Bobwhite Nesting Ecology and Modern Agriculture: A Management Experiment

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Abstract: Northern bobwhite (*Colinus virginianus*) populations have declined on a continental scale. One factor implicated in the decline is habitat loss through agricultural modernization. To better understand the relationship between northern bobwhite and modern farming, and to examine farm habitat improvement methods, we monitored bobwhite ($N = 218$) from April to September 1993 and 1994 on two study areas, western (WSA) and eastern (ESA), each divided into one filter strip (FS) (treatment) and one non-filter strip (NFS) (reference) section on Alligator River National Wildlife Refuge's farming units in Dare County, North Carolina. Filter strips were 9.4 m wide planted and natural vegetation buffer zones surrounding drainage-ditches in crop fields. Using radio-telemetry, we followed bobwhite, identified nest incubations and hatchings, and monitored hatched broods. We examined the null hypotheses that number of captures, distances to first nest from capture site, number of nest incubation initiations, nest success, and adult and brood survival would be identical on FS and NFS sections. With equal effort, there were 142 and 65 bobwhite captured on the WSA FS and NFS sections, and 75 and 48 bobwhite captured on the ESA FS and NFS sections, respectively. Pooling data across areas, sections, and years, 42 quail initiated 53 clutches. There were 31 and 3 incubations initiated on the WSA FS and NFS sections, respectively. There were 13 and 6 incubations initiated on the ESA FS and NFS sections, respectively. Pooling across areas, sections, and years there was 1 incubation/3 and 1 incubation/8 transmittered bobwhite on FS and NFS sections, respectively. Pooling clutch ($N = 28$) data for all areas, sections, and years, clutches averaged 11.7 (SE = 0.75), and declined over time ($P = 0.006$). Nest success, pooled across years

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for section, was 32% ($N = 44$, 14 successful) and 44% ($n = 9$, 4 successful) for FS and NFS sections, respectively, and did not differ ($P > 0.05$). Pooling across sections by year, nesting success did not differ between years ($P = 0.11$), but differed between early (≤ 15 Jul) and late (> 15 Jul) periods (19.4% and 54.5%, respectively, $P = 0.02$). Quail on NFS areas exhibited greater movements from capture site to first nest. Pooling survival data across areas, sections, and years sub-adult/adult survival from 1 April to 29 September was 33% (95% CI = 24% − 42%). Brood survival to 28 days ($N = 5$) ranged from 0%–100% and averaged 68% (SE = 17%). Higher nesting success and high brood survival in the later periods were correlated with maturation of broadcast-planted soybeans.

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Bobwhite quail nesting ecology has been the focus of much research (Stoddard 1931, Errington 1933, Parmalee 1955, Lehmann 1946, Speake and Haugen 1960, Klimstra and Scott 1957, Rosene 1969, Klimstra and Roseberry 1975, Roseberry and Klimstra 1984, Curtis et al. 1993, Suchy and Munkel 1993, Devos and Mueller 1993). However, few studies have examined effects of replicated habitat manipulation on bobwhite nesting ecology in modern agricultural settings.

The continental quail population has declined at a rate of 2.4%/year since 1966 (Church et al. 1993). Much habitat has been lost from changes in agricultural practices (Minser and Dimmick 1988, Burger et al. 1990, Brennan 1991). Modern farmers, to remain competitive, have converted hedgerow, fencerow, and fallow habitats into production areas, eliminating much nesting and brood rearing cover associated with pre-World War II era farms (Stoddard 1931, Rosene 1969, Roseberry and Klimstra 1984, Brennan 1991). Therefore, the need for research to assess the bobwhite's relationship to modern agriculture, and investigates methods of improving bobwhite habitat on modern farms exists.

Accordingly, this study was designed and implemented to examine bobwhite reproductive ecology in relation to modern farming systems, and to examine filter strip effects on bobwhite nesting ecology in modern farmlands. We tested the null hypotheses that rate of capture, distances from capture site to first nest, number of incubation initiations, nesting success, and adult and brood survival would be identical on farming areas with and without filter strips.

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Methods

Study Area

Study areas consisted of 2 portions [western study area (WSA), and eastern study area (ESA)] of Alligator River National Wildlife Refuge's (ARNWR) farming units separated by a 5-km buffer zone composed of moist-soil waterfowl management units and crop fields. ARNWR is located in Dare County, North Carolina, in the northeastern coastal plain. The area surrounding the farming units is non-human populated pocosin and mixed-pine/bottomland hardwood (approx. 80,000 ha).

The study areas were further divided to create 1 filter strip (FS) and 1 non-filter strip (NFS) section on each portion. To achieve this arrangement, existing filter strips were removed from designated NFS sections and left in place on FS sections. The WSA FS section (WSAFS) and NFS section (WSANFS) included 281.6 ha and 218.8 ha, respectively. The ESA FS section (ESAFS) was 640 ha. The ESA NFS section (ESANFS) was 217.2 ha and 410.8 ha in 1993 and 1994, respectively. All sections (N = 4) contained numerous drainage-ditches. Ditches on both study areas were parallel and occurred at approximate 100 m intervals. Ditch length averaged 0.9 km (range: 0.3–1.3 km). Field size within each section averaged 6 ha (range: 4–10 ha). Number of field blocks per section averaged 50 (range: 30–81). Habitat categories for both study areas included: crop, wooded (peninsulas of woodland jutting into farming areas), filter strip, road/levee, and fallow (land left out of production >1 year) (Table 1).

Filter strips, established to filter runoff and prevent sedimentation, consisted of planted vegetation or strips of natural vegetation along agricultural drainage ditches. Filter strip widths averaged 9.4 m (N = 99, SE = 0.14) from edge to edge including the ditch itself. Width of cover crossectionally along non-filter strip ditches averaged 2.5 m (N = 99, SE = 0.05) including the ditch width. Filter strips accounted for 4.9%–9.4% of coverage in treatment areas. Filter strips were not mowed, but ditch banks on FS and NFS sections were mowed during winter.

ARNWR filter strips were planted with a mixture of kobe lespedeza (*Lespedeza striata*), ladino clover (*Trifolium repens*), and serecia lespedeza (*Lespedeza cuneata*) between 1989–1992. Planted filter strips had been largely reclaimed by naturally occurring vegetation. Primary invaders, listed from highest to lowest percentage of cover, were golden rod (*Solidago* sp.), fennel (*Eupatorium* sp.), broomsedge (*Andropogen* sp.), Panic grass (*Panicum* sp.), and paspalum (*Paspalum* sp.).

Farming systems on the study areas differed from most coastal plains farms in 1) most soybeans were not planted with traditional grain drills in rows on 8″ centers; they were broadcast-seeded behind tractors using spin spreaders and

Table 1. Percentage occurrence of habitat in 1993 and 1994 on all sections of the Alligator River National Wildlife Refuge study areas, Dare County, North Carolina.

	Habitat				
Year	Crop	Wooded[a]	Filter	Road/levee	Fallow
		1993			
WSA[b]	60.0	12.0	4.0	1.8	22.2
ESA[c]	63.0	1.9	4.9	2.2	28.0
WSAFS[d]	58.0	14.0	5.5	1.7	20.8
WSANFS[e]	64.0	8.8	2.2	2.0	23.0
ESAFS[f]	60.5	2.5	5.7	2.3	29.0
ESANFS[g]	70.0	0	2.4	1.6	26.0
		1994			
WSA	77.0	12.0	6.0	1.8	3.2
ESA	69.0	2.6	9.4	2.3	16.7
WASFS	73.0	14.0	8.0	1.7	3.3
WSANFS	82.8	8.8	2.7	2.0	3.7
ESAFS	69.0	2.6	9.4	2.3	16.7
ESANFS	75.0	0	2.3	1.4	21.3

[a]Wooded peninsulas jutting into the farming areas.
[b]Western study area.
[c]Eastern study area.
[d]Western study area filter strip section.
[e]Western study area non-filter strip section.
[f]Eastern study area filter strip section.
[g]Eastern study area non-filter strip area.

lightly disked into the soil, and 2) cropping rotations consisted of winter wheat followed by broadcast-seeded soybeans, with little use of corn (*Zea maize*) in the rotation. Refuge policy excluded use of restricted-use pesticides, and quail hunting on the study areas was prohibited.

Capture Methods

We captured northern bobwhite from February through July using funnel entrance traps (Stoddard 1931). Quail were aged (Stoddard 1931, Leopold 1939, Haugen 1957) and fitted with 6.1-g necklace transmitters modified for harnesses.

Transmittered quail were located daily, preferably prior to 1100 hours, to determine location and nesting status. Incubating birds were flagged from 3 directions within 3–5 m using dark engineer's tape. When incubation was terminated, flagged areas were searched until the nest was found. Number of chicks hatched was determined by counting hatched eggs. Brood survival was determined by flush counting 28 days post-hatch, while adult survival was determined from radio-telemetry.

Analytical Methods

On the basis of ecological and agricultural activity, the nesting season was divided into five periods for analyses: early spring (15 May and prior), late spring (16 May to 15 Jun), early summer (16 Jun to 15 Jul), mid summer (16 Jul to 15 Aug), and late summer (16 Aug and after). Data collected in these categories were recombined into (≤ 15 Jul) and late (> 15 Jul) periods for some analyses.

Differences in nesting success by period, nesting success by habitat type, and clutch size by period were tested for using tests of 2 proportions, chi-squared independence analysis, and t-tests, respectively (Steel and Torrie 1980). Straight line distances to first nest from capture sites were estimated using an Atlas, Geographic Information System (McManus, J. M. 1995, personal communication, GEO-GRAPHICS, Raleigh, NC. 919-859-6217). Differences in distance distributions between FS and NFS areas were tested with the Kolmogorov-Smirnov 2-sample test (Steel and Torrie 1980).

Survival rates of adults and sub-adults were estimated for 26 1-week periods beginning 1 April and ending 29 September. Survival rates were estimated using the staggered-entry procedure (Pollock et al. 1989). Survival curves were compared using the log-rank procedure. Differences in end-of-period survival rates were tested using z-tests. Significance level for all statistical tests was 0.05.

Results

We captured 330 bobwhite of which 218, 101 in 1993 (69 female) and 117 in 1994 (74 female), were transmittered and monitored during the nesting seasons. Of the bobwhite transmittered, 44 died within a 10 day transmitter adjustment period and were excluded from all analyses. Including bobwhite that were not radio-tagged, 142 and 65 bobwhite were captured on the WSA FS and NFS sections with equal effort, respectively. There were 75 and 48 bobwhite captured on the ESA FS and NFS sections with equal effort, respectively.

Chronology

We heard the first bobwhite calls on 13 April 1993 and 12 April 1994. Earliest observed incubation of a nest was 16 May 1994. Forty-two bobwhite reached incubation initiating 53 clutches. Males initiated 2 clutches and a third male took over an incubation after a hen was taken by a predator (5.6% male incubation). There were 31 and 3 incubations initiated on the WSA FS and NFS sections, respectively. There were 13 and 6 incubations initiated on the ESA FS and NFS areas, respectively. Pooling across areas, sections, and years, there was 1 clutch incubation/3 and 1 clutch incubation/8 transmittered bobwhite on FS and NFS sections, respectively. Clutch incubation initiations were spread evenly over spring and summer periods, with exception of late-summer. Bobwhite incubated fewer clutches in late-summer (N = 6 nests) than in earlier periods (N = 15–16 nests). Percentage of hens initiating incubation during late summer was 51% lower than during early spring to mid summer periods.

Clutch Size, Nesting Success, and Hatchability

Mean clutch size (N = 28) was 11.7 (SE = 0.75). Nesting success rates were 50% (N = 16) and 27% (N = 37) for 1993 and 1994, respectively, and did not differ ($P = 0.11$). Pooled nesting success ($N = 53$, 18 hatches) was 34%. Clutch size declined and nesting success increased from early to late periods ($P < 0.001$ and $P = 0.02$, respectively) (Table 2). There were no differences in nesting success by habitat type ($P = 0.08$) (Table 3). Combining data from both years, nesting success on NFS (44%, $n = 9$) and FS (32%, $n = 44$) sections did not differ ($P = 0.16$). Egg ($n = 121$) hatchability was 92.5%.

Distance from Capture Site to First Nest

Mean distances from capture site to first nest, pooled across study areas, were 340 m ($N = 36$) (SE = 30) and 1,460 m ($N = 5$, SE = 836) for bobwhite captured on FS and NFS sections, respectively. Although mean distances did not differ ($P = 0.43$), distributions of distances to first nest for FS and NFS area captured bobwhite differed significantly ($P < 0.05$).

Renests

Eleven of 53 nests were renests (20.7%). Seven bobwhite renested once and 2 renested twice. Renesting success was 45%. Renest clutch size ($N = 7$) aver-

Table 2. Clutch size and nesting success of bobwhite quail by period and by early (prior or on 15 July) and late (after 15 July) season pooled on Alligator River National Wildlife Refuge, Dare County, North Carolina from May–September 1993 and 1994.

Period	(*N*) Clutches known	Mean clutch size	(*N*) Incubations initiated	Number reaching hatch	Success rate
Late-spring	9	15.0	16	3	18.8
Early-summer	5	12.0	15	3	20.0
Mid-summer	9	9.2	16	8	50.0
Late-summer	5	9.8	6	4	66.0
Prior or on 15 July	14	13.5	31	6	19.4
After 15 July	14	9.5	22	12	54.5

Table 3. Nesting success (including renests) by habitat type pooled and pooled for early (prior or on 15 July) and late (after 15 July) seasons on Alligator River National Wildlife Refuge farming units, Dare County, North Carolina from May–September 1993 and 1994.

	Nests			Incubations			
Habitat Type	(*N*)	(*N*) Successful[a]	% Successful	No. on or prior to 15 July	% Success	No. after 15 July	% Success
Fallow	17	5	29.4	11	18.0	6	50.0
Crop	15	7	46.6	2	0.0	13	53.8
FS[b]	14	2	14.3	12	8.3	2	50.0
Other[c]	7	4	52.0	6	50.0	1	100.0

[a]Successful. [b]Filter strip. [c]Other = road and levee edge, wooded, and area outside the study perimeter.

aged 9.7 (SE = 0.78). Mean time between nesting attempts was 36 days (range: 16 to 64 days).

Adult Survival

Sub-adult/adult survival rates from 1 April to 29 September were 41% (95% C.I. = 28%–55%) and 28% (95% C.I. = 16%–39%) for 1993 and 1994, respectively, and did not differ ($P = 0.12$). Survival pooled for both years was 33% (95% C.I. = 25%–42%). Pooled female survival across both years was 37% (95% C.I. = 24%–49%). Survival rates were fairly even for the 26 weeks of the season (Fig. 1). Low sample sizes of NFS, male, and adult bobwhite precluded testing for survival differences between treatment and reference areas, age classes, and sexes; and, survival estimates in these categories were unreliable (Pollock et al. 1989).

Brood survival rates ($n = 5$) to 28 days ranged from 0%–100%, and averaged 68% (SE = 18%). Excluding one brood with zero survivorship, brood survival rates ($N = 4$) ranged from 75%–100% and averaged 85% (SE = 5%).

Mortality and Nest Loss Factors

Causes of sub-adult/adult mortality ($N = 106$) were unknown predation (29%), avian predation (29%), mammalian predation (18%), farming operations (7%), and other (17%). Predation accounted for 76% of the confirmed deaths. Causes of chick mortality were undetermined. Causes of nest ($n = 35$) loss were unknown (11%), mammal (29%), reptile (snake) (43%) and farming operations (17%).

Discussion

On our study area, quail reproductive parameters were similar to those reported in the literature. Seasonal mean clutch size of 11.7 (SE = 0.75) was similar to those of 11.9, 12.9, and 12.8, reported by Dimmick (1974), Parmalee (1955), and Devos and Mueller (1993), respectively. They were somewhat lower than the 14.41 and 13.7 reported by Stoddard (1931) and Roseberry and Klimstra (1984), respectively. Decline in clutch size with progression of the nesting season was reported by Stoddard (1931), Errington (1933), Lehmann (1946), and Klimstra and Roseberry (1975), and primarily represents the decline in clutch size between first nests and renests (Burger et al. 1995). The ARNWR overall nesting success rate of 34% was similar to those of 38.8%, 39.4%, and 33.7% reported by Dimmick (1974), Klimstra and Scott (1957), and Klimstra and Roseberry (1975), respectively. Devos and Mueller (1993) found 45% nesting success in rolling pine lands managed specifically for high bobwhite densities in north Florida, and similar nesting success rates for early and late seasons. The highest nesting success rate reported was 55% by Suchy and Munkel (1993) in what they describe as the best remaining bobwhite habitat in Iowa.

In contrast to the data of Speake and Haugen (1960) and Klimstra and

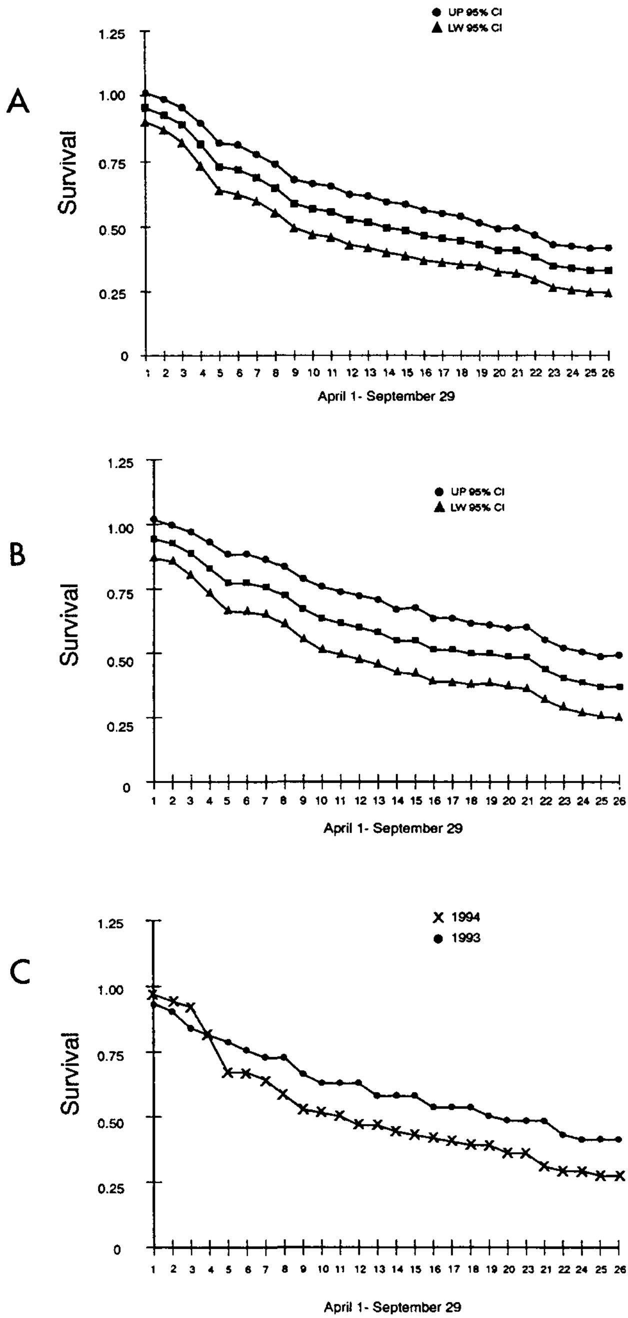

Figure 1. Survival curves on Alligator River National Wildlife Refuge farming units from 1 April–29 September 1993 and 1994: A) pooled for both years, B) pooled female survival, and C) individual years pooled.

Roseberry (1975), nesting success was highest on ARNWR farms during late periods. Nesting success was low in all habitat types prior to 15 July. An increase in nesting success after 15 July accompanied an increase in habitat provided by maturing soybeans. Depending on section and year, crop maturation produced a 1.5x to 12x increase in available nesting area. After 15 July, bobwhite nesting habitat use shifted from filter strips and fallow fields to soybean fields. Vegetative characteristics of ARNWR broadcast-planted soybean fields approximated vegetative characteristics of suitable quail nesting habitats described in the literature (Stoddard 1931, Rosene 1969, Klimstra and Roseberry 1975).

Treatment Effects

Filter strips had positive and negative effects on quail productivity. Filter strips provided cover, movement corridors, and nesting habitat during the early period. Filter strip areas were more productive compared to NFS areas with respect to trapping success and nest incubation initiations. Though trapping efforts were equal on FS and NFS areas, there were more bobwhite captured in FS sections on both study areas. Further, there was 1 nest incubation/3 transmittered bobwhite and 1 nest incubation/8 transmittered bobwhite on FS and NFS areas, respectively; and NFS birds exhibited the more extreme movements from capture site to first nest. Despite the positives, nesting success in filter strips during the early period was low; and, though it would seem the decreased movements exhibited by FS section bobwhites should accrue survival benefits, low sample sizes precluded testing FS versus NFS adult and brood survivals.

Agricultural Effects

Though sample size prevented testing effects of filter strips on survival, the uniformity of survival rates throughout the sampling period suggested that agricultural activities were not causing abnormal mortality via direct impacts. Additionally, three radio-monitored bobwhite broods between 7 and 10 days old were located in soybean fields as insecticides were aerially sprayed; these broods experienced good survival rates. Apparently, insecticides used had no direct effect on brood survival. Indirect impacts of insecticides were beyond the scope of this study.

Though survival did not appear to be directly affected by agricultural activity, nesting and recruitment were. Agricultural activity, i.e. disking and planting, was constant through May and June. Most early-season nesting areas, i.e. fallow fields, were removed by disking during May. Many early bobwhite nests, and some adult bobwhite were lost to tillage in the form of disking. As July progressed, farming activity decreased, and soybean maturation proceeded, increasing available nesting cover. As nesting cover increased, nesting success increased. Unfortunately, clutch size and percentage of extant hens initiating clutch incubations declined simultaneously. Therefore, number of chicks produced was lower than if an equal amount of nesting habitat had been available in the early period. Burger et al. (1995) emphasized that, perhaps most importantly, lack of early season nesting cover decreases the opportunity for hen renesting. Additionally, if first nesting success is low, hens are less likely to leave later clutches with males and incubate a third clutch (Burger et al. 1995). Our data, integrated with the results of Burger et al. (1995), Curtis et al. (1993), Devos and Mueller (1993), and Suchy and Munkel (1993) suggest that lack of early season nesting cover could greatly reduce recruitment. A question of great concern is how early versus late brood production impacts fall recruitment in agricultural areas.

A study conducted in Nevada by Stinnet and Klebenow (1986) on use of irrigated farmlands by California quail (*Callipepla californicus*) demonstrated that field borders, though less than 1% of the total area, were preferred by California quail during all seasons. Minser and Dimmick (1988) found 11 quail nests in no-till planted crop fields, but no nests in conventionally planted crop fields. Our data, as well as that of Burger et al. (1995), suggest that limited early season nesting habitat in agricultural landscapes may substantially reduce quail recruitment. On our study area, filter strips provided early season habitat, but nesting success was low. Integrating filter strips within full-season no-till, or broadcast-planted soybean farming systems may provide the early season nesting and brood rearing habitat required for expression of the bobwhite's high reproductive potential.

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