1999.

Table 4. Kaplan-Meier nest survival estimates, 95% confidence intervals, and log-rank statistics for mallard hens monitored in central Illinois during spring/summer, 1998-2000.

Year	Age of hen	No. at risk	No. failed	Survival	95% CI	χ^2	P
1998	Adult	28	15	0.3647	0.1663 - 0.5631	4.980	0.026
	Yearling	15	12	0.1429	0.0000 - 0.3262		
1999	Adult	26	22	0.1067	0.0000 - 0.2351	1.132	0.251
	Yearling	19	15	0.2105	0.0272 - 0.3938		
	Combined	45	37	0.1559	0.0473 - 0.2645		
2000	Adult	33	30	0.0606	0.0000 - 0.1613	0.070	0.792
	Yearling	6	5	0.1667	0.0000 - 0.4648		
	Combined	39	35	0.0641	0.0000 - 0.1672		

Table 5. Kaplan-Meier survival estimates and 95% confidence intervals for mallard ducklings in central Illinois during spring/summer, 1998-2000.

Year	No. at risk	No. failed	Survival[a]	95% CI
1998	82	34	0.5004 a	0.3748 - 0.6260
1999	58	31	0.3877 b	0.2481 - 0.5273
2000	38	17	0.4008 ab	0.2183 - 0.5833

[a] Survival estimates with different letters were statistically different ($\underline{P} \leq 0.05$), log-rank statistics.

Table 6. Kaplan-Meier survival estimates, 95% confidence intervals, and log-rank statistics for mallard hens equipped with radio transmitters in central Illinois during spring/summer, 1998-2000.

Year	Age of hen	No. at risk	No. failed	Survival	95% CI	χ^2	P
1998	Adult	19	4	0.6241	0.2476 - 1.0000	0.005	0.943
	Yearling	9	2	0.7500	0.4499 - 1.0000		
	Combined	28	6	0.6721	0.4001 - 0.9441		
1999	Adult	17	3	0.7161	0.4182 - 1.0000	3.800	0.051
	Yearling	20	9	0.5455	0.3254 - 0.7656		
	Combined	37	12	0.5994	0.3916 - 0.8072		
2000	Adult	24	4	0.7929	0.6049 - 0.9810	0.005	0.946
	Yearling	8	1	0.8571	0.5978 - 1.0000		
	Combined	32	5	0.7997	0.6343 - 0.9651		
1998-2000	Combined	97	23	0.6531	0.4889 - 0.8173	1.104	0.576

Table 7. Estimates of parameters (SE) used to calculate recruitment (R) and change in population size (C) for breeding mallards in central Illinois during 1998-2000.

Parameter	Year		
	1998	1999	2000
Hen success	0.37	0.21	0.15
Duckling survival[a]	0.500 (0.064)	0.388 (0.071)	0.401 (0.093)
Brood size at hatch	8.20 (0.87)	8.29 (0.64)	9.50 (0.87)
Recruitment (R)	0.76	0.34	0.29
Adult female survival[b]	0.57 (0.01)	0.57 (0.01)	0.57 (0.01)
Juvenile female survival[b]	0.59 (0.02)	0.59 (0.02)	0.59 (0.02)
Female summer survival[c]	0.83	0.83	0.83
Population change (C)	1.11	0.81	0.78

[a] Duckling survival was calculated to 20 days posthatch.

[b] Smith and Reynolds (1992:311).

[c] Anderson (1975:23).

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