To the Graduate Council:

I am submitting herewith a thesis written by Billy Wayne Harris II entitled "Nesting Success and Nesting Ecology of Northern Bobwhite in Western Tennessee." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

Ralph W Dimmick

Dr. Ralph W. Dimmick, Major Professor

We have read this thesis
and recommend its acceptance:

David A Buehler

David A Etnier

Accepted for the Council:

Associate Vice Chancellor and
Dean of The Graduate School

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a Master's degree at The University of Tennessee, Knoxville, I agree that the Library shall make it available to borrowers under rules of the Library. Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of the source is made.

Permission for extensive quotation from or reproduction of this thesis may by granted by my major professor, or in his absence, by the Head of Interlibrary Services when, in the opinion of either, the proposed use of the material is for scholarly purposes. Any copying or use of the material in this thesis for financial gain shall not be allowed without my written permission.

Signature Billy Wayne Harris II

Date 4-6-95

NESTING SUCCESS AND NESTING ECOLOGY OF NORTHERN BOBWHITE IN WESTERN TENNESSEE

A Thesis
Presented for the
Master of Science Degree
The University of Tennessee, Knoxville

Billy Wayne Harris, II
May 1995

Acknowledgements

I wish to thank my major professor, Dr. Ralph W. Dimmick, Professor of Wildlife Science, University of Tennessee, for his support, friendship, and guidance during my time spent in Knoxville. I also wish to thank my committee members, Dr. David A. Buehler, Assistant Professor of Wildlife Science, University of Tennessee, and Dr. David A. Etnier, Professor of Zoology, University of Tennessee, for their friendship and review of this thesis. Many thanks also go to Mr. William G. Minser, Research Associate, University of Tennessee, for his assistance, advice, friendship, and inexhaustable sense of humor.

Thanks go to many fellow graduate students and friends, including John Bartlett, Brian Clark, Chris Diehl, Thomas Eason, Rick Eastridge, Shane Gaither, Mark Garner, Bob Inman, Joressia Jamison, Jeff Jones, Kirk Miles, Dwight O'Neal, Joel Pedersen, Frank Van Manen, Ben West, Sherry West, and Kathy Yoke, who provided the assistance and fellowship to keep my going. John Schneider provided statistical assistance. I truly appreciate all the secretarial assistance and humor provided by Susan Caldwell, Sharon Farrell, Kelli Key, Lavetta Tate, Martha Thompson, Gloria Walker, and Terri White of the Department of Forestry, Wildlife, and Fisheries. I also want to thank my

friends and neighbors, the Medlin and Pacetti families, for their support and friendship.

Finally I would like to thank my parents, Bill and Donna Harris, my brother Jonathan, and my grandparents. Without their help and support my work would not have been possible.

Abstract

Nesting success and nesting ecology of northern bobwhites (*Colinus virginianus*) were studied on Ames Plantation, Fayette Co., Tennessee. Data for the study were collected from 1967-1973 as part of a long term University of Tennessee research project concerned with many aspects of bobwhite ecology. The major objectives of this study were to: (1) correlate bobwhite nesting success with nesting habitat, (2) determine seasonal changes in bobwhite nesting success, and (3) characterize bobwhite nesting ecology and nesting habitat attributes in western Tennessee. The Mayfield method for estimating nesting success was utilized to obtain egg and nest survival rates over all variables. Overall egg (Me) and nest (Mn) survival rates were 8.52% (N = 2448) and 7.37% (N = 232), respectively. Nesting success was related to area management, distance to edge, cover height, percent shade, dominant vegetation, and subdominant vegetation at nest sites. Eggs in nests located in burned areas (14.52%) were more likely to hatch than other eggs. Eggs survived at higher rates in nests at distances of 3.7 to 7.2 m from an edge (28.06%) than other nests. Eggs in nests located in areas with cover 0 to 20 cm tall (46.86%) and 31 to 40 percent shade (80.05%) were more successfulthan all others. Vegetation types supporting the highest egg

survival rates were miscellaneous (63.75%) and panicum (*Panicum* spp.) (49.18%) dominant types and partridge pea (*Cassia fasciculata*) (65.48%) and broomsedge (*Andropogon virginicus*) (54.72%) subdominant types. Egg survival increased throughout the nesting season from May (0.50%) through August (38.85%). Precipitation during January was positively correlated with egg survival while the number of unusually cold winter nights (below -12 C) was negatively correlated with reproductive success. Overall nesting ecology of bobwhites on Ames Plantation was similar to that on other areas. Mean size for 252 complete clutches was 11.6, with a hatching rate (the percent of eggs in nests at hatching time that hatched) of 96.7%. The onset of nest building was week 4 April with nests hatching from 5 June through 17 September.

Table of Contents

Chapter		Page
I.	Introduction	1
II.	Study Area Description	4
III.	Methods	8
	Data Collection	8
	Data Analysis	12
	Data Entry	12
	Mayfield Success Calculations	12
	Nesting Ecology	15
	Habitat Use	15
IV.	Results	16
	Data Collection	16
	Data Analysis	16
	Data Entry	16
	Mayfield Calculations	18
	Overall Survival	18
	Survival Related to Habitat	18
	Survival Related to Seasonal Chronology	29
	Survival Related to Weather	30
	Survival Related to Miscellaneous Factors	35
	The Mayfield Method and Standard Success Estimators	37
	Nesting Ecology	42
	Habitat Use	46
V.	Discussion	53
	Survival Related to Habitat	55
	Survival Related to Seasonal Chronology	60
	Survival Related to Weather	62
	Survival Related to Miscellaneous Factors	64
	Nesting Ecology	67
VI.	Management Implications	68
	Literature Cited	71
	Appendix	77
	VITA	81

List of Tables

Table		Page
1.	Summary of bobwhite nests located on Ames Plantation, Fayette Co., Tennessee, 1967-1973	17
2.	Yearly reproductive success of bobwhites on Ames Plantation, Fayette Co., Tennessee, 1967-1973	19
3.	Bobwhite nesting success rates by area management, Ames Plantation, Fayette Co., Tennessee, 1967-1973	21
4.	Bobwhite nesting success rates by distance to edge, Ames Plantation, Fayette Co., Tennessee, 1967-1973	22
5.	Bobwhite nesting success rates by cover height, Ames Plantation, Fayette Co., Tennessee, 1967-1973	24
6.	Bobwhite nesting success rates by percent shade, Ames Plantation, Fayette Co., Tennessee, 1967-1973	25
7.	Bobwhite nesting success rates by dominant vegetation, Ames Plantation, Fayette Co., Tennessee, 1967-1973	27
8.	Bobwhite nesting success rates by subdominant vegetation, Ames Plantation, Fayette Co., Tennessee, 1967-1973	28
9.	Bobwhite nesting success rates by incubating parent, Ames Plantation, Fayette Co., Tennessee, 1967-1973	36
10.	Summary of Pearson correlation coefficients between the Mayfield and standard methods of calculating bobwhite reproductive success, Ames Plantation, Fayette Co., Tennessee, 1967-1973	40
11.	Summary of Pearson correlation coefficients between 4 bobwhite reproductive success estimators and both March and December bobwhite populations, Ames Plantation, Fayette Co., Tennessee, 1967-1973	41

12. Summary of bobwhite clutch sizes and hatching rates by year, Ames Plantation, Fayette Co., Tennessee, 1967-1973..... 43

13. Summary of ultimate fates of bobwhite nests, Ames Plantation, Fayette Co., Tennessee 1967-1973..... 47

14. Summary of cover heights at bobwhite nest sites, Ames Plantation, Fayette Co., Tennessee, 1967-1973..... 49

15. Summary of cover types at bobwhite nest sites, Ames Plantation, Fayette Co., Tennessee, 1967-1973..... 51

16. Climatological data recorded at Bolivar Water Works, Hardeman Co., Tennessee, 1967-73..... 78

List of Figures

Figure		Page
1.	Location of Ames Plantation (*) in Hardeman and Fayette Counties, Tennessee.....	5
2.	Ames Plantation Morning Field Trial Course showing the west pasture (A), east pasture (B), north Turner Ditch (C), south Turner Ditch (D), and Goddard Farm (E) nest search areas.....	9
3.	Bobwhite reproductive success rates by month of nest initiation, Ames Plantation, Fayette Co., Tennessee, 1967-1973.....	31
4.	Bobwhite reproductive success rates by week of nest initiation, Ames Plantation, Fayette Co., Tennessee, 1967-1973.....	32
5.	Mean January temperatures and yearly egg success rate, Ames Plantation, Fayette Co., Tennessee, 1967-1973.....	34
6.	Yearly bobwhite reproductive success rates vs. pre-breeding population size, Ames Plantation, Fayette Co., Tennessee, 1967-1973.....	38
7.	Bobwhite nests initiation by week, Ames Plantation, Fayette Co., Tennessee, 1967-1973.....	44
8.	Bobwhite nests hatching by week, Ames Plantation, Fayette Co., Tennessee, 1967-1973.....	45

Chapter I

Introduction

Limited research has been conducted on northern bobwhite (*Colinus virginianus*) nesting success and nesting habitat. However, a multitude of studies, including investigations of population density, predation, hunting impacts, habitat management practices, and overall bobwhite ecology have been completed throughout the species' broad range. The limited number of nesting research projects may reflect the difficulty in locating a sufficient number of quail nests for study.

Several bobwhite nesting studies yielded similar results when nesting success was defined as the percentage of nests hatching. Success rates in southern Illinois ranged from 21.0 to 52.8% with a 15-year mean of 32.7% for 793 nests (Roseberry and Klimstra 1984). Dimmick (1974) observed 766 "used" nests (nests with eggs or egg fragments when found) over 7 nesting seasons on Ames Plantation in western Tennessee. Success rates on this area ranged from 17.1 to 36.6% with a mean of 23.0%. Minser and Dimmick (1988) calculated success rates of 16.0 and 18.0% for 2 relatively small samples (N=19 and N=11, respectively) of nests from other study sites on Ames Plantation. Success

rates in southwest Georgia were 17.5% on Nilo Plantation and 18.6% on an adjoining tract (Simpson and Frazier 1974). Several earlier studies, however, estimated higher success rates. Stoddard (1931) reported success rates ranging from 28.0 to 41.8% in southern Georgia and northern Florida. Nesting success rates averaged 46.0% in southwestern Texas (Lehmann 1946), 62.9% in eastern Texas (Parmalee 1955), and 39.4% in southern Illinois (Klimstra and Scott 1957).

Each of the preceding studies determined success of nests from hatching data. In each of these studies, a nest that hatched 1 egg was considered as successful as a nest that hatched 15 eggs. This crude measure of relative productivity may be adjusted by estimating nesting success from recorded exposure or risk time (Mayfield 1961, 1975). Mayfield success rates are generated using data from all active nests that were revisited by researchers regardless of the stage in which they were first found or their ultimate fate.

This technique increases sample sizes of nests that can be utilized for analyzing nesting success. Although the Mayfield method has not been used to estimate bobwhite productivity, it has proved to be valuable in studies of many other bird species including Kirtland's warblers (*Dendroica kirtlandii*) (Mayfield 1961, 1975), dickcissels (*Spiza americana*) (Zimmerman 1982), dabbling ducks (*Anas*

spp.) (Duebbert and Lokemoen 1980, Klett et al. 1988, Sovada et al. 1995), white-tipped doves (*Leptotila verreauxi*) (Boydstun and DeYoung 1987), white-tailed tropicbirds (*Phaethon lepturus*) (Schaffner 1991), and simulated ground nests (Angelstam 1986, Sugden and Beyersbergen 1986).

The major objectives of this study were:

1) to correlate bobwhite nesting success with various attributes of nesting habitat.
2) to evaluate bobwhite nesting success with regard to seasonal chronology and among years.
3) to characterize bobwhite nesting ecology and nesting habitat attributes in western Tennessee.

Chapter II

Study Area Description

Data for this study were collected on Ames Plantation, a 7527-ha University of Tennessee Agricultural Experiment Farm in Hardeman and Fayette counties in southwestern Tennessee. Ames Plantation, near Grand Junction, is approximately 96 km east of Memphis and 16 km north of the Mississippi state line (Figure 1). An 850.5-ha area of the plantation has been used for a bobwhite study from 1966 until the present. This area is also the morning course for the National Bird Dog Field Trial Championship for pointing bird dogs. About 324 ha of the 850.5-ha study area was maintained in suitable nesting habitat during the period of study (Dimmick 1971).

The topography of the area, typical of the southern Mississippi Valley silty upland physiographic province, is relatively flat although deep ditches have been cut from many years of erosion. Elevations in Fayette County range from 81 to 180 m above sea level (ASL) with a mean of 120 m ASL. Soils are chiefly deep, fertile silt loams overlying sandy substrates (Flowers 1964). Most soils on the area are extremely well-drained, highly erodible, and good for agricultural practices (Houston 1991). Streams are

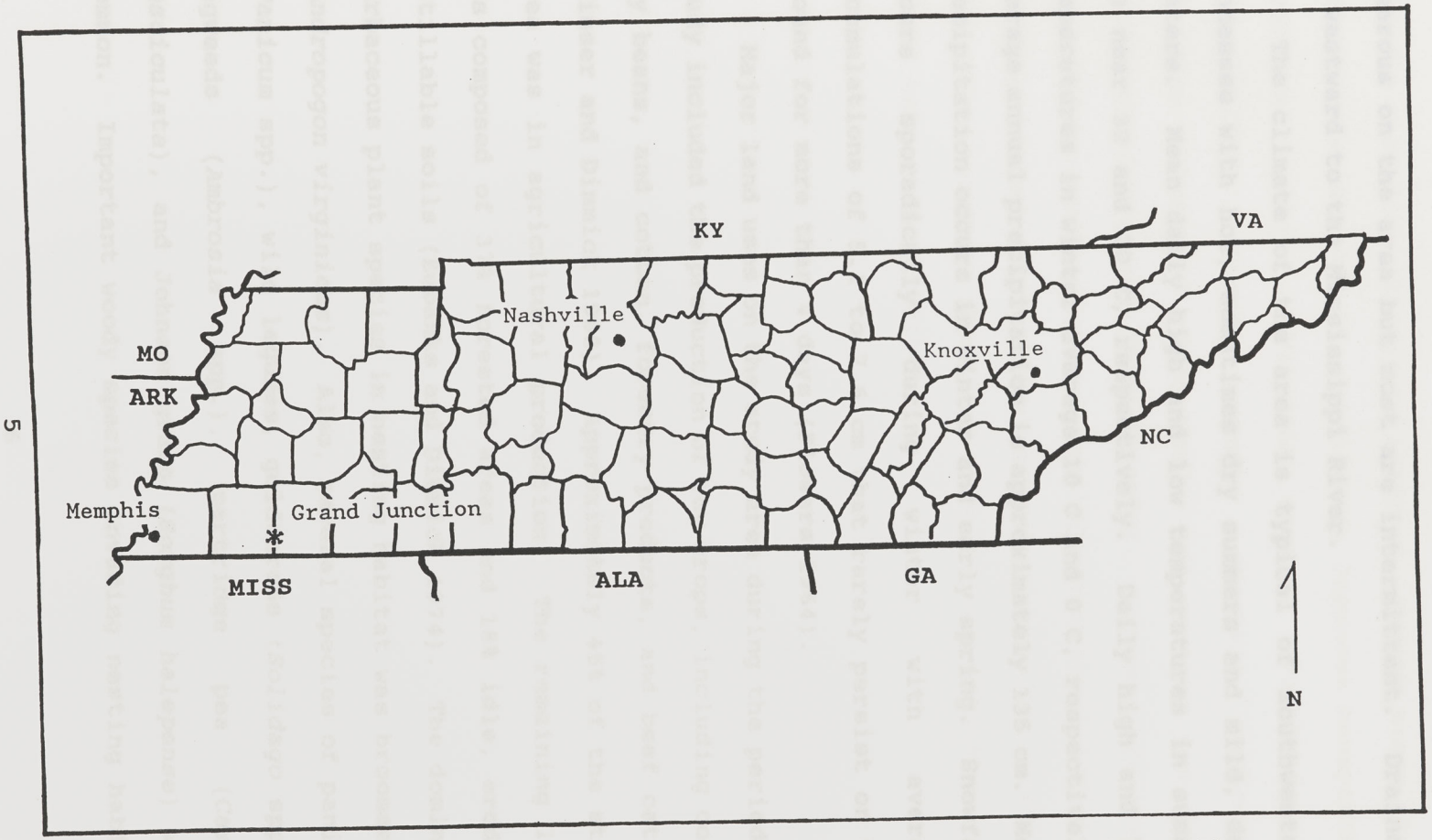


Figure 1. Location of Ames Plantation (*) in Hardeman and Fayette counties, Tennessee.

numerous on the area but most are intermittent. Drainage is westward to the Mississippi River.

The climate of the area is typical of southwestern Tennessee with hot, sometimes dry summers and mild, damp winters. Mean daily high and low temperatures in summer are near 32 and 20 C, respectively. Daily high and low temperatures in winter average 10 C and 0 C, respectively. Average annual precipitation is approximately 135 cm. Most precipitation occurs in winter and early spring. Snowfall occurs sporadically during winter with average accumulations of 5.1 to 7.6 cm that rarely persist on the ground for more than 4 days (Flowers 1964).

Major land uses on the study area during the period of study included the production of row crops, including corn, soy beans, and cotton, forestry products, and beef cattle (Minser and Dimmick 1988). Approximately 45% of the study area was in agricultural production. The remaining land was composed of 37% forested areas and 18% idle, eroded, untillable soils (Eubanks and Dimmick 1974). The dominant herbaceous plant species in nesting habitat was broomsedge (*Andropogon virginicus*). Also, several species of panicum (*Panicum* spp.), wild legumes, goldenrods (*Solidago* spp.), ragweeds (*Ambrosia* spp.), partridge pea (*Cassia fasciculata*), and Johnson grass (*Sorghum halepense*) were common. Important woody species invading nesting habitat

included sassafras (*Sassafras albidum*), smooth sumac (*Rhus glabra*), winged sumac (*R. copallina*), Japanese honeysuckle (*Lonicera japonica*), Virginia creeper (*Parthenocissus quinquefolia*), trumpet creeper (*Campsis radicans*), persimmon (*Diospyros virginiana*), and eastern red cedar (*Juniperus virginiana*) (Eubanks 1972). Forested areas were dominated by various lowland oaks (*Quercus* spp.) and sweet gum (*Liquidambar styraciflua*) in moist areas and loblolly pine (*Pinus taeda*), shortleaf pine (*Pinus echinata*), and upland oaks on drier sites.

Chapter III

Methods

I. Data Collection

Bobwhite nest searches were completed from 1967 through 1973 on 5 separate areas of suitable nesting habitat. These 5 areas, west pasture, east pasture, north Turner Ditch, south Turner Ditch, and Goddard Farm, accounted for approximately 81 ha of the 850.5-ha study area (Figure 2). Nests were located by teams of 3 to 5 persons walking in close proximity to each other parting the vegetation with staffs (Dimmick 1971, 1974). After each nest was located a detailed map was constructed and a set of habitat and nest characteristics were recorded. Nests were also marked with survey flagging to aid in future location. Markers were placed at a distance from nests to minimize detection by predators.

Data collected upon initial discovery of the nests included date, number of eggs in nest, search area, present status, area management, direction of nest entrance, slope degree, distance to "ecotone", distance to "edge", land use type, cover height, cover density, distance to permanent water, percent shade, approximate nest initiation date, dominant vegetation, subdominant vegetation, and sex of

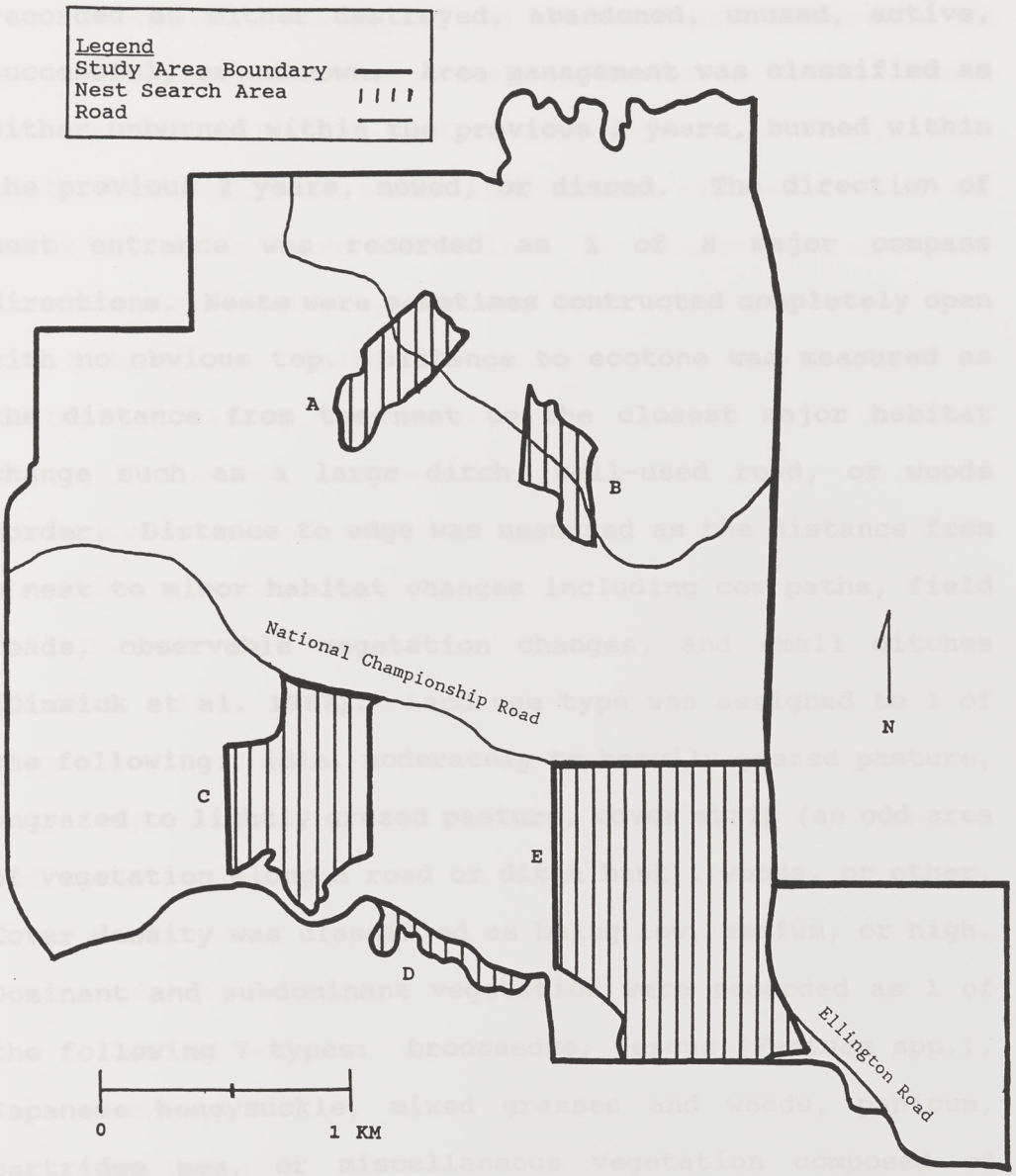


Figure 2. Ames Plantation Morning Field Trial Course showing the west pasture (A), east pasture (B), north Turner Ditch (C), south Turner Ditch (D), and Goddard Farm (E) nest search areas.

incubating parent. Although most of these variables are self-explanatory others need clarification. Status was recorded as either destroyed, abandoned, unused, active, successful, or unknown. Area management was classified as either unburned within the previous 2 years, burned within the previous 2 years, mowed, or disced. The direction of nest entrance was recorded as 1 of 8 major compass directions. Nests were sometimes contructed completely open with no obvious top. Distance to ecotone was measured as the distance from the nest to the closest major habitat change such as a large ditch, well-used road, or woods border. Distance to edge was measured as the distance from a nest to minor habitat changes including cow paths, field roads, observable vegetation changes, and small ditches (Dimmick et al. 1967). Land use type was assigned to 1 of the following: idle, moderately to heavily grazed pasture, ungrazed to lightly grazed pasture, cover strip (an odd area of vegetation along a road or ditch bank), woods, or other. Cover density was classified as being low, medium, or high. Dominant and subdominant vegetation were recorded as 1 of the following 7 types: broomsedge, fescue (*Festuca* spp.), Japanese honeysuckle, mixed grasses and weeds, panicum, partridge pea, or miscellaneous vegetation composed of goldenrod, sumacs, ragweeds, blackberry (*Rubus* spp.), or

woods. Incubating parent was cock, hen, alternating, or none.

Nests were revisited at 1 to 5-day intervals to determine their progress. Data collected on revisits were date, number of eggs in nest, status, and incubating parent. Nests were revisited until they either hatched or failed. Fates of nests were determined by inspecting the nest structure and contents. Fate of nest was recorded as 1 of the following: destroyed during egg laying, abandoned during egg laying, destroyed during incubation, abandoned during incubation, destroyed during incubation and followed through egg laying, abandoned during incubation and followed through egg laying, hatched, unused, destroyed at a previous but unknown time when found, abandoned when found, or unknown. Active nests were checked for the presence of pipped shell caps which indicated hatching. The presence of small egg fragments, chewed eggs, or no egg fragments indicated destruction of the nest. Old, discolored, or dirty eggs were typical signs that a nest had been abandoned. Abandonment may have resulted from the death of one or both parents, or may have been the decision of one or both parents.

Climatological information for the period was compiled from data collected at the Bolivar, Tennessee weather station (U.S. Environmental Data Service 1967-1973), 25 km

to the northeast. Climatological parameters used to examine relationships between weather patterns and bobwhite reproductive success included mean monthly high and low temperatures, mean monthly temperature, extreme winter low temperatures, yearly precipitation, monthly precipitation, greatest single day precipitation, and the number of days per month with precipitation.

II. Data Analysis

i. Data Entry

Original field data were entered into an Alpha4 database (Alpha Software Corp., Burlington, MA). All information from initial location of each nest was entered for analysis. Data from revisits were manipulated upon data entry to allow for ease in calculating nesting success. Manipulation consisted of recording additional variables determined from originally recorded variables, including number of days revisited, egg-days during laying, nest-days during laying, egg-days during incubation, and nest-days during incubation.

ii. Mayfield Calculations

Reproductive success rates (egg and nest survival rates) were calculated using methods described by Mayfield (1961,1975). The Mayfield method incorporates the use of

exposure data, the egg-day and nest-day. An egg-day is 1 egg surviving intact for 1 day and, similarly, a nest-day is 1 nest surviving intact for 1 day. This method allows for the use of data from nests which were visited at least 2 times while the nest was active, regardless of whether the nest was ultimately successful. The destruction, predation, or abandonment of a nest between visits was estimated to have happened at the midpoint between the respective days. The sample sizes (N) of eggs and nests were reported in tables as "Total Eggs" and "Total Nests".

Mayfield's studies of nesting success were accomplished using data from Kirtland's Warbler (*Dendroica kirtlandii*) nests. The differences between estimating the nesting success of this altricial passerine and the precocial northern bobwhite can be adjusted. Mayfield calculations for bobwhites follow nests through the laying and incubation periods, rather than the incubation and fledgling periods of altricial songbirds.

Data were entered into the SAS System (SAS Institute Inc., Cary, NC) to generate Mayfield egg (Me) and nest (Mn) success probabilities. These probabilities were analyzed with respect to year, habitat, seasonal chronology, weather, and miscellaneous variables. One-way analysis of variance (ANOVA) was used to test for differences among survival probabilities across variable classes. Patterns in residual

vs. predicted value plots suggested normal distributions over all variables.

Mayfield egg (Me) and nest (Mn) survival estimates were generated using the following formulae:

1. **Me = ESL * ESI * HR**, where

ESL = (# eggs surviving laying / # egg-days laying)^{Ch}

C = mean clutch size for the sample

ESI = (# eggs surviving incubation / # egg-days incubation)^{23}

23 = mean incubation time in days

HR = # eggs that hatch / # eggs in nest at hatching

and 2. **Mn = NSL * NSI**, where

NSL = (# nests surviving laying / # nests-days laying)^{Ch}

C = mean clutch size for the sample

NSI = (# nests surviving incubation / # nests-days incubation)^{23}

23 = mean incubation time in days

Although the chance of a nest being successful is an important aspect of this study, the probability of success for eggs is a more accurate indicator of recruitment. Therefore, the survival percentages of eggs was selected as the primary measure of nesting success. Nest survival was discussed only when nest survival differed from egg survival.

iii. Nesting Ecology

A summary of nesting ecology on the study area was completed in SAS from applicable simple statistics of selected variables. Nesting ecology data were analyzed in a manner to yield results in a form comparable to those utilized by Stoddard (1931), Rosene (1969), and Roseberry and Klimstra (1984). Analysis of nesting ecology concentrated on mean clutch size, hatching rate, nest chronology, incubating parent, direction of nests, and fates of nests.

iv. Habitat Use

Habitat use was determined by the prevalence of nests in various land use types. SAS was used to calculate frequencies of dominant and subdominant vegetation types, cover height, cover density, and area management at known nest sites.

Chapter IV

Results

I. Data Collection

A total of 1563 bobwhite nests was located over the 7 nesting seasons of this study (Table 1). The number of nests found in a single season ranged from 170 in 1973 to 310 in 1967. Nearly half (766) of these nest contained eggs or egg remains when found. Of all nests, 232 or 14.8% were active when first observed; this sub-sample was used to determine survival probabilities by the Mayfield method. All nests, including the 232 active nests, were used to describe nesting ecology and determine attributes of bobwhite nesting habitat.

II. Data Analysis

i. Data Entry

Original data and calculations from these data were used to generate Mayfield risk-exposure variables. A total of 3688 exposure-days yielded 2635 egg-days laying, 352 nest-days laying, 23,071 egg-days incubating, and 2130 nest-days incubating.

Table 1. Summary of bobwhite nests located on Ames Plantation, Fayette Co., Tennessee, 1967-1973.

Year	Mayfield Nests[1/]	Percent of Mayfield Nests	Total Nests[2/]	Percent of Total Nests
1967	25	10.8	310	19.8
1968	43	18.6	238	15.2
1969	52	22.4	177	11.3
1970	27	11.6	176	11.3
1971	23	9.9	245	15.7
1972	29	12.5	247	15.8
1973	33	14.2	170	10.9
Total	232	100.0	1563	100.0

1/ - Yearly number of nests applicable to Mayfield estimations.
2/ - Yearly total of all located nests.

ii. Mayfield Calculations

The Mayfield method was used to estimate overall nesting success and nesting success with respect to habitat, seasonal chronology, weather, and miscellaneous factors. Both egg (Me) and nest (Mn) survival estimates were determined for all categories within variables. Egg and nest survival were also determined separately for each of the 2 periods of a clutch's existence, laying and incubation. Egg and nest survival during laying and/or incubation are presented separately only when differences occur between these 2 stages of nest history.

Overall Survival

Mayfield analysis of 232 active nests estimated that 8.52% of eggs laid would survive to hatch (Table 2). Yearly egg survival rates ranged from 2.38% in 1970 to a 14.60% in 1967.

Survival Related to Habitat

Success rates for eggs and nests were computed for nine habitat variables (area management, distance to edge, cover height, percent shade, dominant vegetation, subdominant vegetation, distance to ecotone, land use type, and cover density). Within six of these habitat variables, survival

Table 2. Yearly reproductive success of bobwhites on Ames Plantation, Fayette Co., Tennessee, 1967-1973.

	Eggs		Nests	
Year	Total Eggs	Me[1/]	Total Nests	Mn[2/]
1967	265	9.07	25	15.38
1968	449	14.60	43	12.06
1969	567	6.62	52	5.47
1970	285	2.38	27	1.94
1971	251	6.47	23	6.50
1972	316	7.74	29	5.14
1973	315	14.28	33	7.97
Total	2448	8.52	232	7.37

1/ - Represents Mayfield egg survival estimate which equals the percent of eggs that hatch.

2/ - Represents Mayfield nest survival estimate which equals the percent of nests that hatch at least 1 egg.

rates were related to some quantitative and/or qualitative characteristic of the habitat.

Area management

The probability of an egg surviving to hatch was highest in areas burned within the previous 2 years (14.52%, N = 683) (Table 3). Egg survival was higher in burned areas than in areas unburned (P = 0.07) or mowed (P = 0.004).

The survival advantage in burned areas occurred during incubation (49.82%) (P < 0.1). Egg survival was 27.92% in unburned and 24.06% in mowed areas during incubation. Survival during laying did not differ among management regimes (P > = 0.1).

Edge

Egg and nest survival related to edge was estimated for four distance classes. Egg survival was greatest in a zone 3.7 to 7.2 m from an edge (28.06%, N = 542) and was higher than in all other classes (P < 0.1) (Table 4). Egg survival was lowest when nests were located 7.3 to 16.5 m from an edge (5.56%, N = 569).

The probability that a nest would survive to hatching was highest within the 3.7 to 7.2-m and >16.5-m classes (Table 4). Nests located 7.3 to 16.5 m from an edge were least likely to survive until hatching.

Egg survival during laying was higher in nests located 3.7 to 7.2 m (57.49%) from an edge than in all other nests

Table 3. Bobwhite nesting success rates by area management, Ames Plantation Fayette Co., Tennessee, 1967-1973.

Area Management	Eggs[1/]				Nests[2/]			
	Total Eggs	n	Me	S.E.	Total Nests	n	Mn	S.E.
burned[3,4/]	683	6	14.52[a]	2.14	70	6	7.94	2.08
unburned	1598	7	8.66[b]	1.97	146	7	7.62	1.92
mowed	154	1	1.72[b]	5.23	15	1	2.45	5.09

1/ - Me = Mayfield egg survival estimate = percent of eggs that hatch; n = number of annual Mayfield estimates in sample. Me differed by management regime ($F = 3.61$, $df = 2$, $P = 0.06$).

2/ - Mn = Mayfield nest survival estimate = percent of nests that hatch at least 1 egg; n = number of annual Mayfield estimates in sample. Mn did not differ by management regime ($F = 0.51$, $df = 2$, $P = 0.61$).

3/ - Survival rates not sharing at least 1 superscripted letter differ statistically ($P < 0.1$).

4/ - All figures based on least square means of respective management survival rates.

Table 4. Bobwhite nesting success rates by distance to "edge", Ames Plantation, Fayette Co., Tennessee, 1967-1973.

Distance to "Edge"	Eggs[1/]				Nests[2/]			
	Total Eggs	n	Me	S.E.	Total Nests	n	Mn	S.E.
0 - 3.6 m[3,4/]	754	7	9.90[a]	5.75	69	7	9.55[a]	6.31
3.7 - 7.2 m	542	6	28.06[b]	6.20	52	7	28.35[b]	6.31
7.3 - 16.5 m	569	6	5.56[a]	6.20	54	7	3.75[a]	6.31
>16.5 m	583	6	10.06[a]	6.20	57	6	10.78[a]	6.82

1/ - Me = Mayfield egg survival estimate = percent of eggs that hatch; n = number of annual Mayfield estimates in sample. Me differed by distance to edge ($F = 2.61$, $df = 3$, $P = 0.08$).

2/ - Mn = Mayfield nest survival estimate = percent of nests that hatch at least 1 egg; n = number of annual Mayfield estimates in sample. Mn differed by distance to edge ($F = 2.82$, $df = 3$, $P = 0.06$).

3/ - Survival rates not sharing at least 1 superscripted letter differ statistically ($P < 0.1$).

4/ - All figures based on least square means of respective management survival rates.

(P<0.1). Egg survival during incubation was not different across zones (P > = 0.1).

Cover height

Egg and nest survival was estimated for 6 classes of cover height. Nests located in 0 to 20-cm cover supported the highest egg survival (46.86%, N = 152); lowest egg survival (7.81%, N = 533) was observed in 41 to 50-cm cover (Table 5). Egg survival did not differ among 0 to 20-cm, 61 to 120-cm, and 51 to 60-cm height classes (P < 0.1), the three height classes supporting the highest survival rates.

The survival advantage among cover height classes was during laying. Egg survival during laying was highest in areas with cover heights of 0 to 20 cm, 51 to 60 cm, and 61 to 120 cm (P < 0.1). No differences were detected among vegetation height classes during incubation (P > = 0.1).

Percent shade

Egg survival rate in relation to percent shade at nest sites was highest in sites with 31 to 40% shade (80.05%, N = 96) and lowest in sites with 0% (6.90%, N = 1570) and 21 to 30% shade (< 0.01%, N = 103) (Table 6). Sites with 31 to 40% shade differed from all other classes (P < 0.1). Nest survival across classes was similar to egg survival.

The survival advantage among percent shade classes was observed during laying. Egg survival during laying was

Table 5. Bobwhite nesting success rates by cover height, Ames Plantation, Fayette Co., Tennessee, 1967-1973.

	Eggs[1/]				Nests[2/]			
Cover Height	Total Eggs	n	Me	S.E.	Total Nests	n	Mn	S.E.
0 - 20 cm[3,4/]	152	2	46.86[a]	14.00	14	3	19.75	12.38
21 - 30 cm	481	5	10.77[bc]	8.86	47	5	16.39	9.58
31 - 40 cm	761	7	7.83[b]	7.48	70	7	6.01	8.10
41 - 50 cm	533	6	7.81[b]	8.08	50	7	6.82	8.10
51 - 60 cm	382	5	29.84[ac]	8.86	37	6	29.29	8.75
61 - 120 cm	139	2	39.05[a]	14.00	14	3	25.50	12.38

1/ - Me = Mayfield egg survival estimate = percent of eggs that hatch; n = number of annual Mayfield estimates in sample. Me differed by cover height ($F = 2.26$, $df = 5$, $P = 0.08$).

2/ - Mn = Mayfield nest survival estimate = percent of nests that hatch at least 1 egg; n = number of annual Mayfield estimates in sample. Mn did not differ by cover height ($F = 1.16$, $df = 5$, $P = 0.36$).

3/ - Survival rates not sharing at least 1 superscripted letter differ statistically ($P < 0.1$).

4/ - All figures based on least square means of respective management survival rates.

Table 6. Bobwhite nesting success rates by percent shade, Ames Plantation, Fayette Co., Tennessee, 1967-1973.

	Eggs[1/]				Nests[2/]			
Percent Shade	Total Eggs	n	Me	S.E.	Total Nests	n	Mn	S.E.
0[3,4/]	1570	7	6.90[a]	5.96	147	7	6.96[a]	6.13
1 - 10	191	4	31.28[b]	7.86	23	4	20.42[ab]	8.11
11 - 20	203	1	24.46[ab]	15.77	17	3	4.60[a]	9.37
21 -30	103	1	<0.01[c]	15.77	9	1	<0.01[ab]	16.22
31 - 40	96	2	80.05[d]	11.15	9	2	80.16[c]	11.47
41 - 50	66	2	36.70[b]	11.15	6	3	30.16[b]	9.37
>50	219	2	13.01[abc]	11.15	21	3	4.63[a]	9.36

1/ - Me = Mayfield egg survival estimate = percent of eggs that hatch; n = number of annual Mayfield estimates in sample. Me differed by percent shade ($F = 6.78$, $df = 6$, $P = 0.0025$).

2/ - Mn = Mayfield nest survival estimate = percent of nests that hatch at least 1 egg; n = number of annual Mayfield estimates in sample. Mn differed by percent shade ($F = 4.15$, $df = 6$, $P = 0.01$).

3/ - Survival rates not sharing at least 1 superscripted letter differ statistically ($P < 0.1$).

4/ - All figures based on least square means of respective management survival rates.

highest in nests found in both 31 to 40% (100.00%) and 41 to 50% shade (100.00%) areas ($P < 0.1$).

Dominant vegetation

Four of 7 dominant vegetation types yielded reliable samples. Areas dominated by miscellaneous vegetation supported the highest egg survival rate (63.75%, N = 175) while the lowest egg survival was in broomsedge (8.39%, N = 1580) (Table 7).

Subdominant vegetation

Four of 7 subdominant vegetation types provided samples large enough for analysis. Egg survival was highest in partridge pea (65.48%, N = 268); nests located in areas where miscellaneous vegetation was subdominant were least successful (3.94%, N = 426) (Table 8). Egg survival in areas with broomsedge subdominant was 54.72% (N = 91) and not different than in partridge pea ($P = 0.63$). Egg survival rates in mixed weeds and grasses and miscellaneous subdominant vegetation were lower ($P = 0.004$ and $P = 0.003$, respectively) than in partridge pea. Nest survival was also highest in partridge pea and broomsedge ($P < 0.1$). Egg survival rates during laying and incubation were not different across subdominant vegetation types ($P >= 0.1$).

Ecotone

Egg success in relation to distance to ecotone was estimated for four distance classes. Survival rates were

Table 7. Bobwhite nesting success rates by dominant vegetation, Ames Plantation, Fayette Co., Tennessee, 1967-1973.

Dominant Vegetation	Eggs[1/]				Nests[2/]			
	Total Eggs	n	Me	S.E.	Total Nests	n	Mn	S.E.
misc.[3,4/]	175	2	63.75[a]	15.91	15	3	45.32	18.19
panicum	90	1	49.18[ab]	22.51	9	1	19.93	31.51
mixed weeds and grasses	503	6	23.10[b]	9.19	49	6	27.25	12.86
broomsedge	1580	7	8.39[b]	8.51	148	7	8.75	11.90

1/ - Me = Mayfield egg survival estimate = percent of eggs that hatch; n = number of annual Mayfield estimates in sample. Me differed by dominant vegetation ($F = 3.62$, $df = 3$, $P = 0.05$).

2/ - Mn = Mayfield nest survival estimate = percent of nests that hatch at least 1 egg; n = number of annual Mayfield estimates in sample. Mn did not differ by dominant vegetation ($F = 0.88$, $df = 4$, $P = 0.50$).

3/ - Survival rates not sharing at least 1 superscripted letter differ statistically ($P < 0.1$).

4/ - All figures based on least square means of respective management survival rates.

Table 8. Bobwhite nesting success rates by subdominant vegetation, Ames Plantation, Fayette Co., Tennessee, 1967-1973.

Subdominant Vegetation	Eggs[1/]				Nests[2/]			
	Total Eggs	n	Me	S.E.	Total Nests	n	Mn	S.E.
partridge pea[3,4/]	268	4	65.48[a]	12.46	24	4	60.17[a]	14.65
broomsedge	91	2	54.72[a]	17.63	10	3	36.73[ab]	16.92
mixed weeds and grasses	1157	7	11.47[b]	9.42	117	7	9.04[b]	11.07
misc.	426	5	3.94[b]	11.15	37	5	5.48[b]	13.10

1/ - Me = Mayfield egg survival estimate = percent of eggs that hatch; n = number of annual Mayfield estimates in sample. Me differed by subdominant vegetation ($F = 3.32$, $df = 6$, $P = 0.03$).

2/ - Mn = Mayfield nest survival estimate = percent of nests that hatch at least 1 egg; n = number of annual Mayfield estimates in sample. Mn differed by subdominant ($F = 5.81$, $df = 5$, $P = 0.004$).

3/ - Survival rates not sharing at least 1 superscripted letter differ statistically ($P < 0.1$).

4/ - All figures based on least square means of respective management survival rates.

not different among distances to ecotone (P > = 0.1). Egg survival was 13.75% (N = 692) in nests located 0.0 to 4.5-m from an ecotone and 5.77% (N = 596) in nests found 11.1 to 23.4-m from an ecotone.

Land use type

Egg and nests survival rates were not different among land use types (P > = 0.1). Egg survival was 28.35% (N = 168) in ungrazed pastures. Survival probabilities were 19.57% (N = 160) in grazed pastures and 20.00% (N = 216) in cover strips. Survival was 8.13% (N = 1838) in idle areas.

Cover density

Egg and nest survival rates across varying cover densities were not different (P > = 0.1). Nests located in heavy (N = 342) and light (N = 505) cover density supported egg survival rates of 24.24% and 11.65%, respectively. Nests in medium density cover supported an egg survival rate of 9.70% (N = 1045).

Survival Related to Seasonal Chronology

Egg and nest survival rates were analyzed with reference to the date of nest initiation by pooling data for months and weeks. Tests of significance were possible only for comparisons among months.

Success by month of initiation

Numbers of nests located in May, June, July, and August were adequate for estimating nesting success. Egg survival probabilities increased each month from May (0.50%, N = 472) through August (38.85%, N = 77). The probability that an egg would survive to hatching was significantly higher in August than in all other months ($P < 0.1$). The probability of survival for an egg in a nest initiated in July (18.50%, N = 758) was higher than for May ($P = 0.005$). This pattern was evident for each nesting season independently as well as for all years pooled (Figure 3).

Success by week of initiation

Weekly egg and nest survival probabilities were calculated from week 3 of May through week 4 of July (Figure 4). Although a trend of increasing weekly survival was evident, week to week variation was high.

Survival Related to Weather

Two of seven climatological parameters, January precipitation and the number of nights below -12 C during January and February, were related to egg survival. January precipitation was positively correlated with bobwhite egg survival (See Appendix, Table 16). The number of nights below -12 C was negatively correlated with egg survival. Although yearly precipitation was not correlated with egg

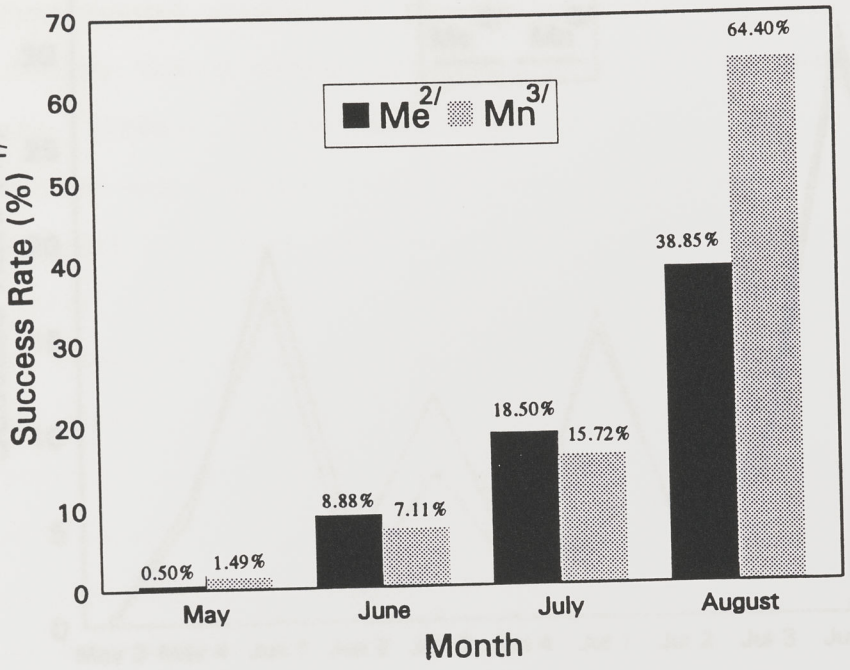


Figure 3. Bobwhite reproductive success rates by month of nest initiation, Ames Plantation, Fayette Co., Tennessee, 1967-1973.

1/ - All figures based on least square means of respective monthly survival rates.

2/ - Represents Mayfield egg survival estimate which equals the percent of eggs that hatch.

3/ - Represents Mayfield nests survival estimate which equals the percent of nests that hatch at least 1 egg.

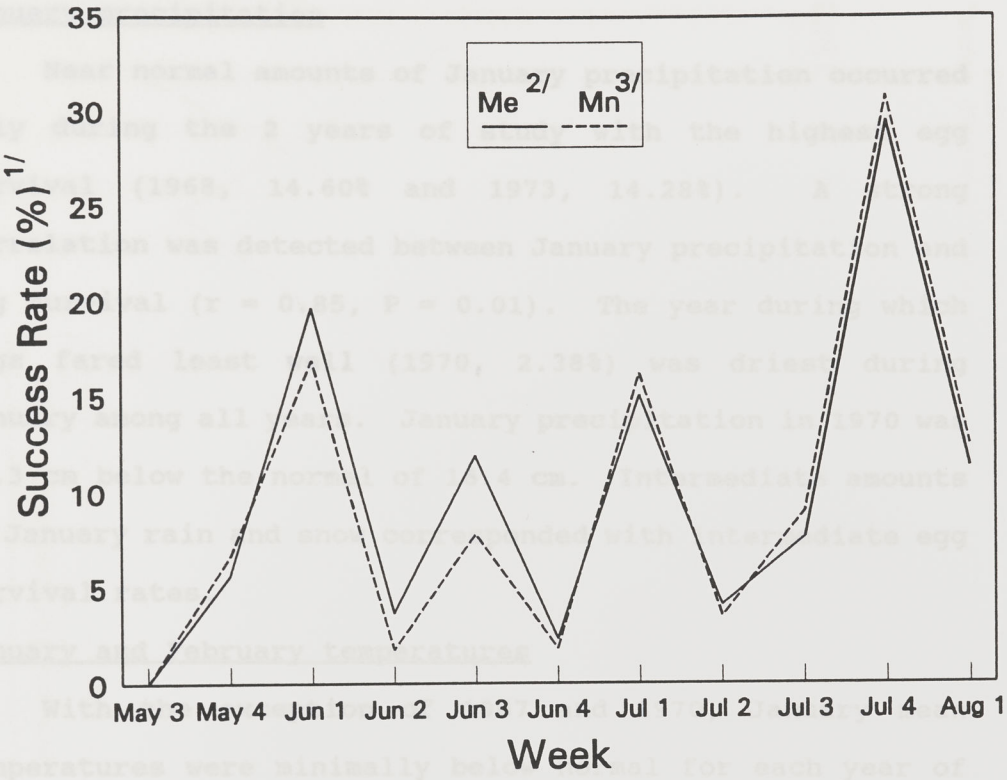


Figure 4. Bobwhite reproductive success rates by week of nest initiation, Ames Plantation, Fayette, Co., Tennessee, 1967-1973.

1/ - All figures based on true means of respective weekly survival rates.

2/ - Represents Mayfield egg survival estimate which equals the percent of eggs that hatch.

3/ - Represents Mayfield nest survival estimate which equals the percent of nests that hatch at least 1 egg.

survival, a relationship was apparent when viewing the precipitation data.

January precipitation

Near normal amounts of January precipitation occurred only during the 2 years of study with the highest egg survival (1968, 14.60% and 1973, 14.28%). A strong correlation was detected between January precipitation and egg survival ($r = 0.85$, $P = 0.01$). The year during which eggs fared least well (1970, 2.38%) was driest during January among all years. January precipitation in 1970 was 11.3 cm below the normal of 16.4 cm. Intermediate amounts of January rain and snow corresponded with intermediate egg survival rates.

January and February temperatures

With the exception of 1967 and 1970, January mean temperatures were minimally below normal for each year of study (Figure 5). Mean January temperature was an unusually low 1.3 c during 1970, the year with lowest egg survival. The number of nights of below -12 C during January and February were negatively correlated with egg survival ($r = -0.69$, $P = 0.09$).

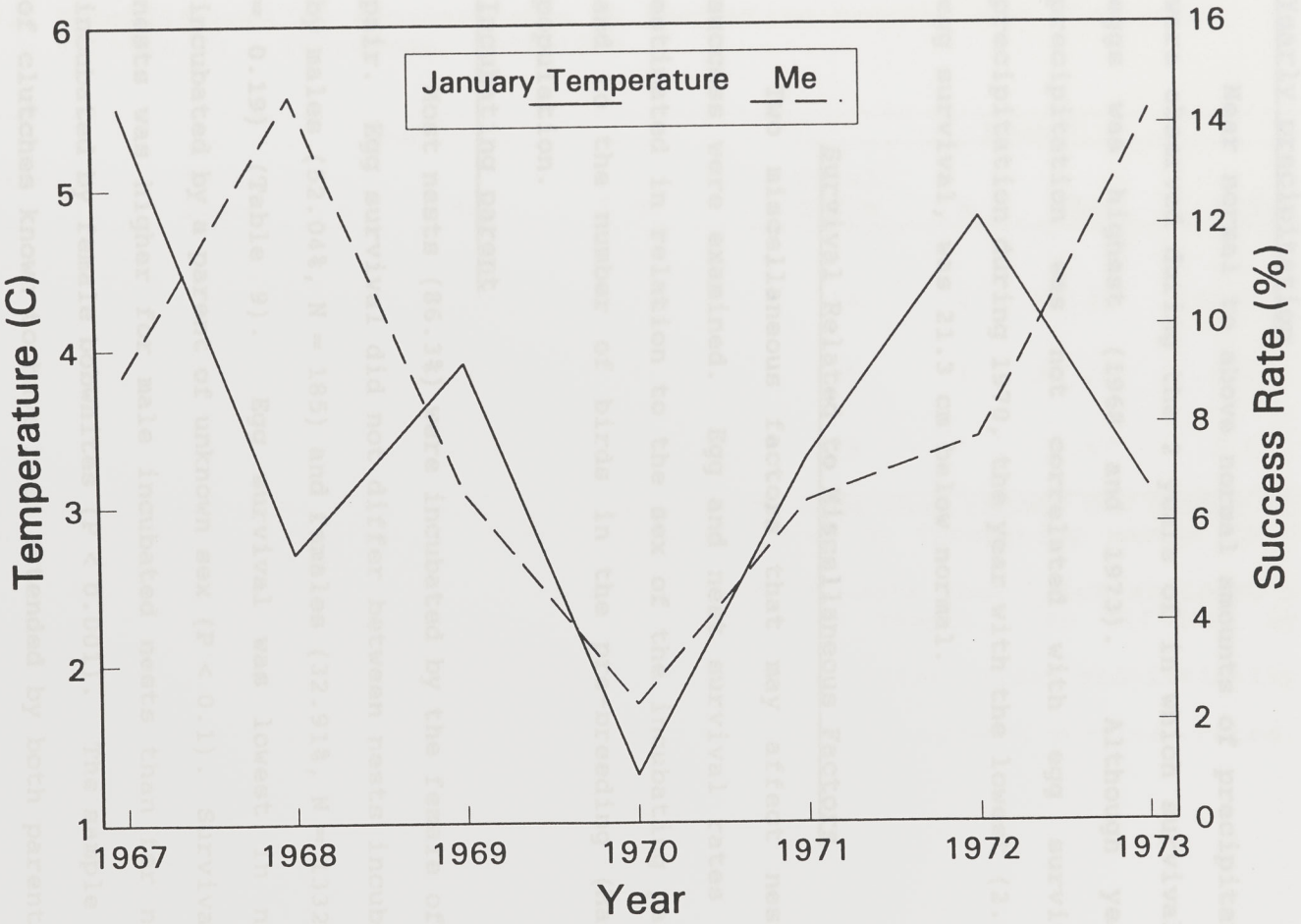


Figure 5. Mean January temperatures and yearly egg success rate, Ames Plantation, Fayette Co., Tennessee, 1967-1973.

Yearly precipitation

Near normal to above normal amounts of precipitation were observed during the 2 years of in which survival of eggs was highest (1968 and 1973). Although yearly precipitation was not correlated with egg survival, precipitation during 1970, the year with the lowest (2.38%) egg survival, was 21.3 cm below normal.

Survival Related to Miscellaneous Factors

Two miscellaneous factors that may affect nesting success were examined. Egg and nest survival rates were estimated in relation to the sex of the incubating parent and to the number of birds in the pre-breeding (March) population.

Incubating parent

Most nests (86.3%) were incubated by the female of the pair. Egg survival did not differ between nests incubated by males (52.04%, N = 185) and females (32.91%, N = 1332) ($P = 0.19$) (Table 9). Egg survival was lowest in nests incubated by a parent of unknown sex ($P < 0.1$). Survival of nests was higher for male incubated nests than for nests incubated by female bobwhites ($P < 0.001$). The sample size of clutches known to have been attended by both parents (N = 3) was not adequate for reliable analysis.

Table 9. Bobwhite nesting success rates by incubating parent, Ames Plantation, Fayette Co., Tennessee, 1967-1973.

Incubating Parent	Eggs[1/]				Nests[2/]			
	Total Eggs	n	Me	S.E.	Total Nests	n	Mn	S.E.
male[3,4/]	185	4	54.04[a]	12.16	16	4	56.13[a]	10.32
female	1332	2	32.91[a]	6.50	120	3	31.15[b]	5.51
unknown	748	7	1.01[b]	7.69	79	7	0.67[c]	5.51

1/ - Me = Mayfield egg survival estimate = percent of eggs that hatch; n = number of annual Mayfield estimates in sample. Me differed by incubating parent ($F = 8.67$, $df = 3$, $P = 0.003$).

2/ - Mn = Mayfield nest survival estimate = percent of nests that hatch at least 1 egg; n = number of annual Mayfield estimates in sample. Mn differed by incubating parent ($F = 18.82$, $df = 3$, $P < 0.001$).

3/ - Survival rates not sharing at least 1 superscripted letter differ statistically ($P < 0.1$).

4/ - All figures based on least square means of respective management survival rates.

The survival rate during incubation for eggs attended by males (82.87%) was significantly higher than for those incubated by hens (46.64%) ($P < 0.001$) or an unknown parent ($P < 0.001$).

Pre-breeding population size

March population estimates were recorded for the entire study area during the period of study (Dimmick, unpubl. data). Egg survival rates were not correlated with pre-breeding population size ($r = 0.31$, $P = 0.5$) (Figure 6).

The Mayfield Method and Standard Success Estimators

The data utilized in this study were originally analyzed by Dimmick (1974) using 2 standard methods for estimating nesting success. The first standard method involved compiling data on all nests that were known to have been used at some time, past or active when found ($N = 766$). This determination was based on the presence of eggs or egg remains. Fates of nests with egg remains were determined by the condition of each nest and the nature of egg fragments found within. The number of nests hatched over the total number used was given as nesting success. A second, likely more accurate method used by Dimmick (1974) involved analysis of a smaller sub-set of used nests, those nests that were active when found ($N = 232$). This was the same

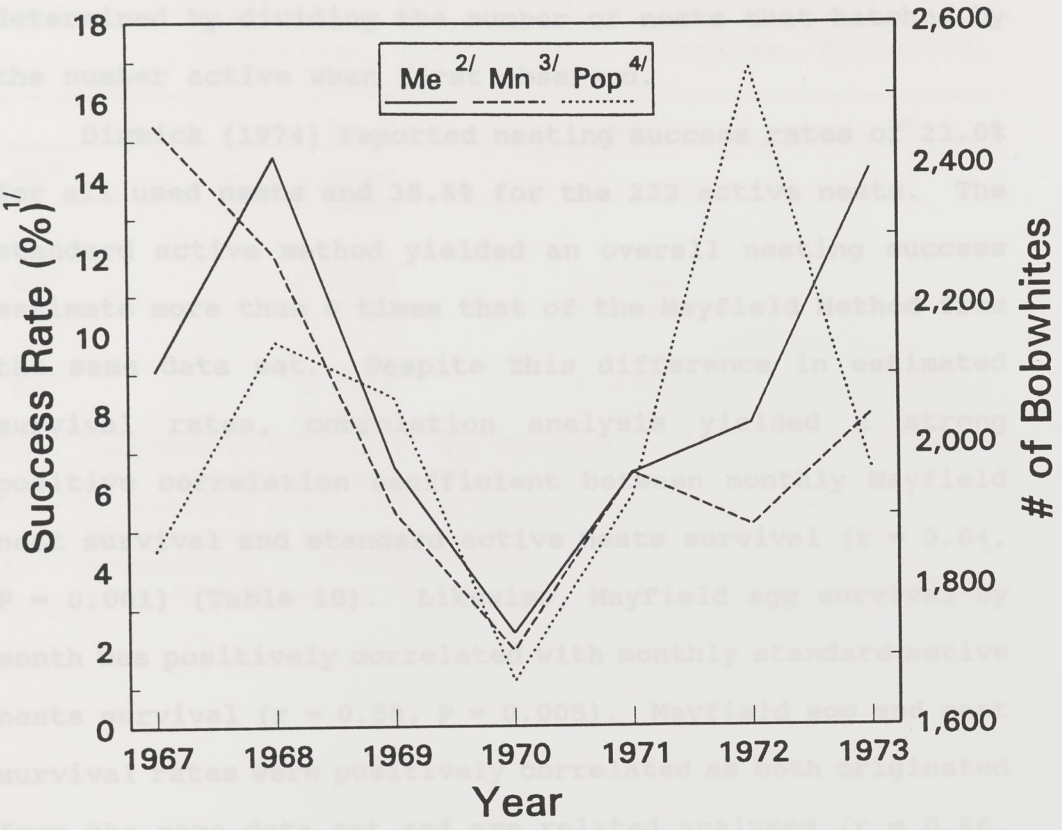


Figure 6. Yearly bobwhite reproductive success rates vs. pre-breeding population size, Ames Plantation, Fayette Co., Tennessee, 1967-1973.

1/ - All figures based on true means of respective weekly survival rates.

2/ - Represents Mayfield egg survival estimate which equals the percent of eggs that hatch.

3/ - Represents Mayfield nest survival estimate which equals the percent of nests that hatch at least 1 egg.

4/ - Pre-breeding population estimate of entire Morning Field Trial Course, Ames Plantation, Fayette Co., Tennessee, 1967-1973.

sub-set used for Mayfield calculations. Nesting success was determined by dividing the number of nests that hatched by the number active when first observed.

Dimmick (1974) reported nesting success rates of 23.0% for all used nests and 38.8% for the 232 active nests. The standard active method yielded an overall nesting success estimate more than 4 times that of the Mayfield Method from the same data set. Despite this difference in estimated survival rates, correlation analysis yielded a strong positive correlation coefficient between monthly Mayfield nest survival and standard active nests survival ($r = 0.64$, $P = 0.001$) (Table 10). Likewise, Mayfield egg survival by month was positively correlated with monthly standard active nests survival ($r = 0.58$, $P = 0.005$). Mayfield egg and nest survival rates were positively correlated as both originated from the same data set and are related analyses ($r = 0.86$, $P = 4.0\ E^{-7}$).

Reproductive success rates calculated using the 4 estimators of nesting success (Mayfield egg and nest, standard used and active) were not positively correlated with March or December populations (Table 11). A negative relationship did exist between the standard used nests method and subsequent December populations ($r = -0.75$, $P = 0.05$) (Dimmick 1974).

Table 10. Summary of Pearson Correlation Coefficients between the Mayfield and traditional methods of calculating bobwhite reproductive success, Ames Plantation, Fayette Co., Tennessee, 1967-1973.

	Me	Mn	SA
Me[1/]	r = 1.0000 P = 0.0000		
Mn[2/]	0.8562 4.0 E-7	1.0000 0.0000	
SA[3/]	0.5794 0.0047	0.6365 0.0015	1.0000 0.0000

1/ - Represents Mayfield egg survival estimate which equals the percent of eggs that hatch.

2/ - Represents Mayfield nest survival estimate which equals the percent of nests that hatch at least 1 egg.

3/ - Represents a standard nest survival estimate where only known active nests were utilized in calculations.

Table 11. Summary of Pearson Correlation Coefficients between 4 bobwhite reproductive success estimators and both March (pre-breeding) and December (post-breeding) bobwhite populations, Ames Plantation, Fayette Co., Tennessee, 1967-1973.

	March Population	December Population
Me[1/]	r = 0.3087 p = 0.5006	0.2507 0.5876
Mn[2/]	-0.0053 0.9910	0.4727 0.2841
SU[3/]	-0.0326 0.9447	-0.7496 0.0524
SA[4/]	-0.2903 0.5276	-0.4705 0.2867

1/ - Represents Mayfield egg survival estimate which equals the percent of eggs that hatch.
2/ - Represents Mayfield nest survival estimate which equals the percent of nests that hatch at least 1 egg.
3/ - Represents a standard nest survival estimate where all active nest and nests with egg remains are utilized in calculations.
4/ - Represents a standard nest survival estimate where only known active nests are utilized in calculations.

iii. Nesting Ecology

Nesting ecology analyses included calculations of mean clutch size and hatching rate. Notes on nesting chronology, incubating parent, direction of nest, and fate of nest were also compiled to clarify nesting ecology.

Clutch size

Mean size for 252 clutches known to be complete was 11.55 with a range of 3 to 26 eggs. Clutch sizes averaged highest in 1970 ($\bar{x}$ = 12.7, N=27) and lowest in 1973 ($\bar{x}$ = 10.5, N=32) (Table 12).

Hatching rate

Hatching rate was calculated by dividing the number of eggs known to have hatched by the number of eggs known to have been in nests at hatching. Mean hatching rate over the entire study was 96.71% (N = 2910). Hatching rate varied little among years, ranging from 94.26% in 1969 (N = 651) to 98.88% in 1972 (N = 364) (Table 12).

Nesting chronology

The earliest and latest starting dates for incubation of full clutches were 23 April and 15 August, respectively. Mean date for initiation of incubation was 21 June (N = 231). The onset of nest building activity was week 4 April (Figure 7). The earliest and latest hatching dates were 5 June and 17 September. Mean hatching date was 26 July (Figure 8).

Table 12. Summary of bobwhite clutch sizes and hatching rates by year, Ames Plantation, Fayette Co., Tennessee, 1967-1973.

	Clutch Size			Hatching Rate	
Year	Mean	N	Range	Mean	N
1967	10.6	29	4 - 15	97.3	307
1968	11.4	52	4 - 24	98.0	592
1969	11.8	55	3 - 26	94.3	651
1970	12.7	27	5 - 22	96.2	344
1971	11.3	28	3 - 20	97.6	317
1972	12.6	29	6 - 23	98.9	364
1973	10.5	32	4 - 17	95.7	335
Total	11.6	252	3 - 26	96.7	2910

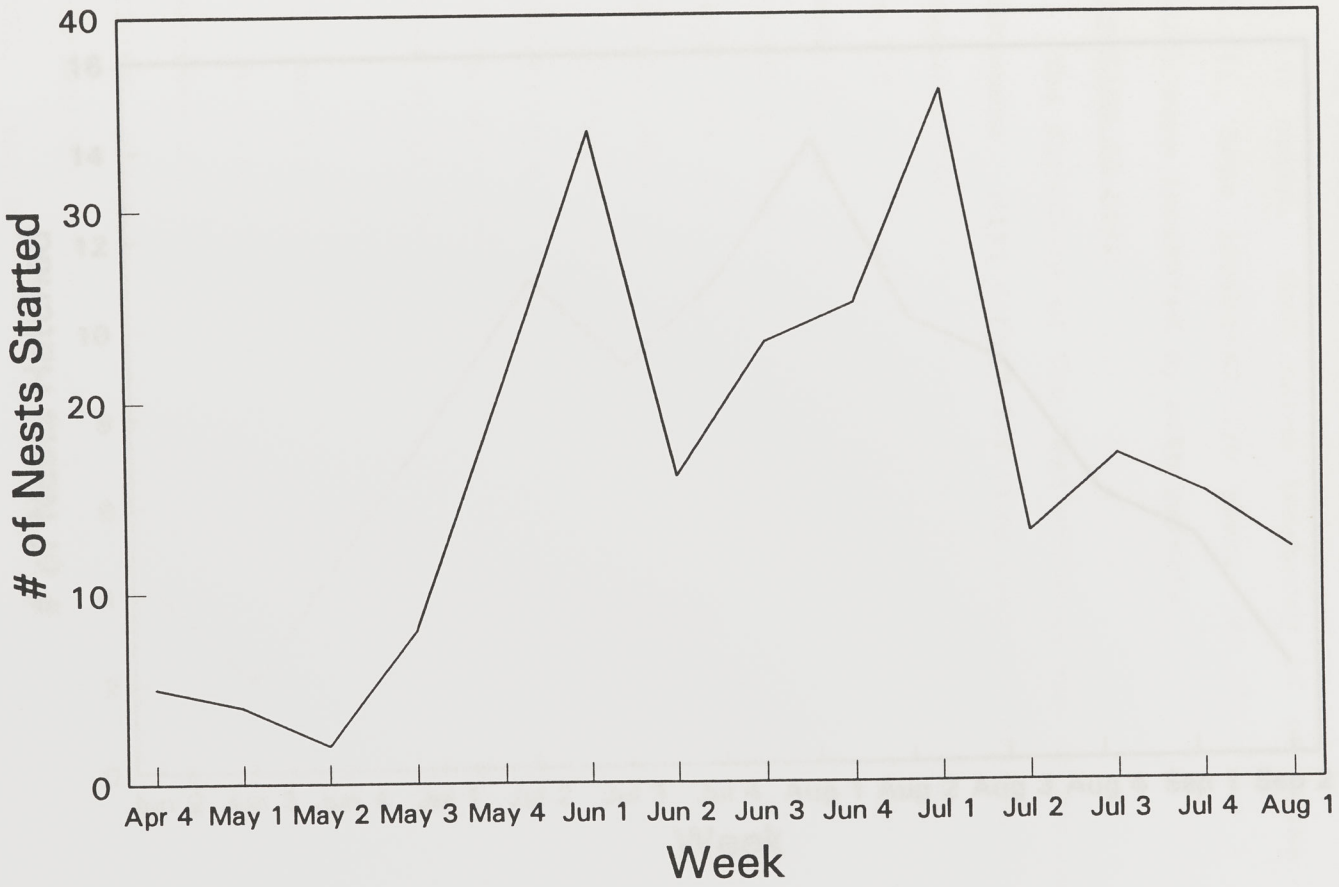


Figure 7. Bobwhite nest initiation by week, Ames Plantation, Fayette Co., Tennessee, 1967-1973.

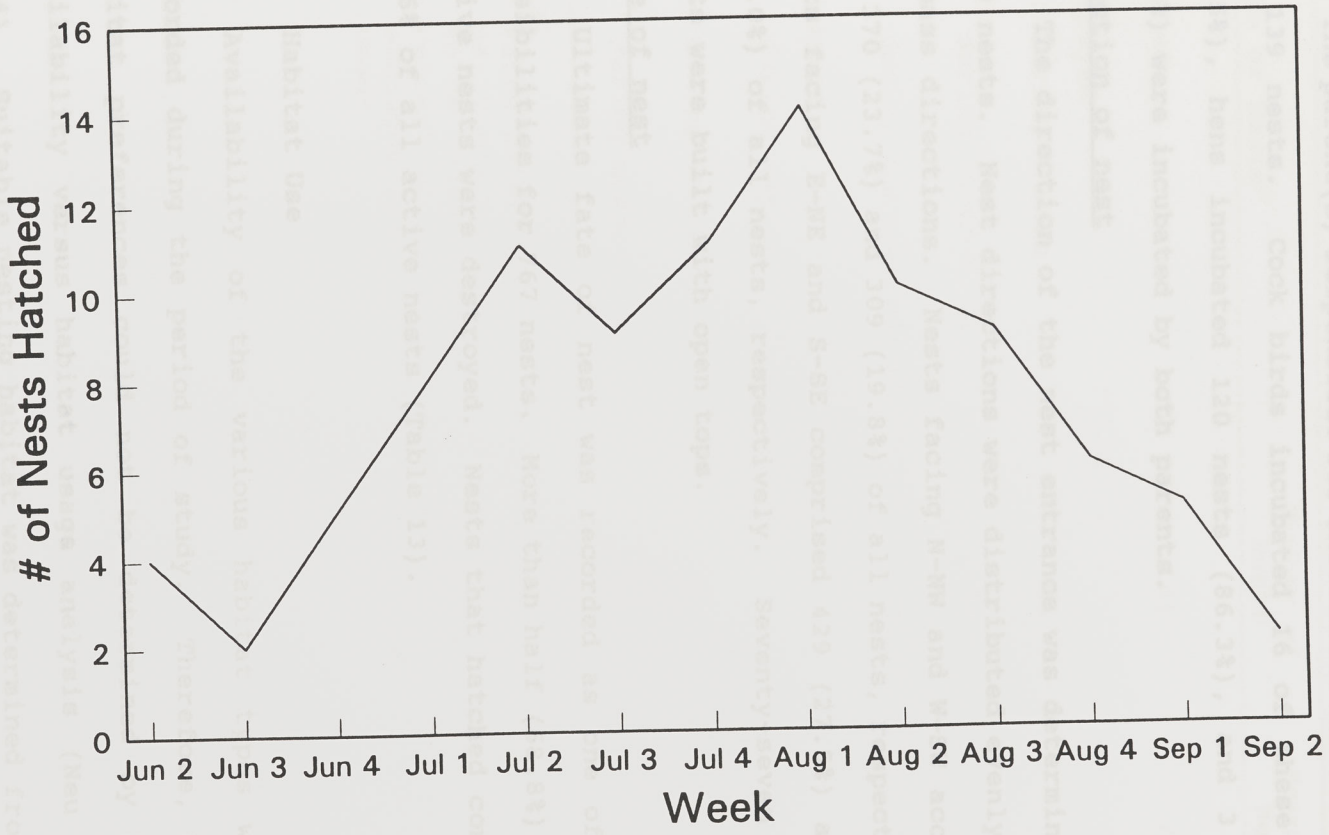


Figure 8. Bobwhite nest hatching by week, Ames Plantation, Fayette Co., Tennessee, 1967-1973.

Incubating parent

The parent(s) responsible for incubation was determined for 139 nests. Cock birds incubated 16 of these nests (11.5%), hens incubated 120 nests (86.3%), and 3 nests (2.2%) were incubated by both parents.

Direction of nest

The direction of the nest entrance was determined for 1559 nests. Nest directions were distributed evenly among compass directions. Nests facing N-NW and W-SW accounted for 370 (23.7%) and 309 (19.8%) of all nests, respectively. Nests facing E-NE and S-SE comprised 429 (27.5%) and 374 (24.0%) of all nests, respectively. Seventy-seven (4.9%) nests were built with open tops.

Fate of nest

Ultimate fate of nest was recorded as one of three possibilities for 767 nests. More than half (68.8%) of all active nests were destroyed. Nests that hatched comprised 23.6% of all active nests (Table 13).

iv. Habitat Use

Availability of the various habitat types was not recorded during the period of study. Therefore, nesting habitat preferences could not be determined by habitat availability versus habitat usage analysis (Neu et al. 1974). Suitable nesting habitat was determined from area

Table 13. Summary of ultimate fates of bobwhite nests, Ames Plantation, Fayette Co., Tennessee, 1967-1973.

Fates of Nests[1/]	Number of Nests	Percent of Nests[2/]
hatched	181	23.6
destroyed		
during laying	35	4.6
during incubation	91	11.9
during unknown period	401	52.3
abandoned		
during laying	13	1.7
during incubation	10	1.3
during unknown period	35	4.6
Total	767	100.0

1/ - Fates determined by inspection of inactive nests and daily monitoring of active nests; 351 nests were believed to be unused and 445 nest had unknown fates.

2/ - Percent of active or known to be active nests found, excludes nests not showing some sign of eggs or fresh usage.

management, distance to edge, cover height, percent shade, vegetation type, distance to ecotone, land use type, and cover density data. No apparent relationship was observed between nest location and distances to edge and ecotone.

Area management

More than half (911, 58.8%) of all nests were located in areas that had not been disturbed during the previous 2 years. Recently burned areas contained 465 nests (30.0%); mowed or disced areas contained 173 (11.2%) nests.

Edge

Distance to edge ranged from 0 to 185 m. Nests were located evenly among varying distances to edge. Distances to edge were 0 to 3.6 m (402, 25.9%), 3.7 to 7.2 m (303, 19.5%), 7.3 to 16.5 m (421, 27.1%), and 16.6 to 185.0 m (428, 27.5%).

Cover height

Cover height was measured at 1560 nests sites. It was 30 to 40-cm at 442 (28.3%) of these. An additional 416 (26.7%) nests were located in cover 40 to 50-cm in height (Table 14). Only 65 nests (4.2%) were located in areas with cover height less than 20-cm.

Percent shade

Percent shade was 0.0 at 1079 (69.3%) nest sites. Nests located in 1 to 10% shade accounted for 9.2% of nests and 6.4% were found in 10 to 20% shade.

Table 14. Summary of cover heights at bobwhite nest sites, Ames Plantation, Fayette Co., Tennessee, 1967-1973.

Cover Height	Number of Nests	Percent of Nests
0 - 20 cm	65	4.2
21 - 30 cm	280	18.0
31 - 40 cm	442	28.3
41 - 50 cm	416	26.7
51 - 60 cm	205	13.1
61 - 120 cm	152	9.7
Total	1560	100.0

Vegetation

Vegetation types, both dominant and subdominant, were recorded at 1559 nest sites. Dominant vegetation was broomsedge at 64.7% of nest sites, mixed weeds and grasses at 20.5%, partridge pea at 4.4%, and miscellaneous at 6.6%. Subdominant vegetation of mixed weeds and grasses was apparent in 64.8% of nest sites; partridge pea comprised 10.2% of subdominant vegetation records. Miscellaneous subdominant types were reported at 17.5% of all nest sites.

Ecotone

Nests were located 0 to 185 m from an ecotone. No apparent relationship existed between nest location and distance to ecotone. Distances to an ecotone were 0 to 4.6 m (336, 21.6%), 4.7 to 11 m (411,26.4%), 11.1 to 24 m (407, 26.3%), and 24.1 to 185 m (401, 25.8%).

Land use type

Idle areas contained most of the nests. Of 1209 nests with land use type recorded, 899 (74.4%) were in idle areas. The only other land use type containing a sizable number (197) of nests was ungrazed pasture (16.3%) (Table 15). Habitat in these 2 land use types was similar in most cases.

Table 15. Summary of land use types at bobwhite nest sites, Ames Plantation, Fayette Co., Tennessee, 1967-1973.

Land Use Type	Number of Nests	Percent of Nests
idle	899	74.3
ungrazed pasture	197	16.3
cover strip	74	6.1
grazed pasture	29	2.4
woods	8	0.7
other	2	0.2
Total	1209	100.0

Cover density

Cover density at most (58.8%) nest sites was medium (N = 1135). This was followed by light (23.2%) and heavy (18.9%) cover.

Chapter V

Discussion

Three major parameters thought to be partially responsible for variations in bobwhite reproductive success were examined using the Mayfield method for estimating nesting success. These were habitat, seasonal chronology, and weather related variables. Miscellaneous factors believed to be related to bobwhite nesting success, incubating parent and pre-breeding (March) population size, were likewise examined. Also studied were the general nesting ecology and nesting habitat utilized by bobwhites. All aspects were important for comparisons with studies from other areas.

The Mayfield method has been both praised and denigrated in the literature. Hensler and Nichols (1981) stated that in cases where the amount of time between visits was no more than a few days, the Mayfield method was an accurate estimator of nesting success. Conversely, Miller and Johnson (1978) and Green (1977) argued that Mayfield's assumption of equal survivability may inflate the estimated nesting success rate. Miller and Johnson (1978), from estimations of duck nest survival, proposed that a nest was less likely to fail with the progression of time rather than

experiencing equal survivability throughout its life. They calculated expected nest survival for nests that did not ultimately hatch and found that an unsuccessful nest was more likely to be destroyed during the first 40% of its exposure time. The validity of the assumption can be increased by shortening the time between visits. Intervals during this study were usually 3 or 4 days. A later report by Johnson (1979) concluded that the Mayfield method is acceptably accurate when intervals between visits are relatively short (< = 15 days).

Bobwhite nesting success rates calculated by Mayfield's method and the standard nesting success estimator (Dimmick 1974) were positively correlated. Standard nesting success estimates were higher than Mayfield egg survival rates. Duebbert and Lokemoen (1980) compared the Mayfield method to the standard estimator and concluded that the standard estimator overestimated nesting success in mallards (*Anas platyrhyncos*), gadwalls (*Anas strepera*), and blue-winged teal (*Anas discors*). They found that variability between the 2 methods was greater when nest survival was low (standard survival 59.0%, Mayfield survival 35.0%) and much reduced when nest survival was high (standard survival 91.0%, Mayfield survival 76.0%).

The variability among years in egg and nest survival was likely a function of many interacting factors during this study. The following components attempt to explain this variation.

I. Survival Related to Habitat

Six habitat variables proved to have significant effects on bobwhite egg survival. These variables were: area management, distance to edge, cover height, percent shade, dominant vegetation, and subdominant vegetation.

i. Area Management

Area management was defined as burned, unburned, or mowed. Areas that were recently burned were better for nesting than unburned or mowed areas (Table 3). Fritzell (1975) reported that blue-winged teal nests were more successful in burned areas (38.5%) than in unburned areas (15.0%). He concluded that predators searched burned areas with less intensity because of lower nest densities and lower numbers of buffer prey such as voles (*Microtus* spp.) and white-footed mice (*Peromyscus* spp.). Cotton rats (*Sigmodon hispidus*), another buffer prey species, are more prevalent in areas with substantial litter accumulation associated with unburned areas (Odum et al. 1973). Two later nesting studies reported results similar to those of

Fritzell (1975). Esler and Grand (1993) determined that high nest densities resulted in high predation rates and lower success of artificial waterfowl nests. Andersson and Wiklund (1978) reported that spacing intervals between nests were positively related to nesting success of fieldfares (*Turdus pilaris*). Andersson and Wiklund (1978) also concluded wide spacing by some nesting birds is a predator avoidance strategy. Buhnerkempe et al. (1984) found that vegetation structure created by burning indirectly increased greater prairie chicken (*Tympanuchus cupido*) nesting success in Illinois. They concluded that high nest densities in residual cover areas led to higher predation rates and lower nesting success. In general, the impacts of predators on nesting success of ground nesting birds is often devastating (Duebbert and Kantrud 1974, Klett et al. 1988, Campbell 1990, Lokemoen and Woodward 1993) and may be decreased by burning.

Nest density during the period of study on Ames Plantation was higher in unburned than in burned habitat (Dimmick 1971). Klimstra and Scott (1957) reported that burned areas in southern Illinois were little used and were less attractive to nesting bobwhites. Studies by Stoddard (1931) and Rosene (1969) also reported much higher incidence of nests in unburned compared to burned areas. In the burned areas on Ames Plantation, lower nest density and

consequential decreased predation may have been responsible for higher egg survival.

ii. Distance to Edge

The distance a nest was located from an edge was a second habitat variable with significant implications for reproductive success. Eggs in nests located 3.7 to 7.2 m from an edge were 3 times more likely to survive than eggs in nests 0 to 3.6 m and greater than 16.5 m from an edge; eggs in nests 3.7 to 7.2 m from an edge were 5 times more likely to survive than eggs in nests 7.3 to 16.5 m from an edge. Nests located close to an edge may be more vulnerable to predators using the edge as a travel lane. The relationship between success of nests and distance to edge was strongly positive for ducks nesting in Alberta (Keith 1961). Hines and Mitchell (1983) concluded that large plots of nesting cover were better for nesting gadwalls due to decreased edge. They found predator search abilities were reduced when the amount of edge was minimal.

In contrast, Yahner and Wright (1985) and Esler and Grand (1993) found no relationship between predation rates and distance to edge for waterfowl nests. They, like others, concluded that nest density was the most important factor controlling predation rates.

iii. Cover Height

Nests located in areas with cover 0 to 20 cm tall hatched 46.86% of eggs; 6% of all nests were located in vegetation 0 to 20 cm tall. Nests located in cover 41 to 50 cm high had an egg survival rate of 7.81% and accounted for 21.5% of all nests. The high egg and nest survival in extremely short cover appears contradictory. However, Clark and Nudds (1991) stated that the concealment of nest is most important for protecting nests from avian predation. Cover height may be less significant than other factors for reducing predation from mammals and/or snakes.

Nests found in 51 to 60 and 61 to 120-cm high cover were almost as successful as those located in 0 to 20-cm cover. The relationship between cover height and nest loss rates were not obvious.

iv. Percent Shade

More nests were found in areas with 0% shade than in all other classes combined but egg survival was highest (80.05%) among nests in areas with 31 to 40% shade. Although most nests were located in areas with no shade, egg survival in those areas was comparatively low. Stoddard (1931), Rosene (1969), and Stanford (1972) reported that hot, dry conditions at the nest site, as experienced in direct sunlight, were certainly causes for high embryonic

mortality within the egg and decreased productivity. In another study in Texas, Lehmann (1946) proposed that bobwhites searched out grass clumps with considerable green blades as nest sites because they provided better protection from the sun than did dry grass alone. The incidence of a higher nest abandonment rate in areas with 0% shade compared to other areas suggest that the heat and sunlight in areas with no shade negatively impacts bobwhites on Ames Plantation.

v. Dominant Vegetation

Egg and nest survival were unusually high for the 15 nests located in miscellaneous dominant vegetation. Egg survival was 63.75% for nests located in miscellaneous vegetation (goldenrod, sumacs, ragweeds, and blackberry). Nests with panicum as dominant vegetation also yielded a high egg survival rate (49.18%), though not higher than all other classes.

Broomsedge was the most common dominant vegetation type (64.7% of all nests sites). However, only 8.39% of eggs laid in areas dominated by broomsedge ultimately hatched. The high success rate within miscellaneous vegetation may reflect Fritzell's (1975) contention that some predators are more effective in certain vegetation types.

vi. Subdominant Vegetation

Subdominant vegetation was usually one of four major types. Variation in egg and/or nest success was high among subdominant types. Partridge pea and broomsedge yielded the highest success rates. Miscellaneous vegetation, the type producing high egg and nest survival rates as a dominant vegetation, yielded an egg survival rate of only 3.94% when subdominant.

Results from this study suggest that broomsedge is more secure for nesting where it is subdominant rather than dominant. This is supported by findings in southern Illinois (Roseberry and Klimstra 1984, Klimstra and Scott 1957). They found that bobwhites preferred nesting areas with only scattered clumps of broomsedge, not homogenous stands.

II. Survival Related to Seasonal Chronology

Nesting success estimates were determined for the months of May, June, July, and August. Egg and nest survival rates increased throughout the period (Figure 3) although the number of nests peaked during mid-summer. These findings agreed with results reported by Simpson (1972) for bobwhites in southwest Georgia; Sugden and Beyersbergen (1986) and Greenwood et al. (1995) reported similar chronological changes in duck nest success.

However, Lehmann (1946) reported little chronological variation in nesting success in Texas bobwhites. In contrast, nesting survival in southern Illinois was over 44.0% for nests hatching prior to 27 May and steadily declined to 29.0% for nests due to hatch after July 7 (Roseberry and Klimstra 1984). Klimstra and Scott (1957) also reported declining bobwhite nest success as the season advanced in southern Illinois. One explanation offered for these decreasing survival rates was an increase in predation (Roseberry and Klimstra 1984).

Although this study, other bobwhite studies by Simpson (1972) and Lehmann (1946), and waterfowl studies by Sugden and Beyersbergen (1986) and Greenwood et al. (1995) were geographically separated by long distances, most nests in each were located in areas where disturbance during the nesting season was minimal. An increase in the quality of vegetative cover may have been responsible for increases in success as the season advanced in these areas. Greenwood et al. (1995) explained that buffer prey increased as more luxuriant vegetation and plant litter developed over time. By contrast, 32.0% of nests found by Roseberry and Klimstra (1984) were located in agricultural areas, usually hayfields. These areas were mowed in mid to late summer which may have decreased nesting success from direct

destruction by farming activities and indirectly by exposing nests to predators.

III. Survival Related to Weather

January precipitation and January and February temperatures were the only weather parameters correlated with egg and nest survival. Although yearly precipitation and survival rates were not correlated, an apparent positive relationship existed.

i. Precipitation

A positive relationship was apparent between egg survival rate and January precipitation. Rainfall has an obvious influence on bobwhite reproduction in arid regions, such as Texas (Errington 1942, Lehmann 1946, Parmalee 1955, Koerth and Guthery 1991). In other areas of the species' range the effects of rainfall are more subtle (Roseberry and Klimstra 1984). Speake and Haugen (1960) reported a significant positive correlation between summer rainfall and the percentage of young in the fall population in Alabama. Precipitation in the form of snowfall, although an important predictor of productivity in Illinois (Roseberry and Klimstra 1972), was minimal during the period of study on Ames Plantation.

January and/or yearly rainfall may be important in the development of certain habitat attributes necessary for high egg and nest survival. Nesting habitat may be better for building nests and providing needed cover in years with higher amounts of precipitation.

ii. Temperature

January and February temperatures, when unusually low, seemed to negatively influence reproductive success. Extended periods of extremely cold temperatures (below -12 C) may be the critical element contributing to the negative relationship between January and February temperatures and reproductive success. The 8 nights of unusually low temperature during January and February 1970 may have stressed future breeders to a point of decreased reproductive success. The 3 best years for egg and nest survival had no more than 2 nights below -12 C. Roseberry and Klimstra (1972, 1984) and Trammell (1986) proposed that periods of severe winter stress reduces reproductive success. McRae and Dimmick (1982) stated that hens in poor physical condition from a stressful winter may also show less desire to renest than do healthy hens, therefore reducing productivity and reproductive success. Severe winter weather may also delay the onset of nesting activities (Stanford 1972).

Contrary to the findings of Speake and Haugen (1960) in Alabama, Stanford (1972) in Missouri, and others, weather variability was not a major factor influencing reproduction during this study. However, weather extremes, such as severe drought or extended snow cover, did not occur on Ames Plantation during the period of study.

IV. Survival Related to Miscellaneous Factors

One of 2 miscellaneous variables examined, incubating parent, had a significant effect on reproductive success. An important miscellaneous factor not addressed during the period of study was observer impacts on nest and egg survival.

i. Incubating Parent

Although there was no difference in egg survival between nests incubated by male vs. female bobwhites, nest survival was higher when males incubated. Nests incubated by males and/or females were more successful than nests for which the incubating parent was unknown (Table 9). This difference was likely due to the fact that many of the nests with no observed guardian had been previously abandoned, abandoned after the initial observer disturbance, or the parent(s) had been killed. Occasionally, a bobwhite hen may lay a clutch of eggs that is incubated by her mate and then

lay a second clutch incubated by herself; therefore, 1 pair can successfully produce 2 broods during a nesting season (Roseberry and Klimstra 1984). Methods utilized during the study on Ames Plantation did not permit identifying the degree of double-clutching in the population.

ii. Pre-breeding Population Size

Pre-breeding population size was not correlated with nesting success during the period of study. Although a clear relationship was not evident between March population size and reproductive success, the lowest year of egg and nest survival, 1970, had a corresponding low pre-breeding population. These findings support findings of Simpson and Frazier (1974) in Georgia. They found that areas with average quail densities (0.63 birds/hectare) had no higher nesting success rates than areas with high population densities (>5 birds/hectare). Roseberry and Klimstra (1984) could not determine the effect of density on reproductive success in southern Illinois. Others have reported an increase in nest abandonment in bobwhites (Kabat and Thompson 1963) and ring-necked pheasants (*Phasianus colchicus*) (Linder and Agee 1965) because incubating hens were in contact with chicks of other hens. This contact stimulated brooding behavior directed toward the strange chicks and thus led to the abandonment of their own nests.

Results from this study suggest that the principle of inversity may not hold true when bobwhite population densities are unusually low (as in 1970). Future nesting studies should address this point as a possible predictor of yearly reproductive success.

iii. Nests Observer Impacts

The impacts of observers on egg and nest survival are unknown for this study. Observer impacts may bias estimates of nesting success. Observers walking to and from nests sites leave paths in the surrounding vegetation and scent trails for predators, such as red foxes (*Vulpes vulpes*), gray foxes (*Urocyon cinereoargenteus*), coyotes (*Canis latrans*), and feral cats (*Felis domesticus*), to follow. Esler and Grand (1993) reported predation on artificial duck nests visited daily was significantly higher than on nests visited at 7, 14, and 28 day intervals. They proposed that trampled surrounding vegetation was a cue for predators to locate nests. Lehmann (1946) may have reduced human scent trails by walking on stilts to nest sites but this doesn't seem practical for nesting studies with large numbers of nests to be observed. These observer trails may lead to underestimation of nesting success and overestimation of predator impact and/or abandonment rate during nesting studies.

V. Nesting Ecology

General aspects of bobwhite nesting ecology on Ames Plantation were comparable to those reported in several other areas of the South and Midwest. Mean clutch size and the onset of nesting activities were similar on Ames Plantation, Illinois (Klimstra and Scott 1957, Roseberry and Klimstra 1984), north Florida-south Georgia (Stoddard 1931), and Texas (Lehmann 1946). Also, findings on fates of nests (Klimstra and Scott 1957; Roseberry and Klimstra 1984) and incubating parent (Stoddard 1931) were in agreement with results from this study.

Chapter VI

Management Implications

Northern bobwhite reproductive success in southwestern Tennessee varied according to habitat, seasonal chronology, and weather conditions. Of these independent environmental variables, only habitat can be manipulated in bobwhite management programs. Although nesting habitat preferences could not be determined from this study, nesting success rates related to nesting habitat utilized can be helpful for delineating high quality nesting habitat in agricultural areas in western Tennessee.

Prescribed burning appears to be a useful management tool for managing quality nesting habitat. Burning keeps nesting areas in relatively early successional grasses and weeds, reduces the vegetation density and litter at ground level, and increases the growth and abundance of legumes (Lemon 1967). This vegetative structure allows quail to move more freely on foot during their reproductive activities and provides quality cover and feeding areas for chicks. However, burning does reduce the amount of dead vegetation necessary for nest construction. Consequently, in homogenous stands of grasses, such as broomsedge, burning may reduce the areas attractiveness to nesting quail during

the following season. To counteract possible negative effects of burning, a comprehensive plan to burn portions of the nesting habitat every 2 to 3 years should maintain high quality nesting grounds in perpetuity.

Vegetation type within nesting areas is another important habitat variable to be considered and is influenced by burning or mowing practices. Areas with dominant vegetation of panicum or other grasses mixed with forbs, and containing broomsedge as a subdominant species seem to be the most secure places for bobwhite nests. Broomsedge, although very important for nest placement and construction, may inhibit movement of quail when it is in dense stands (Roseberry and Klimstra 1984). Clumps of broomsedge scattered among other forbs and grasses is probably the best vegetation profile for nesting bobwhites in southwest Tennessee and surrounding areas.

This study suggests that minimizing the proportionate amount of edge in nesting areas, by making them larger or more uniform in shape, may increase egg survival. One possible negative effect of managing for high quality nesting habitat is an increase in nest density which may lead to an increase in predation.

Although the data for this study were collected many years previous, implications to management are more evident today than ever. With the conversion of many idle lands,

once quail chick factories, to pasture and housing developments there have been serious declines in quality nesting areas. In response to these habitat losses, quail populations have continued to decline in many areas. Quail management practices will be of limited effectiveness unless idle, early successional areas are maintained and managed to provide appropriate nesting habitat.

Literature Cited

Andersson, M., and C.G. Wiklund. 1978. Clumping versus spacing out: experiments on nest predation in fieldfares (Turdus pilaris). Anim. Behav. 26:1207-1212.

Angelstam, P. 1986. Predation on ground-nesting birds' nests in relation to predator densities and habitat edge. Oikos 47:365-373.

Boydstun, C.P., and C.A. DeYoung. 1987. Nesting success of white-tipped doves in south Texas. J. Wildl. Manage. 51:791-793.

Buhnerkempe, J.E., W.R. Edwards, D.R. Vance, and R.L. Westemeier. 1984. Effects of residual vegetation on prairie-chicken nest placement and success. Wildl. Soc. Bull. 11112:382-386.

Campbell, B.H. 1990. Factors affecting the nesting success of dusky Canada geese, Branta canadensis occidentalis, on the Copper River Delta, Alaska. Can. Field-Nat. 104:567-574.

Clark, R.G., and T.D. Nudds. 1991. Habitat patch size and duck nesting success: the crucial experiments have not been performed. Wildl. Soc. Bull. 19:534-543.

Dimmick, R.W., T.R. Eubanks, and D. Capen. 1967. Micro-environmental studies including temperature and relative humidity at bobwhite quail nest sites in west Tennessee. Prog. Rep. for Project No. MS-3-A-3. Dept. of Forestry, Agricultural Experiment Station. Univ. of Tenn., Knoxville 18pp.

_____. 1971. The influence of controlled burning o n nesting patterns of bobwhite in west Tennessee. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 25:149-155.

_____. 1974. Populations and reproductive effort among bobwhites in western Tennessee. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 28:594-602.

Duebbert, H.F., and J.T. Lokemoen. 1980. High duck nesting success in a predator-reduced environment. J. Wildl. Manage. 44:428-437.

_____, and H.A. Kantrud. 1974. Upland duck nesting related to land use and predator reduction. J. Wildl. Manage. 38:257-265.

Errington, P.L. 1933. The nesting and the life equation of the Wisconsin bobwhite. Wilson Bull. 45:122-132.

_____. 1942. Productivity in populations of higher vertebrates. J. Wildl. Manage. 6:170-177.

Esler, D., and J.B. Grand. 1993. Factors influencing depredation of artificial duck nest. J. Wildl. Manage. 57:244-248.

Eubanks, T.R. 1972. Food habits of bobwhite quail (*Colinus virginianus*) on Ames Plantation in west Tennessee. M.S. Thesis. Univ. of Tenn., Knoxville 88pp.

_____, and R.W. Dimmick. 1974. Dietary patterns of bobwhite quail on Ames Plantation. Bull. 534. Dept. of Forestrty, Agricultural Experiment Station. Univ. of Tenn., Knoxville 38pp.

Flowers, R.L. 1964. Soil survey of Fayette County, Tennessee. U.S. Dept. of Agric. Soil Surv. Service. No. 13. 168pp.

Fritzell, E.K. 1975. Effects of agricultural burning on nesting waterfowl. Can. Field-Nat. 89:21-27.

Green, R.F. 1977. Do more birds produce fewer young? a comment on Mayfield's measure of nest success. Wilson Bull. 89:173-175.

Greenwood, R.J., A.B. Sargeant, D.H. Johnson, L.M. Cowardin, and T.L. Shaffer. 1995. Factors associated with duck nest success in the prairie pothole region of Canada. Wildl. Monogr. 128. 57pp.

Hensler, G.L., and J.D. Nichols. 1981. The Mayfield method of estimating nesting success: a model, estimators and simulation results. Wilson Bull. 93:42-53.

Hines, J.E., and G.J. Mitchell. 1983. Gadwall nest-site selection and nesting success. J. Wildl. Manage. 47:1063-1071.

Houston, A.E. 1991. Beaver control and reforestation of drained beaver impoundments. Phd. Diss. The University of Tennessee, Knoxville. 132pp.

Johnson, D.H. 1979. Estimating nest success: the Mayfield method and an alternative. Auk 96:651-661.

Kabat, C., and D.R. Thompson. 1963. Wisconsin quail, 1834-1962: population dynamics and habitat management. Wisc. Conserv. Dept. Tech. Bull. 30. 136pp.

Keith, L.B. 1961. A study of waterfowl ecology on small impoundments in southeastern Alberta. Wildl. Monogr. 6. 88pp.

Klett, A.T., T.L. Shaffer, and D.H. Johnson. 1988. Duck nest success in the prairie pothole region. J. Wildl. Manage. 52:431-440.

Klimstra, W.D., and T.G. Scott. 1957. Progress report on bobwhite nesting in southern Illinois. Proc. Annu. Conf. S.E. Assoc. Game and Fish Comm. 11:351-355.

Koerth, N.E., and F.S. Guthery. 1991. Water restriction effects on northern bobwhite reproduction. J. Wildl. Manage. 55:132-137.

Lehmann, V.W. 1946. Bobwhite quail reproduction in southwestern Texas. J. Wildl. Manage. 10:111-123.

Lemon, P.C. 1967. Effects of firs on herbs of the southeastern United States and central Africa. Proceed. Annu. Tall Timbers Fire Eco. Conf. 6:113-128.

Linder, R.L., and C.P. Agee. 1965. Regulation of pheasant density through nest abandonment in south-central Nebraska. Trans. North Am. Wildl. Nat. Res. Conf. 25:214-230.

Lokemoen, J.T., and R.O. Woodward. 1993. An assessment of predator barriers and predator control to enhance duck nest success on peninsulas. Wildl. Soc. Bull. 21:275-282.

Mayfield, H.F. 1961. Nest success calculated from exposure. Wilson Bull. 73:255-261.

_____. 1975. Suggestions for calculating nest success. Wilson Bull. 87:456-466.

McRae, W.A., and R.W. Dimmick. 1982. Body fat and blood-serum values of breeding wild bobwhites. J. Wildl. Manage. 46:268-271.

Miller, H.W., and D.H. Johnson. 1978. Interpreting the results of nesting studies. J. Wildl. Manage. 42:471-476.

Minser, W.G., and R.W. Dimmick. 1988. Bobwhite quail use of no-till versus conventionally planted crops in western Tennessee. J. Soil and Water Conserv. 43:270-272.

Neu, C.W., C.R. Byers, and J.M. Peek. 1974. A technique for analysis of utilization-availability data. J. Wildl. Manage. 38:541-545.

Odum, E.P., S.E. Pomeroy, J.C. Dickinson, and K. Hutcheson. 1973. The effects of late winter litter burn on the conposition, productivity, and diversity of a 4-year old fallow-field in Georgia. Proceed. Annu. Tall Timbers Fire Eco. Conf. 13:399-419.

Parmalee, P.W. 1955. Some factors affecting nesting success of bobwhite quail in east-central Texas. Am. Midl. Nat. 53:45-55.

Roseberry, J.L., and W.D. Klimstra. 1972. Some aspects of the dynamics of a hunted bobwhite population. Pp. 268-282. In J.A. Morrison and J.C. Lewis (Eds.). Proc. First Natil. Bobwhite Quail Symp., Oklahoma State Univ., Stillwater, Okla. 390pp.

_____, and _____. 1984. Population ecology of the bobwhite. Southern Ill. Univ. Press., Carbondale and Edwardsville. 259pp.

Rosene, W. 1969. The bobwhite: Its life and management. Rutgers Univ. Press., New Brunswick, N.J. 418pp.

Schaffner, F.C. 1991. Nest-site selection and nesting success of white-tailed tropicbirds (*Phaethon lepturus*) at Cayo Luis Pena, Puerto Rico. Auk 108:911-922.

Simpson, R.C. 1972. A study of bobwhite quail nest initiation dates, clutch sizes, and hatch sizes in southwest Georgia. Pp.199-204. In J.A. Morrison and J.C. Lewis (Eds.). Proc. First Natl. Bobwhite Quail Symp., Oklahoma State Univ., Stillwater, Okla. 390pp.

_____, and F.W. Frazier. 1974. Bobwhite nesting success on two selected areas with different population densities. Proc. Annu. Conf. S.E. Assoc. Game and Fish Comm. 27:338-341.

Sovada, M.A., A.B. Sargeant, and J.W. Grier. 1995. Differential effects of coyotes and red foxes on duck nest success. J. Wildl. Manage. 59:1-9.

Speake, D.W., and A.O. Haugen. 1960. Quail reproduction and weather in Alabama. Proc. Annu. Conf. S.E. Assoc. Game and Fish Comm. 14:85-97.

Stanford, J.A. 1972. Bobwhite quail population dynamics: relationships of weather, nesting, production patterms, fall population characteristics, and harvest in Missouri quail. Pp.115-139. In J.A. Morrison and J.C. Lewis (Eds.). Proc. First Natl. Bobwhite Quail Symp., Oklahoma State Univ., Stillwater, Okla. 390pp.

Stoddard, H.L. 1931. The bobwhite quail: its' habitat, preservation and increase. Charles Scribner's Sons, New York. 599pp.

Sugden, L.G., and G.W. Beyersbergen. 1986. Effect of density and concealment on American crow predation of simulated duck nests. J. Wildl. Manage. 50:9-14.

Trammell, H.E. 1986. Bobwhite quail: I. some physiological paramenters during late breeding season; II. wing fat as an indicator of total body fat. M.S. Thesis. The University of Tennessee, Knoxville. 103pp.

U.S. Environmental Data Service. 1967-1973. Climatological Data. Tennessee. Asheville, N.C. 72-78.

Yahner, R.H., and A.L. Wright. 1985. Depredation on artificial ground nests: efffects of edge and plot age. J. Wildl. Manage. 49:508-513.

Zimmerman, J.L. 1982. Nesting success of dickcissels (*Spiza americana*) in preferred and less preferred habitats. Auk 99:292-298.

Appendix

Table 16. Climatological data recorded at Bolivar Water Works, Hardeman Co., Tennessee, 1967-1973.

Year	Month	Mean Temperature (C)	Total Precipitation (cm)
1967	January	5.6	5.83
	February	3.6	6.70
	March	13.8	10.13
	April	18.3	11.88
	May	19.0	12.70
	June	24.5	0.90
	July	23.9	20.35
	August	22.5	15.48
	September	20.9	5.13
	October	15.1	8.50
	November	7.5	5.15
	December	6.2	21.30
	Total	15.1	124.98
1968	January	2.7	15.65
	February	1.5	3.50
	March	9.1	16.15
	April	16.0	15.50
	May	19.6	8.93
	June	24.6	3.83
	July	25.6	7.38
	August	26.2	4.55
	September	20.6	16.73
	October	15.0	8.63
	November	9.3	15.43
	December	4.3	12.38
	Total	14.5	128.53
1969	January	3.9	8.88
	February	NA	9.63
	March	6.3	5.88
	April	16.2	15.75
	May	20.9	7.20
	June	24.8	4.88
	July	28.2	7.45
	August	25.2	22.00
	September	21.6	3.60
	October	15.9	6.85
	November	9.7	10.28
	December	4.3	18.15
	Total	17.5	115.03

Table 16. (cont.)

Year	Month	Mean Temperature (C)	Total Precipitation (cm)
1970	January	1.3	5.10
	February	4.5	10.18
	March	8.8	12.60
	April	17.7	17.73
	May	22.2	12.10
	June	23.7	9.58
	July	25.3	6.28
	August	26.8	12.38
	September	25.2	13.38
	October	16.6	11.85
	November	8.4	5.98
	December	7.2	8.25
	Total	15.6	111.13
1971	January	3.3	7.13
	February	4.1	17.33
	March	7.1	8.30
	April	14.7	8.50
	May	17.0	11.08
	June	25.2	9.03
	July	25.3	12.40
	August	23.8	20.30
	September	23.3	16.53
	October	19.2	0.50
	November	9.5	3.53
	December	8.8	13.53
	Total	15.1	128.13
1972	January	4.8	12.40
	February	7.4	5.30
	March	9.6	13.05
	April	15.8	8.90
	May	19.3	10.83
	June	22.9	11.90
	July	24.9	17.65
	August	25.3	8.23
	September	23.8	17.35
	October	15.2	13.28
	November	7.9	19.38
	December	4.2	25.00
	Total	15.1	162.90

Table 16. (cont.)

Year	Month	Mean Temperature (C)	Total Precipitation (cm)
1973	January	3.1	16.05
	February	4.1	8.63
	March	13.6	20.30
	April	13.7	25.15
	May	17.9	20.45
	June	25.0	4.48
	July	26.2	12.15
	August	24.4	5.23
	September	23.0	7.53
	October	18.1	6.80
	November	12.2	22.63
	December	5.3	8.28
	Total	15.6	157.65

VITA

Billy Wayne Harris II was born in Gastonia, North Carolina on May 7, 1970. He graduated from West Lincoln High School in June 1988 and soon entered North Carolina State University working toward a B.S. degree in Fisheries and Wildlife Sciences, which he received in May 1992. He was offered a research assistanship at the University of Tennessee in August 1992 and a teaching assistantship in August 1994. He completed the requirements for a M.S. degree in Wildlife Science in April 1995. He is currently a field research assistant studying bird communities at Oregon State University.