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QUAIL IV: PROCEEDINGS OF THE FOURTH NATIONAL QUAIL SYMPOSIUM

Edited by

LEONARD A. BRENNAN, WILLIAM E. PALMER,
LOREN W. BURGER, JR., AND TERESA L. PRUDEN

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C. Genest

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The Quail IV Logo of northern bobwhite, mountain quail, California quail, and Montezuma quail was painted in watercolor by Cathy Genest Godfrey.

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Many people contributed to the success of the Fourth National Quail Symposium. Nick Wiley, of the Florida Fish and Game Commission (now Florida Fish and Wildlife Conservation Commission) provided critical organizational help to put the conference together. Tommy Hines helped secure funding for printing the proceedings at the 11th hour.

Kaye Gainey and Katherine Ross organized registration materials, the book of abstracts, and numerous other details small and large that are essential to a successful conference.

Steve Lindeman helped organize audiovisual resources and numerous other logistical details.

Keith Moser did yeoman work organizing a fleet of rental vans that transported people between downtown Tallahassee and Tall Timbers.

I sincerely appreciate the way that all speakers and workshop leaders organized their high-quality presentations and workshops. Furthermore, I also appreciate the editorial and technical help provided by Bill Palmer, Wes Burger, and Teresa Pruden. They all made sure the papers in this volume were held to a high editorial standard.

I thank the administration and trustees of Tall Timbers Research Station for allowing me to use my time, and myriad institutional resources, to host Quail IV, and make it a success.

LAB
Tallahassee, FL

PREFACE

Leonard A. Brennan
Tall Timbers Research Station, 13093 Henry Beadel Drive, Tallahassee, FL 32312

This volume represents the fourth installment from a series of national quail symposia that began in Oklahoma during 1972. On May 6–9, 1997, Tall Timbers Research Station, in cooperation with the Florida Game and Fresh Water Fish Commission, hosted Quail IV: Fourth National Quail Symposium. The purpose of Quail IV was to bring together researchers, managers, administrators and landowners interested in the management and biology of wild quail, so that they could assess the state-of-the-art of quail management and research.

As you will see from these proceedings, there is a lot of research being conducted on quail. Most of this research involves northern bobwhites, but there is also significant work being conducted on most western species of quail as well. All of the research presented at Quail IV, including the work on western quail species, has broader implications for game bird and wildlife management. There is something to be learned from everyone who is conducting quail research.

The Herbert Stoddard Memorial Game Bird Lecture, which has been a regular feature of recent Game Bird Seminars at Tall Timbers, was a featured part of the Quail IV program. Dr. Dick Potts, Director General of the Game Conservancy, gave the Fourth Stoddard Memorial Lecture at Quail IV. Dr. Potts' pioneering research on partridge populations and management in England has served as a model for much of the bobwhite research that has been conducted here in the states during the past decade.

Along with the contributed oral and poster papers, workshops on: (1) Modeling Habitat and Populations, (2) Collecting and Analyzing Telemetry Data, (3) Farm Bill Provisions for Quail, and (4) Strategies for Developing Quail Management Plans, were critical parts of the program. Concluding remarks by John Roseberry from a researcher's viewpoint, and Hunter Drew from a manager's perspective, rounded out the program after George Hurst roasted the conference organizers at the banquet. I look forward to Quail V in 2002.

FOURTH HERBERT L. STODDARD, SR. MEMORIAL GAME BIRD LECTURER:

DR. G. R. POTTS

Leonard A. Brennan
Tall Timbers Research Station, 13093 Henry Beadel Drive, Tallahassee, FL 32312-0918

The Stoddard Memorial lectures began during the 1994 Game Bird Seminar at Tall Timbers. The purpose of the lecture is to bring a distinguished biologist to Tall Timbers and have him or her speak about how Stoddard's ideas influenced his or her research program and development as a scientist or manager. Since Tall Timbers was hosting Quail IV, I thought it made sense to incorporate the Stoddard Lecture as part of the Fourth National Quail Symposium.

Dick Potts is the preeminent game bird researcher alive today. As you will see in his paper, Stoddard's ideas had a significant impact on Dick's predecessors at the Game Conservancy, an organization that is a leader in game bird research on both sides of the Atlantic.

Dick's record of research has been essential for moving game bird biology out of the realm of traditional descriptive natural history and into the modern era of quantitative ecology and controlled, manipulative field experiments. Such concepts are being embraced by game bird researchers in America, thanks in no small part to the seminal work of Dr. Potts.

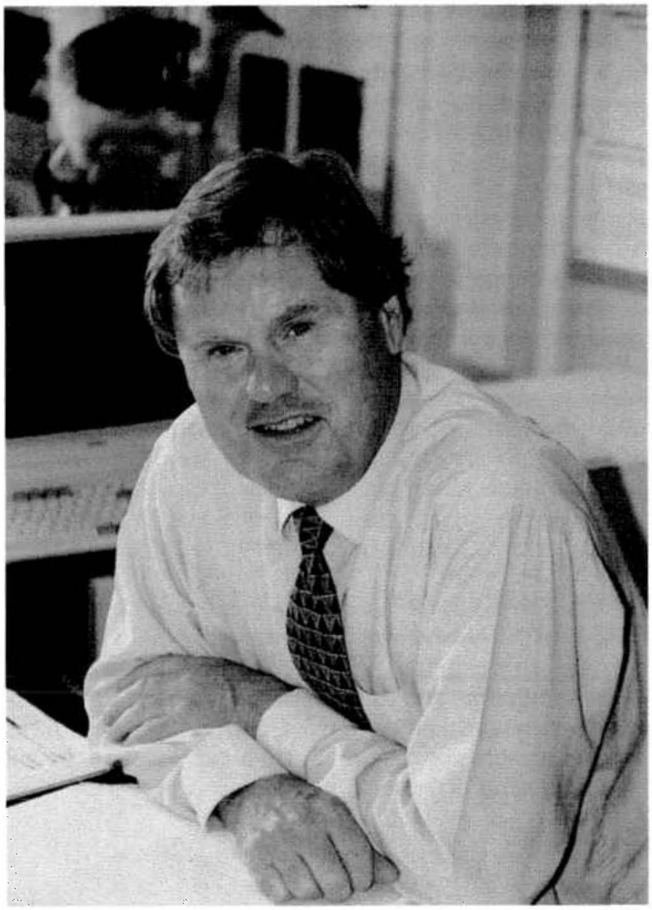
In 1986, Dick Potts published a classic book *The Partridge: Pesticides, Predation, and Conservation,* which made me, and many of my contemporaries, completely rethink our approaches to game bird research, especially in the context of modern agricultural and forest environments and how the present condition of these environments affect wildlife. The effects of pesticides, (especially the indirect effects of modern chemicals that do not bioaccumulate, but can be problematic for wildlife), to say nothing of predation, are both hot button topics that engender conversation and debate which quickly outstrip the inferential bounds of published information. Dick tackled the nefarious problems of pesticides and predation head-on as factors responsible for the vexing decline of gray partridge (*Perdix perdix*) in England. Because Dick took an approach to his partridge research that incorporated long-term data collection, field experiments, and modeling, he was able to advance a conservation agenda for partridge population recovery based on sound science.

Herbert Stoddard's ideas influenced the development and direction of both Tall Timbers Research Station and the Game Conservancy. The Game Conservancy was founded the same year that Stoddard published his "big book" on bobwhites. By correspondence and in personal visits, Stoddard communicated his ideas about game birds and their management to the founders of the Game Conservancy, and thus had a great impact on the development of this important organization. Having Dr. Potts deliver the Stoddard Memorial lecture is yet another example of Stoddard's ideas and inspiration coming full-circle. As the host of Quail IV, I cannot think of an individual more suited than Dr. Potts to be the 4th Stoddard Memorial Lecturer.

FOURTH STODDARD MEMORIAL GAME BIRD LECTURE

USING THE SCIENTIFIC METHOD TO IMPROVE GAME BIRD MANAGEMENT AND RESEARCH: TIME

G. R. Potts
The Game Conservancy Trust, Fordingbridge, Hampshire, SP6 1EF, United Kingdom



G.R. Potts
Fourth Stoddard Game Bird Lecturer

ABSTRACT

Aware of the time lag that frequently exists between declines in biodiversity and effective conservation to correct and reverse the declines, I examine some reasons behind this problem. Experience with species as diverse as the shag (*Phalacrocorax aristotelis*) and grey partridge (*Perdix perdix*) shows the main problem to be the long period of time needed to detect problems, to define causation, to install effective changes in policy and, finally, to bring about restoration. The time needed to conduct research and implement policy to solve such problems often exceeds the time span of a career in ecology. Speedier results are therefore essential, but they will depend in part on removing the barriers between practitioners and theorists on the one hand and between practical applied ecologists and bureaucratic policy makers on the other.

Citation: Potts, G.R. 2000. Using the scientific method to improve game bird management and research: time. Pages 2–6 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, Jr., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

Two events in the early 1930's, the publication of Stoddard's (1931) monograph on the northern bobwhite (*Colinus virginianus*) and the establishment of The Game Conservancy, were unrelated—but not for long. Stoddard visited some Game Conservancy study areas at the beginning of June 1935 and further inspired our organization with the idea of game as a by-product of farm crops. In his case, of course, the crop was timber that was managed by selective logging, "carried out with the welfare of game prominently in the picture."

Stoddard regularly corresponded with my predecessors. In one letter dated November 1945 he wrote to A. D. Middleton, "I am afraid you will be greatly disappointed with the game research that you will find under way in the United States." Nevertheless, he continued to encourage bobwhite quail managers using, in part, his knowledge of successes with the grey partridge (*Perdix perdix*) in the United Kingdom (UK). Similarly, Middleton visited Stoddard in 1947 and immediately began to encourage partridge managers using his knowledge of bobwhite quail management in the United States.

All this is a long time ago, but it does introduce the theme of my talk, which is time. How much time do we need to carry out the research necessary to solve a problem? There is also the related question—do we need long-term monitoring? After all, say the critics, monitoring does not advance science in the way that experiments can. There is no virtue in long-term data gathering for its own sake. I suppose monitoring could become a completely mindless exercise, though it will not be mindless if the objectives are clear.

For as long as I can remember, there have been vacuous arguments about the value of long-term studies. Long-term monitoring projects have suffered, particularly where government departments have been involved (e.g., in the UK the Rothamsted annual aphid surveys financed by the Ministry of Agriculture, Fisheries & Food (MAFF) and the continuous plankton survey, once funded by MAFF, now financed with private funds by The Sir Alister Hardy Foundation for Ocean Science). My proposition here is that long-term work is not a virtue, it is a necessity that stems from the long-term basis on which nature itself operates.

I will show that the length of time necessary to diagnose a problem, get action on that problem, and monitor the remedy, often must be measured in decades. I will argue that things must be speeded up, and that it would help if scientists were to become more involved in policy issues, and less detached from practical considerations. By the same token, policy makers need to have more practical and scientific experience.

METHODS AND RESULTS

Below I draw on some of my own experiences to illustrate the amount of time it takes for research to provide solutions to problems.

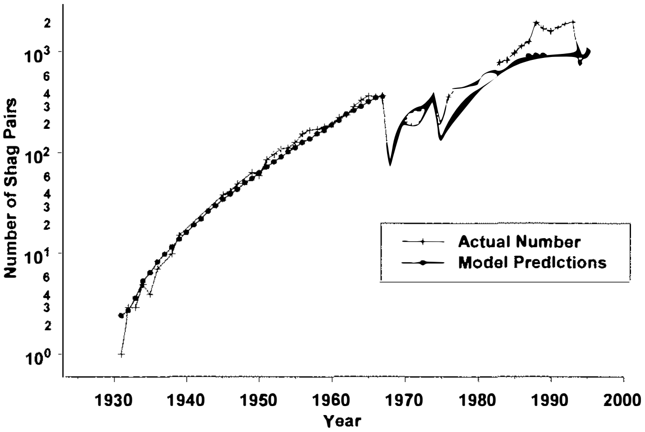


Fig. 1. Comparisons of actual and modeled population trend of the shag (*Phalacrocorax aristotelis*) on the Fame Islands, United Kingdom from 1930 to 1995.

Monitoring and Modeling

The first example I shall give is that of the shag (*Phalacrocorax aristotelis*) on the Farne Islands. The population model used to predict annual changes was a simple one written in 1978 but it took nearly 30 years of monitoring to accumulate enough data to develop it. It was only after 14 years of annual ringing, mostly by John Coulson of the University of Durham, that sufficient data had been collected to start the studies that we began in 1962. Seventeen years later we were able to produce a model of population growth. The redistribution of sites and breeding success following the red tide of 1968 was as predicted, and this gave us the confidence to publish (Potts et al. 1980). However, the question remained: How good was the model?

Our model certainly fitted the retrospective data well (Figure 1) but for the future it turned out to be too pessimistic, because we had not studied the shags for a sufficient amount of time. We had not foreseen that the birds would spread to many other islands in the Farne Islands group. The model basically represented what would happen on 4 of the 11 Farne Islands, and when inferences from the model are limited to these 4 sites it remains satisfactory. The birds, however, now breed on a further 4 other islands, all of which are less suitable than the original 4, but support significant numbers of birds, nonetheless. Neither did we consider that the strict control of disturbance by tourists would have such a benefit to the birds by reducing predation by herring gulls (*Larus argentatus*). Nor did we even consider that guillemots (*Uria aalge*), which return earlier to nest sites than shags, would increase and eventually take over many of the best nest sites.

Although we predicted a peak shag population of a little less than 1,000 pairs, the population now looks as though it might reach a ceiling at about 2,500 pairs (Figure 1). Before we leave the shag example it is instructive to suppose that we had checked the numbers only once, in 1995, 16 years after the model was completed. In that year there were 1,016 pairs and we might congratulate ourselves since the number is very close to what was predicted. There were, however, already 1,948 pairs by 1993, over twice what we had expected. The comparatively low numbers in 1995 were due to the effects of very high mortality during 1994. Such results show the benefits of annual monitoring and a danger of using only limited spot checks as a substitute for monitoring.

My Sussex study on partridges had its origins in a monitoring project started by others in 1954 (a farmer, Christopher Hunt, and a gamekeeper, Fred Allen). Their ideas were based on the Damerham study which began in 1947 and on 7 years work by A.D. Middleton prior to World War II. Thus, my partridge model developed in 1977 was written after no less than 37 years work, mostly by others (Potts 1986). The model accurately predicted the changes in the Sussex study partridge population through to the present time. However, density-dependent nesting mortality was higher than expected, offset by lower density-dependent winter losses than expected (Potts and Aebischer 1994). Furthermore, various experiments justified the basic model parameters. The structure and role of nest predation was verified in the Salisbury Plain experiment (Tapper et al. 1996), and there was validation of this point from North Dakota (Carroll 1992) and Poland (Panek 1997). The supposed effects of pesticides on chick survival were verified in a number of experiments (Rands 1986, Sotherton 1991).

The Sussex partridge model, however, has not been able to predict the situation accurately on the 824-acre (333-hectares) farm managed by the Trust since 1992. In that year, there was one pair of partridges and by now we had predicted that we would have 12 pairs, whereas in fact we have only 4 or 5.

Although 57 years of study have been insufficient to develop a model that will produce really robust predictions, we do have a model which has proved very useful in partridge conservation. In particular, it drew attention to the intensity of density-dependent nest predation that was otherwise obscure, and implemented the management needed to overcome its effects.

One factor discounted in the partridge models was raptor predation. In retrospect, this seems to have been entirely justified and still is; however, the continuous increase in raptor numbers in the area (see Figure 2) draws attention to the need to embed conclusions in the time frame of the study involved. It could even be that at some future point raptors will have overwhelming importance, and could possibly prevent the recovery of partridge populations when all other factors have been controlled by good management. I emphasize we have no data to show this yet but raptor numbers are increasing in the Sussex study area and need to be monitored. During our annual surveys the ratio of partridges seen to raptors seen has changed from 1: 150, to 1:15 over the 30-year Sussex study (Figure 2).

How many years does it take to complete a controlled and replicated experiment to verify a model?

Consider the Salisbury Plain experiment (Tapper et al. 1996). This cross-over test was first designed in 1982 following the experience of Marcstrom and colleagues on islands in the Gulf of Bothnia (Marcstrom et al. 1988). Thus, 14 years elapsed from planning to publication. My estimate would be that it could not have been done more quickly than in 9 years. Game Conservancy Trust (GCT) experiments on conservation headlands took 8 years (Sotherton 1991). GCT work on insecticides and the recovery times of insects affected would also suggest that a minimum of 9 years field work will be necessary from planning to final publication, where a large scale cross-over experiment was involved (Aebischer 1990).

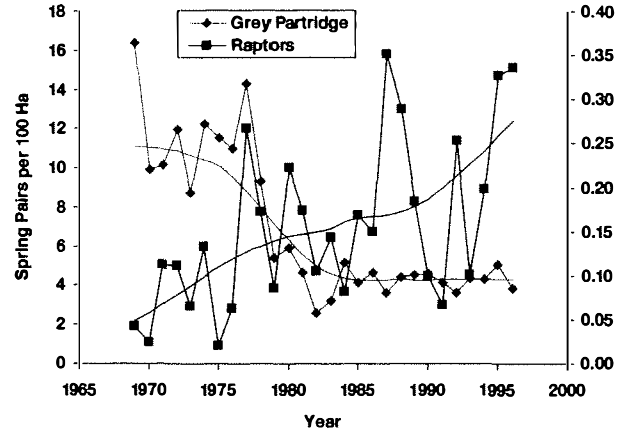


Fig. 2. Results of annual counts of partridge (*Perdix perdix*) and raptors in late August/early September 1969–1997; data from the Sussex Downs study area, United Kingdom.

Most experiments with partridge populations appear to need up to 10 years from first planning to final publication in the refereed scientific press.

How many years does it take to (i) detect a problem, (ii) diagnose its causes, and (iii) start remedial action?

(1) *The insecticide pp′ DDE.*—In a sense, the monitoring that detected the thinning of raptor egg shells due to pp′ DDE began in the 19th century with the collection of eggs for museums. Although, the effect of shell thinning started prior to 1950, it was retrospectively detected in 1966 and proven experimentally in 1969 with bans increasingly effective over the period 1969–1976 (Ratcliffe 1980).

(2) *Seed dressings incorporating the insecticide dieldrin.*—The direct effects of these seed dressings began in 1956, and were detected during the first season of use (Anonymous 1957). The lethal dose (LD_{50}) was only established in the mid-1960's (Robinson et al. 1967) with effective bans over the period 1962–1966 (Ratcliffe 1980).

(3) *The foliar insecticide dimethoate.*—The direct effects on beneficial insects were first quantified in 1975 (Vickerman and Sunderland 1977). Indirect effects on partridge chick survival were first reported in 1990 (Potts 1990). The first measures to restrict the use of this insecticide were to exclude it from the outer 6-meter wide margins of cereal

crops, part of the UK's Pesticides Safety Directorate Review in 1993.

(4) *The demise of traditional undersowing in cereals.*—The indirect effects of this change in cereal growing began in the mid-1960's, with effects first suspected in 1969 (Potts 1970). Adverse effects on insects, particularly sawflies, were documented over the period 1971 (Potts and Vickerman 1974) to the present (Barker and Reynolds 1999). Worthwhile incentives for farmers to restore the practice have been introduced in only 1 ESA recently and in 2 pilot areas of the Arable Stewardship Scheme, which will begin to be effective in the years 1999–2004.

(5) *The indirect effect of non-insecticidal broadleaved herbicides.*—These were first quantified in the mid-1960's (Southwood and Cross 1969), with further documentation accumulated to the present time. Grants for using conservation headlands to mitigate damage for some species were introduced gradually beginning in 1992 (Potts 1997).

How long after the remedial action would it take for the populations to recover?

The recovery times of the sparrowhawk (*Accipiter nisus*) (Newton 1986) and peregrine falcon (*Falco peregrinus*) (Crick and Ratcliffe 1995) were approximately 20–25 years. The shag (this paper) and some raptors (Newton 1994) are still recovering from past effects; their recovery time could be in excess of 75 years. The recovery of the stock dove (*Columba oenas*) could take as long as 20 years (O'Connor and Shrubb 1986). The calculation of recovery times from modelling gives 7 years for the grey partridge (Potts 1986) and 4 years for sawflies (Aebischer 1990).

To summarize, with consideration of length of time needed for monitoring, the time needed for modeling, experimentation, remedial action, and restoration is to be measured in decades. Allowing for overlaps (Potts and Robertson 1994), the total time needed to conduct research on factors limiting the abundance of wildlife populations is in excess of a full career in ecology.

DISCUSSION

There are, of course, several monitoring studies that are effectively permanent but these are rare and exceptional scientific initiatives. Among the best examples are those at Rothamsted, England, where the Broadbaulk and Park-grass experiments have been carried out for 155 and 142 years, respectively. Even at Rothamsted, however, this long-term work contrasts with the relatively few studies there that have lasted more than 3 years (Woiwod 1991).

Some of our longest studies are not very long-term in biological time. One of the most well known is that of the fulmar (*Fulmarus glacialis*) on Eynhallow, Orkney Islands, which took place during the equivalent of the late George Dunnet's entire working life (Jenkins and Wynne-Edwards 1996), yet it encompassed little more than 2 fulmar generations. The larch bud moth (*Zeiraphora griseana*) research in Switzerland, examined after 34 years, covered a period of only 4 cycles long (Clark et al. 1967).

In fact, it is astonishing that we can have a debate at all about the value of long-term work given the age of many organisms; up to 1,400 years for trees in the Amazon (Chambers et al. 1998), possibly longer for the yew (*Taxus baccata*) in the UK (Mabey 1996), 4,700 years for the bristlecone pine (*Pinus aristata*), and 10,500 years for the huon pine (*Lagarostrobos franklinii*) of Tazmania (Anonymous 1995).

One feature of any long-term research is that it would have to persist through the many changes in fashion that seem to dominate animal ecology. The temptation is often to divert wholly into theory problems such as density dependence versus density independence; diversity and stability theory; intrinsic versus extrinsic population regulation; ecosystem energy flow; ideal free distribution consequences; chaos; optimal foraging; acid rain; metapopulation theory; global warming; special effects observed through satellite imagery, and many others including diversity and stability, which are coming round for the second time in a generation (compare, for example, Way 1974 with Tilman et al. 1996). It could be that the attractions of theoretical ecology thwart long-term field work, but there are lots of other reasons ranging from fossilization of scientific careers through to the difficulties of securing long-term funding. What funding organization will today give open-ended career length commitments of the kind that were available to chemists and physicists in Germany in the 19th and early 20th centuries? Yet ideally, planning should be embedded in a time-frame which is greater than the length of individual scientific and administrative careers.

The long time-scales are, I believe, an actual cause of unnecessary reductions in biodiversity. We need a better system, we need to speed up the research and make it more effective and, frankly, more useful.

Given there is insufficient time and support for long-term studies, most policies are driven by incomplete research. It might be possible to make up some lost time or take short cuts by revisiting some of the classic study areas, e.g., those of Paul Errington in Iowa or of the Craigheads in Montana. Common sense could help make up the shortfall too, but it depends on long-term practical experience, something that has been seriously neglected by many ecologists. For example, recent results showing the benefits of plant biodiversity in grassland ecosystems in the USA (Tilman et al. 1996) have been the basis of traditional ley farming in the UK for 200 years.

In today's world, policies are often driven through the media by pressure groups, often on single issues. But who is to blame? How many of us at Quail IV have been regularly involved in trying to influence government policies? The very idea that science should be applied is anathema to some ecologists, but surely we can all agree that research is a better driver of policies than dogma. Please become involved, like Stoddard did all those years ago. It need not detract from your science. At present, however, in both the UK and in the USA the main problem is the lack of effective communication between policy makers and field-based practitioners.

ACKNOWLEDGMENTS

I would like to thank my colleagues and Wendy Smith for helping prepare this paper.

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Note added in proof: Since this paper was delivered on 6 May 1997, research has started on the possible effects of raptors on partridges, and the diversity-stability debate has moved a long way, for example see McCann et al. (1998) Weak trophic interactions and the balance of nature. Nature 395:794–797.—*GRP*.

HABITAT USE BY BREEDING NORTHERN BOBWHITES IN MANAGED OLD-FIELD HABITATS IN MISSISSIPPI

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ABSTRACT

To better understand the proximate and ultimate cues associated with habitat selection in breeding northern bobwhites *(Colinus virginianus)*, we compared habitat use vs. availability at 2 spatial scales equivalent to Johnson's (1980) 2nd and 3rd order selection. We conducted the study in managed old-field habitats in Mississippi, from 1994 to 1996. We also estimated habitat use by broods with respect to availability, and quantified micro-habitat characteristics (4th order selection) at brood-rearing sites and nesting sites. Breeding bobwhites did not establish home ranges at random or allocate resources among patches in proportion to their availability. Breeding bobwhites, given a mosaic of seasonally manipulated old-field habitats, consistently used burned fields, disked fields, and areas with advanced woody succession to define breeding season home ranges. Bobwhites allocated their time and resources more to woody areas and fields that had received a combination of burning and disking. Broods consistently used burned/disked fields in proportion to availability; consistently avoided row crops and pastures; and generally preferred woody corridors. Vegetation characteristics at nest sites did not differ from random sites located within the same patch of habitat. Characteristics among nest sites were similar, yet successful nests were located in the proximity of more bare ground and less litter cover than unsuccessful nest sites. Brood site habitat characteristics were similar to nest sites; however, woody canopy (44.3%) and visual obstruction readings (59.0cm) at brood sites were significantly greater than nest sites (26.6% and 32.5cm).

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INTRODUCTION

Use of the habitat concept is often inconsistent among researchers (Karr 1980), and has throughout the progression of avian ecology, been used to define, in part, the species "niche". Supporters of Grinnell's (1917) conceptualization of niche maintain that (1) relationships exist between a species' distribution and underlying environmental conditions and (2) that niche components reveal relationships with other organisms, and ultimately the community structure where it resides (Rotenberry 1980). In contrast, Elton (1927) defined the niche concept as the functional role of an organism within the community, and adherents to this definition have suggested a distinct separation between a species' habitat and its role (Whitaker et al. 1973). Regardless of the definition used, it becomes obvious that habitat variables illustrate an integral part of a bird species' niche. Quantification of these habitat variables provides insight as to how, when and why birds allocate their time and resources to portions of the plant community, and subsequently the vertebrate community in which they occur.

The process of habitat selection by birds may be described as an adaptive process where individuals develop patterns based on their perception of environmental conditions (Rotenberry 1980). These patterns can be viewed in a hierarchal sense in which a bird first chooses a general place to live (habitat), and then makes subsequent decisions about how to allocate its time within different patches, the search mode it uses, and its responses to physical cues that it encounters (Charnov and Orians 1982). Selection may be based on a specific search image, early learned experience, genetic programming, or any combination of these factors (Klopfer 1970). Although birds should prefer environments in which their survival and reproductive success is good (L'evins 1968, Orians 1980, Orians and Whittenberger 1991), the recognition stimuli which cause a bird to settle in a particular habitat patch may not directly influence the survival and reproductive success (fitness) of that bird (Hildén 1965). These proximate cues, however, are associated with ultimate factors which allow a species to exist under selective pressures (Hildén 1965, Rotenberry 1980). Bobwhites, through an undetermined combination of genetic and behavioral factors, are adapted to cue on characteristics of their surrounding habitat, which through evolutionary history enhanced individual survival and ultimate fitness. However, in modern landscapes which have been altered by humans, proximate ques may have become uncoupled with ultimate rewards measured in terms of fitness gains. Johnson (1980), recognizing that habitat selection operates at multiple spatial scales, introduced the concept of selection order (1st, 2nd, 3rd, 4th), in which orders of higher selection are conditional on the previous level. This approach is useful in ranking habitat components used by animals

Table 1. Area of available habitat types (ha) to breeding northern bobwhites on Trim Cane Wildlife Research and Demonstration Area, MS, 1 April–27 September, 1994 to 1996.

Habitat type	1994		1995		1996	
	ha	%	ha	%	ha	%
Control	59.68	15.7	28.20	7.4	36.45	8.1
Burn	75.76	19.9	77.21	20.3	97.90	21.8
Disk	54.92	14.4	69.10	18.2	45.75	10.2
Burn/Disk	43.97	11.6	58.08	15.3	76.38	17.0
Pasture	25.12	6.6	19.66	5.2	44.55	9.9
Row Crops	39.91	10.5	32.93	8.7	45.99	10.2
Woody	81.26	21.3	94.59	24.9	102.46	22.8
Total	380.62	100.0	379.76	100.0	449.48	100.0

with respect to their availability at multiple hierarchical spatial scales (Johnson 1980).

During the breeding season, habitats used by bobwhites typically contain components that provide escape, nesting, brood-rearing, foraging, and roosting covers (Stoddard 1931, McRae et al. 1979). Several researchers have studied the habitat needs of bobwhites (Stoddard 1931, Errington and Hamerstrom 1936, Lay 1940, Rosene 1969, Moore 1972, Yoho and Dimmick 1972, Simpson 1972, Bell et al. 1985, Mueller et al. 1988, Shaffery 1989, Burger et al. 1990); however, most analyses of habitat use or selection have been conducted at a single, and often undefined, spatial scale. Radio-telemetry facilitates quantification of habitat selection at multiple spatial and temporal scales (i.e., macro- and micro-habitat use throughout a defined period of time). Although application of radio-telemetry in bobwhite research is nearly 3 decades old (Bartholomew 1967), few studies address resource selection in relation to quantified spatiotemporal mosaics. Until recently, habitat use and movements by bobwhites have been quantified almost exclusively during winter (Yoho and Dimmick 1972, Wiseman and Lewis 1981, Bell et al. 1985), with few studies addressing habitat use by breeding bobwhites (Shaffery 1989, Taylor and Guthery 1994). In general, these studies reflect use at the macro-habitat level. In 1994, 3 studies in Mississippi addressed habitat use of bobwhite during the breeding season (Fuller 1994, Lee 1994, Manley 1994). In each study, macro-habitat use was tested with respect to available habitat types, and floristic characteristics were quantified to predict micro-habitat use. These studies provided insight into breeding season habitat selection, however, they did not consider habitat use relative to specific biological processes occurring within the breeding season (prelaying, laying, incubation, and brood-rearing).

Habitat use by bobwhite broods is one of the least studied components of bobwhite ecology (Speake and Sermons 1986, DeVos and Mueller 1993, Taylor and Guthery 1994, Puckett et al. 1995). Roseberry and Klimstra (1984) stated that the life history and ecology of bobwhite chicks during the brood-rearing period is the least documented aspect of the species' biology. This can be attributed to the lack of technical and logistical tools necessary to adequately monitor chicks from hatch to first autumn. In this study, we used radio-marked adult bobwhite to (1) determine breeding bobwhite habitat use at multiple scales, relative to availability of habitats resulting from seasonal habitat manipulations and (2) quantify habitat characteristics at bobwhite nest sites and bobwhite brood sites.

STUDY AREA

We trapped, radiomarked, and monitored bobwhites on a 320 ha managed wildlife area, 10 km north of Starkville, Oktibbeha County, Mississippi. The Trim Cane Wildlife Research and Demonstration Area (TCWA) was under rowcrop production until 1986. Natural plant succession began following crop harvest in 1986. The developing vegetation community consisted primarily of broomsedge (*Andropogon virginicus*), Johnsongrass (*Jorghum halepense*), and annual and perennial forbs, interspersed with woody ditchbank and fencerow habitat (Manley 1994). TCWA was dissected by a network of drainage canals left after the channelization of Trim Cane Creek, and most of the area was subject to frequent inundation during winter and spring. Pioneer hardwood species such as box elder (*Acer negundo*) and green ash (*Fraxinus pennsylvanica*) took control of moist areas in fields adjacent to Trim Cane Creek, and areas of poor drainage throughout the study area.

In 1992, TCWA was divided into 50 fields, each averaging 6.5 ha (Manley 1994). The use of prescribed burning and strip-disking have been considered as beneficial to bobwhites for some time (Stoddard 1931);

Table 2. Simplified ranking matrix[a] comparing proportional habitat use within 100% kernel estimated home ranges with proportions of total available habitat types for Trim Cane Wildlife Research and Demonstration Area, MS, 1 April to 27 September 1994 to 1996.

Habitat type	Habitat type							
	Control	Burn	Disk	Burn/Disk	Pasture	Crops	Woody	Rank[b]
Control		−	−	+++	+++	+++	+	4
Burn	+		+	+++	+++	+++	+	6
Disk	+	−		+++	+++	+++	+	5
Burn/Disk	−−−	−−−	−−−		−−−	−−−	−−−	0
Pasture	−−−	−−−	−−−	+++		+	−−−	2
Crops	−−−	−−−	−−−	+++	−		−−−	1
Woody	−	−	−	+++	+++	+++		3

[a] Positive and negative signs denote selection and avoidance, respectively. Triple signs represent significant deviations from random ($P <$ 0.05).

[b] An increase in rank value signifies increased use of habitat in selecting breeding season home ranges.

Table 3. Simplified ranking matrix[a] comparing the proportions of radio locations for each bird in each habitat type with the proportion of each habitat type within the birds 100% kemel estimated home range for Trim Cane Wildlife Research and Demonstration Area, MS, 1 April to 27 September 1994.

Habitat type	Habitat type							
	Control	Burn	Disk	Bum/Disk	Pasture	Crops	Woody	Rank[b]
Control		+	+	−	+++	+++	−	5
Burn	−		−	−−−	+	+	−−−	3
Disk	−	+		−−−	+	+	−−−	4
Burn/Disk	+	+++	+++		+++	+++	−	6
Pasture	−−−	−	−	−−−		−	−−−	1
Crops	−−−	−	−	−−−	+		−−−	2
Woody	+	+++	+++	+	+++	+++		7

[a] Positive and negative signs denote selection and avoidance, respectively. Triple signs represent significant deviations from random ($P <$ 0.05).
[b] An increase in rank value signifies increased use within home ranges.

therefore, we applied 3 experimental treatments on TCWA to improve bobwhite habitat: prescribed burning, strip-disking, and burn-disk combinations (Manley 1994, Taylor 1996). Control areas were added as a fourth experimental category and were allowed to undergo natural plant succession (Manley 1994). Habitat manipulations were applied at the same annual intervals with the same intensity throughout the study. TCWA contained no pasture, hayfields or fields planted to rowcrops; however, these habitat types were in close proximity to the boundary of the area, and thus were included in use and availability measures.

METHODS

Bobwhites were captured with walk-in funnel traps baited with commercial 3-grain chicken scratch or cracked corn (Stoddard 1931). Birds were aged, sexed, weighed to the nearest 1 g, banded with a #7 aluminum legband, radio-marked with a 5–6 g pendant-style transmitter, and released at the capture site. Radio-transmitters operated on the 148.000 to 149.999 MHz band and included a mortality sensor switch and a 25-cm antenna. Trapping began in late winter, while coveys were still formed and well into the breeding season to maintain an appropriate sample size.

Radio-marked birds were located 5 days/week using a programmable scanning receiver and handheld Yagi, and H-series antennas. Locations were obtained by homing and circling the bird at 25 to 50 m, then plotted on reproductions of aerial photos (Burger 1993). Additionally, we monitored hourly movements of each bobwhite brood during 1 of 3 5-hour intervals each day (0530 to 1030, 0930 to 1530, 1430 to 1930).

We describe habitat use of bobwhite during the reproductive season at 3 spatial scales equivalent to Johnson's (1980) 2nd, 3rd and 4th order selection using compositional analysis (Aebischer et al. 1993). Within the reproductive season, we quantified overall habitat selection and selection at 2 temporal scales: pre-hatch and post-hatch. The pre-hatch interval coincided with specific biological processes including prelaying, laying, and incubation, while the post-hatch interval included the brood-rearing period. Habitat use during the prelaying interval was estimated by reviewing daily telemetry locations of individual birds prior to their initiation of laying. The laying interval was estimated by backdating from known incubation initiation dates (1.2 days/egg multiplied by the number of eggs in clutch) (Klimstra and Roseberry 1975). A bird was classified as incubating when it stayed at the same location for 2 consecutive days during the breeding period. The nest site was then flagged at >10 m from 2 directions, and the following information was recorded: incubation initiation date, clutch size, and general habitat type. Upon hatching of the clutch, we continued to locate the parent bird daily using radio-telemetry. At 3 weeks of age, broods were flushed from the

Table 4. Simplified ranking matrix[a] comparing the proportions of radio locations for each bird in each habitat type with the proportion of each habitat type within the birds 100% kernel estimated home range for Trim Cane Wildlife Research and Demonstration Area, MS, 1 April to 27 September 1995.

Habitat type	Habitat type							
	Control	Burn	Disk	Burn/Disk	Pasture	Crops	Woody	Rank[b]
Control		−	−	−−−	+	−	−−−	2
Burn	+		+	−	+	+	−−−	5
Disk	+	−−−		−−−	+	+	−−−	4
Burn/Disk	+++	+	+++		+++	+++	−	6
Pasture	−	−	−	−−−		−	−−−	1
Crops	+	−	−	−−−	+		−−−	3
Woody	+++	+++	+++	+	+++	+++		7

[a] Positive and negative signs denote selection and avoidance, respectively. Triple signs represent significant deviations from random ($P <$ 0.05).
[b] An increase in rank value signifies increased use within home ranges.

Table 5. Simplified ranking matrix[a] comparing the proportions of radio locations for each bird in each habitat type with the proportion of each habitat type within the birds 100% kernel estimated home range for Trim Cane Wildlife Research and Demonstration Area, MS, 1 April to 27 September 1996.

Habitat type	Habitat type							
	Control	Burn	Disk	Burn/Disk	Pasture	Crops	Woody	Rank[b]
Control		+++	+	−	+++	+++	+	6
Burn	−−−		−−−	−−−	+	+	−	3
Disk	−	+++		−−−	+++	+++	+	5
Burn/Disk	+	+++	+++		+++	+++	+	7
Pasture	−−−	−	−−−	−−−		−	−−−	1
Crops	−−−	−	−−−	−−−	+		−	2
Woody	−	+	−	−	+++	+		4

[a] Positive and negative signs denote selection and avoidance, respectively. Triple signs represent significant deviations from random ($P < 0.05$).

[b] An increase in rank value signifies increased use within home ranges.

roost at dawn to estimate chick survival, and the parent bird was considered brood-rearing as long as 1 or more chicks were present. If a parent bird made a large move in 1 day or paired with another bird, we flushed the bird to determine brood loss or brood abandonment. At times, parent birds were inadvertently flushed during collection of daily telemetry locations or vegetation measurements, and their association with chicks was recorded. We were not able to distinguish between brood abandonment, brood loss or brood mixing (Burger et al. 1995).

We used the adaptive kernel 100% home range estimator (Worton 1989) in program CALHOME (Kie et al. 1996) to delineate home range boundaries. We compared mean home range size between years using a one-way analysis of variance [(PROC GLM) SAS Inst. Inc. 1988]. For each year, we combined all home range boundaries to determine study area availability. Habitat composition in the study area, and within each bird's home range, were determined by intersecting home range polygons with a geographic information system of available habitats on the study area. We compared proportions of each habitat type in the study area (availability) with proportions found in each individual's home range (use) to determine 2nd order selection (Johnson 1980, Aebischer et al. 1993). We then compared proportions of habitats in each home range (availability) with radio locations of each individual (use) to determine 3rd order selection (Johnson 1980, Aebischer et al. 1993). Using multivariate analysis of variance (MANOVA), we tested the null hypotheses that (1) breeding bobwhite define home ranges at random and (2) allocate their time and resources at random. We replaced missing values in MANOVA with a value of 0.00001 (Aebischer et al. 1993). We used paired *t*-tests to compare relative use of each habitat with all others individually, and ranked habitats in order of use. Due to insufficient degrees of freedom for MANOVA (Aebischer et al. 1993), we used Neu et al. (1974) to test hypotheses regarding brood habitat selection.

Assuming that a bird had selected a patch, habitat variables were quantified at 4th order (Johnson 1980) for the incubation and brood-rearing periods. Nests were monitored daily, and visually examined when the radio-marked bird was away from the nest. Hatching and termination days were determined to within 1 day. Upon hatching or nest termination, vegetation measurements were taken at the nest site to determine 4th order structural characteristics (Johnson 1980). Measurements included: litter depth; percentage ground cover for grasses, forbs, and woody species, litter and bare ground; percentage canopy cover for grasses, forbs, and woody species; and Robel visual obstruction index (Robel et al. 1970). Structural characteristics at the nest site were determined from 1 0.1-m^2 plot centered on the nest (Robel et al. 1970), from line intercept readings along a 4-m transect in each of the 4 cardinal directions from the nest (Canfield 1941), and from a 0.1-m^2 plot at the end of each transect (Robel et al. 1970).

Methods for locating and measuring brood-rearing sites closely follow that of nest sites. Brooding adult birds were located ≤5 times/day using hand-held telemetry equipment to walk within 10m of each brood/day and flag the position. Vegetative measurements similar to nest site measurements were taken the following day to quantify 4th order characteristics (Johnson 1980).

We used a comparison of 2 sample means [(PROC TTEST) SAS Inst. Inc. 1988] to test for differences between vegetative characteristics at nest sites and random sites, within the same patch. The same procedure was used to test for differences between vegetative characteristics at successful and unsuccessful nest sites, and to test for vegetative differences between nest sites and brood sites. We used logistic regression to model nest selection and nest success.

RESULTS

From 1994 to 1996, we radio-marked 88 and 51 male and female bobwhites, respectively. We used 24 male and 19 female radio-marked adult bobwhites to estimate habitat use at 2nd and 3rd orders of selection. Of these, 16 females and 5 males incubated 21 nests, 9 of which were successful (5 female and 4 male). These broods, in addition to 2 broods encountered at random (adopted by radio-marked bird or hatched outside study area) yielded 189 brood locations.

Table 6. Habitat use by northern bobwhite broods on Trim Cane Wildlife Research and Demonstration Area, Oktibbeha County, MS, 1 April to 27 September 1994.

Habitat type	Number of locations	Expected use	Observed use	Bonferroni[a] confidence interval	Result
Control	1	0.1568	0.0270	$-0.0458 < P < 0.0998$	Avoided
Burn	4	0.1990	0.1081	$-0.0313 < P < 0.2475$	Proportional
Burn/Disk	6	0.1155	0.1622	$0.0033 < P < 0.3276$	Proportional
Disk	8	0.1443	0.2162	$0.0315 < P < 0.4010$	Proportional
Woody	18	0.2135	0.4865	$0.2622 < P < 0.7108$	Preferred
Crops	0	0.1049	0.0000		Avoided
Pasture	0	0.0660	0.0000		Avoided

[a] After Neu et al. (1974) test conducted at ∝ = 0.05.

Overall Use of Habitat

Study area habitat availability for the breeding seasons of 1994, 1995, and 1996 totaled 380.6, 379.8, and 449.5 ha, respectively (Table 1). Juxtaposition of habitat types and seasonal treatments were similar between years; however, treatment of some fields was altered to deter hardwood encroachment. Home ranges of some bobwhites extended beyond the managed boundary of the study area; therefore, pasture and row crops were available at 2nd order selection. Mean home range size was similar among years ($F = 2.65$; df = 2, 42; $P = 0.08$). Overall habitat use differed from random at 2nd order ($\lambda = 0.36$; df = 6, 40; $P < 0.001$) and was not affected by year ($\lambda = 0.82$; df = 12, 68; $P = 0.84$) or sex ($\lambda = 0.91$; df = 6, 34; $P = 0.74$); therefore, bobwhites exhibited selection in home range establishment. Habitat use at 3rd order selection was similar between sexes ($\lambda = 0.87$; df = 6, 34; $P = 0.55$), yet differed between years ($\lambda = 0.42$; df = 12, 68; $P = 0.002$). Bobwhites did not allocate time among patches in proportion to availability in 1994 ($\lambda = 0.29$; df = 6, 13; $P = 0.006$) or 1995 ($\lambda = 0.12$; df = 6, 10; $P < 0.001$); however, habitat use at 3rd order was proportional to availability in 1996 ($\lambda = 0.09$; df = 6, 2; $P = 0.25$).

Habitats used in home range selection were ranked in increasing order of use, and were similar among years (Table 2). Burned fields, disked fields, woody areas and control fields were used significantly more than burned/disked fields, pastures and row crops at the 2nd order of selection (Table 2). Burned/disked fields were used significantly less than all other habitats, suggesting avoidance in home range definition during the breeding season.

Given that individual bobwhites chose home ranges, habitats used in patch selection (3rd order) were ranked in increasing order of use, and were similar between years (Tables 3, 4 and 5). Individuals used woody areas and burned/disked fields significantly more than burned fields, disked fields, pastures, and row crops for 1994 (Table 3). Similarly, in 1995, woody areas and burned/disked fields were used significantly more than disked fields, pastures, row crops and control fields (Table 4). Woody areas also were selected over burned fields in 1995; however, use of burned fields did not differ significantly from burned/disked fields (Table 4). Bobwhite use of burned/disked fields was more than all other available habitats in 1996, yet was not significantly different from use of control fields (Table 5). Pastures and row crops were used significantly less than control fields, disked fields and burned/disked fields in 1996 (Table 5).

Habitat Use by Broods

Habitat available to bobwhite broods was based on overall study area availability for both years (Table 1). Each year broods used burned/disked fields in proportion to their availability, while avoiding pastures and rowcrops (Tables 6, 7 and 8). Woody corridors were preferred over all other available habitats in 1994 and 1996, while use of other available habitats was stochastic (Tables 6, 7 and 8). Many brood locations were reported in areas recently relieved of standing water, thus providing bare ground with a significant overhead canopy component.

Microhabitat Characteristics at 4th Order Selection

We collected data on vegetation for 3 nest sites in 1994, 9 nest sites in 1995, and 4 nest sites in 1996 (*n*

Table 7. Habitat use by northern bobwhite broods on Trim Cane Wildlife Research and Demonstration Area, Oktibbeha County, MS, 1 April to 27 September 1995.

Habitat type	Number of locations	Expected use	Observed use	Bonferroni[a] confidence interval	Result
Control	14	0.0743	0.1556	$-0.0513 < P < 0.2599$	Proportional
Burn	21	0.2033	0.2333	$-0.1116 < P < 0.3551$	Proportional
Burn/Disk	20	0.1529	0.2222	$-0.1026 < P < 0.3419$	Proportional
Disk	20	0.1820	0.2222	$0.1026 < P < 0.3419$	Proportional
Woody	15	0.2491	0.1667	$0.0594 < P < 0.2739$	Proportional
Crops	0	0.0867	0.0000		Avoided
Pasture	0	0.0518	0.0000		Avoided

[a] After Neu et al. (1974) test conducted at ∝ = 0.05.

Table 8. Habitat use by northern bobwhite broods on Trim Cane Wildlife Research and Demonstration Area, Oktibbeha County, MS, 1 April to 27 September 1996.

Habitat type	Number of locations	Expected use	Observed use	Bonferroni[a] confidence interval	Result
Control	5	0.0811	0.0820	$-0.0139 < P < 0.1779$	Proportional
Burn	6	0.2178	0.0984	$-0.0057 < P < 0.2025$	Avoided
Burn/Disk	9	0.1699	0.1475	$0.0236 < P < 0.2715$	Proportional
Disk	0	0.1018	0.0000		Avoided
Woody	41	0.2280	0.6721	$0.5080 < P < 0.8362$	Preferred
Crops	0	0.1023	0.0000		Avoided
Pasture	0	0.0991	0.0000		Avoided

[a] After Neu et al. (1974) test conducted at $\alpha = 0.05$.

= 16); 1 random site per nest within the same patch (n = 16); and 78 brood locations. Of the 16 nests, 7 were successful and 9 were unsuccessful.

Logistic regression models did not identify vegetation variables or combinations thereof that were useful in predicting nest selection or nest success; therefore, we report univariate results. Vegetation characteristics at nest sites did not differ from random sites located within the same patch of habitat (Table 9), and successful nest sites were similar to unsuccessful nest sites (Table 10). Brood site vegetation characteristics were similar to nest sites; however, woody canopy (44.3%) and visual obstruction readings (59.0cm) at brood sites were significantly higher than at nest sites (26.6% and 37.5cm) (Table 11).

DISCUSSION

Overall Use of Habitat

The specific proximate and ultimate cues associated with habitat selection by breeding bobwhite remain an enigma. Such cues may vary throughout the geographic range of the species. However, breeding bobwhite at TCWA, given a mosiac of seasonally manipulated old-field habitats, consistently used burned fields, disked fields, control fields and woody areas to define their breeding season home ranges. Manley (1994) reported similar habitat use by breeding bobwhite on TCWA during 1993.

Throughout the 1994 and 1995 breeding seasons, woody areas and burned/disked fields were the most used habitat types within each bird's home range. In 1996, bobwhite use of control fields (unmanipulated old fields in more advanced state of plant succession) increased, and was second only to burned/disked fields. Control fields contained a significant and increasing woody component by 1996 and may have increased the proportion of available woody habitat. Woody corridors may have provided advertising posts for male bobwhite, escape cover, and corridors for movement between habitat types. Increased canopy cover also may have provided a cool, dry micro-climate for loafing during extreme heat and excessive rainfall (Johnson and Guthery 1988). The distribution and amount of woody cover available in the landscape may determine the proportion of usable space. Given that bobwhite used woody habitats in greater proportion than their availability (21 to 25%) at both 2nd and 3rd order levels of selection, we suggest optimal percent woody cover is somewhat greater than 20 to 25%.

Burned/disked fields were selected at 3rd order and likely provide annual weed seeds and invertebrates that enhance foraging habitat quality. Additionally, Manley (1994) reported that fields treated with burning and disking contained less litter and more bare ground than other treatments (Manley 1994), and may have provided increased mobility for breeding bobwhites.

Nest Site Microhabitat Selection

Although bobwhites exhibited macrohabitat selection at multiple scales, we did not detect fine scale selection for vegetation characteristics at nest sites. This may imply that bobwhites select patches in which to nest, but within the patch they are less selective with respect to the specific location for nest construction. That is, selection occurs at the spatial scale of the patch, instead of at the nest site spatial scale. If vegetation structure at the nest site has little effect on the probability of a nest hatching, given that a suitable patch is selected for nesting, there may be little pressure for selection of a specific vegetation structure. In support of this hypothesis, we observed no structural differences in habitat patches between successful and unsuccessful nests.

Brood Habitat Selection

Components of brood habitat are rarely defined and probably vary throughout the geographic range of the bobwhite. Stoddard (1931:40–41) recognized that brooding bobwhites require protection from intense sunlight, as well as rain. During this study, broods selectively used woody habitats. Woody cover and high percentages of bare ground have been identified as important components of bobwhite brood habitat (Cantu and Everett 1982, DeVos and Mueller 1993). Our sample of radio-marked adult bobwhites with broods used a variety of habitat types with 19.4% mean bare ground, similar to that reported in central Alabama (22.9%) and northern Missouri (25%) (Speake and Sermons 1986, Burger et al. 1994). Grasses (33.4%), forbs (40.0%) and woody plants (44.3%) provided ≤3 strata of overhead cover. Woody canopy cover (44.3%) was similar to overstory canopy cover (40%) reported by DeVos and Mueller (1993). Brood habitat was structurally different from nesting habitat. Brood sites

Table 9. Mean (cm)[a] vegetative characteristics of bobwhite nest sites and random sites at Trim Cane Wildlife Research and Demonstration Area, MS, 1994 to 1996.

	Nest site			Random			
Variable	$\bar{x}$	%	S.E.	$\bar{x}$	%	S.E.	P
Grass Canopy[b]	143.60	35.9	22.42	165.58	41.4	21.45	0.4847
Forb Canopy[b]	133.31	33.3	19.03	128.02	32.0	22.65	0.8593
Woody Canopy[b]	106.38	26.6	23.45	86.93	21.7	18.39	0.5193
Bare Ground[b]	97.95	24.5	19.03	140.28	35.1	27.31	0.2141
Litter Cover[b]	243.51	60.9	23.36	190.15	47.5	30.05	0.1719
Grass Ground[b]	48.94	12.2	8.40	56.95	14.2	8.12	0.4987
Woody Ground[b]	4.80	1.2	1.97	7.44	1.9	2.08	0.3643
Litter Depth[c]	0.64		0.09	0.52		0.11	0.3914
Nest VOR[d]	45.71		4.21	34.46		4.91	0.0930
VOR[e]	37.52		3.96	38.58		5.17	0.8716

[a] Means computed across all habitat types (nest: $n = 16$ random: $n = 16$).
[b] Values represent mean abundance along a 400 cm transect.
[c] Values represent mean litter depth taken at 50 cm intervals along a 400 cm transect.
[d] Mean Robel reading taken at nest site from 4 cardinal directions.
[e] Mean Robel readings from 4 m radius around nest site in 4 cardinal directions.

had greater woody cover and vegetation density than nest sites.

Taylor and Guthery (1994) reported that brush canopy cover in southern Texas differed among activity sites, and was more dense at midday loafing sites than feeding sites. They suggested that bobwhite managers should manipulate the habitat to accommodate within-day variation of habitat selection by broods. We concur with their recommendation and submit that combinations of burning and strip-disking be imposed on quail lands with a 20 to 25% interspersion of shrubby woody corridors. We also realize the importance of invertebrate abundance and accessibility to quail chicks, and suggest that these seasonal manipulations offer a mosaic of invertebrate rich habitat types while impeding succession.

MANAGEMENT AND RESEARCH IMPLICATIONS

Despite the relatively intensive disturbance regime implemented on TCWA, and selective use of manipulated fields by bobwhites, population density decreased during the study. This was in part attributable to consistently high nest predation and increasing mammalian cause-specific mortality of breeding adults over the life of the study (Taylor and Burger 1997, Taylor et al. this volume). Regrettably, we did not have information on temporal trends in predator community composition or abundance, illustrating that studies examining bobwhite ecology independent of predator context may provide an incomplete picture of population processes.

Bobwhites are adapted to exploit early successional habitats. Bobwhite management is largely control of vegetation successional processes. In old-field habitats, control of advancing natural succession in an ongoing process, but suitable bobwhite habitat can be maintained through combinations of strip-disking and prescribed burning. The disking and burning management practices implemented on TCWA provided early succession habitats which apparently met the annual cycle needs of bobwhites. However, neither this study, nor any previous studies, have clearly defined what con-

Table 10. Mean (cm)[a] vegetative characteristics of successful and unsuccessful bobwhite nest sites at Trim Cane Wildlife Research and Demonstration Area, MS, 1994 to 1996.

	Nest fate						
	Unsuccessful			Successful			
Variable	$\bar{x}$	%	S.E.	$\bar{x}$	%	S.E.	P
Grass Canopy[b]	178.08	44.5	29.21	104.46	26.1	25.35	0.0873
Forb Canopy[b]	122.11	30.5	27.99	149.96	37.5	20.25	0.4586
Woody Canopy[b]	98.19	24.5	23.82	116.11	29.0	43.17	0.7058
Bare Ground[b]	64.64	16.2	13.23	131.11	32.8	34.63	0.0694
Litter Cover[b]	278.50	69.6	13.42	210.75	52.7	46.45	0.1404
Grass Ground[b]	50.33	12.6	8.76	45.04	11.3	14.96	0.7523
Woody Ground[b]	5.42	1.4	2.61	3.50	0.9	2.77	0.6256
Litter Depth[c]	0.78		0.11	0.52		0.14	0.1604
Nest VOR[d]	49.17		6.45	42.32		6.29	0.4689
VOR[e]	34.13		4.76	43.88		8.98	0.3241

[a] Means computed across all habitat types by nest fate (successful: $n = 7$; unsuccessful: $n = 9$).
[b] Values represent mean abundance along a 400 cm transect.
[c] Values represent mean litter depth taken at 50 cm intervals along a 400 cm transect.
[d] Mean Robel reading taken at nest site from 4 cardinal directions.
[e] Mean Robel readings from 4 m radius around nest site in 4 cardinal directions.

Table 11. Mean (cm)[a] vegetative characteristics of bobwhite nest sites and brood sites at Trim Cane Wildlife Research and Demonstration Area, MS, 1994 to 1996.

	Nest			Brood			
Variable	$\bar{x}$	%	S.E.	$\bar{x}$	%	S.E.	P
Grass Canopy[b]	143.60	35.9	22.42	133.77	33.4	9.58	0.6824
Forb Canopy[b]	133.31	33.3	19.03	160.06	40.0	10.67	0.3017
Woody Canopy[b]	106.38B[c]	26.6	23.45	177.20A	44.3	12.71	0.0237
Bare Ground[b]	97.96	24.5	19.03	77.70	19.4	8.34	0.3321
Litter Cover[b]	243.51	60.9	23.36	267.24	66.8	10.65	0.3705
Grass Ground[b]	48.94	12.2	8.40	36.46	9.1	3.79	0.1875
Woody Ground[b]	4.80	1.2	1.97	14.36	3.6	2.86	0.1512
Litter Depth[d]	0.64		0.09	0.89		0.07	0.1386
Center VOR[e]	45.71		4.21	61.71		3.50	0.0544
VOR[f]	37.52B[c]		3.96	59.03A			0.0069

[a] Means computed across all habitat types (nest: $n = 16$; brood sites: $n = 78$).

[b] Values represent mean abundance along a 400 cm transect.

[c] Different letters within rows denote significance ($P < 0.05$).

[d] Values represent mean litter depth taken at 50 cm intervals along a 400 cm transect.

[e] Mean Robel reading taken at site point center from 4 cardinal directions.

[f] Mean Robel readings from 4 m radius around nest site in 4 cardinal directions.

stitutes optimal habitat composition. We propose that management as experimentation could be used in an adaptive resource context to identify optimal landscape composition at multiple spatial scales across a temporal gradient. Such management experiments should include covariates such as predator context and abundance and they should contain control areas where treatments are not applied. We support the contention that a nationally coordinated approach to management and research is required to reverse bobwhite population declines (Church et al. 1993, Brennan 1991, 1993).

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HABITAT MANAGEMENT FOR NORTHERN BOBWHITES IN WISCONSIN: A LONG-TERM ASSESSMENT

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ABSTRACT

An experimental habitat management program was initiated to improve the carrying capacity for northern bobwhites (*Colinus virginianus*) on private lands by the Wisconsin Department of Natural Resources (WDNR) in 1974. During 1975–80, extensive habitat restoration was undertaken on a 60-mi² (155-km²) study area in Richland County to restore hedge row cover, improve riparian corridors and woodlot edges, and construct plots of food and shelter to function as wintering sites for bobwhites. Previous investigations in Wisconsin have documented that the long-term decline of bobwhites was the result of habitat deterioration, principally hedgerow cover. Elsewhere, continuous declines in bobwhite abundance suggest a re-evaluation of the validity of time-honored habitat management practices is in order. Therefore, it seemed appropriate to test the impact of extensive attempts at habitat restoration, especially the development of hedgerows, on one small treatment area in the northern fringe of the geographic range of the northern bobwhite. After 10–15 years of growth, only 25% of the planted hedges were found to be effective for wintering bobwhites (i.e., closed canopies and producing fruits). Planted hedgerow cover suffered from poor survival due to deer browsing, competition from other surrounding vegetation, and changes in property owners and attitudes as farms were sold. Linear brushy cover was measured in 1990 and compared to similar estimates from 1978. During the 12-year span, brushy linear cover, including project hedges, decreased by 41% (5,995 to 3,545 yards/square mile; 2,531 to 1,497 meters/square kilometer). In addition, managed winter food resources after 1980 were reduced by half compared to earlier efforts. Through 1991, bobwhite population trends on the treatment area did not differ from statewide trends, indicating that extensive habitat restoration work had no discernible impact with respect to reversing population declines. Over 60% of the annual variability in bobwhite abundance in Richland County is related to the severity of winters. Despite these results, we still cannot discount the value of managing for hedgerows in Wisconsin. Achievements of this project include: (1) developing a bobwhite management strategy on a landscape scale, (2) gaining a high level of landowner cooperation, and (3) implementing an extensive amount of habitat restoration on private agricultural lands at minimal costs. The major problem with our overall approach is that such habitat restoration work requires continuous attention and maintenance over time to maintain effectiveness. Landowners, while highly cooperative, are not interested in protecting or maintaining habitat improvements for wildlife unless they have a vested stake in the project (i.e., a sense of "ownership"). Habitat restoration on private agricultural lands necessitates first working to change landowner attitudes towards wildlife, with the development of private lands habitat programs as a secondary concern. The outlook for northern bobwhites in the northern fringe of their range is not bright. Northern bobwhite populations will not recover unless they become a by-product of the contemporary agricultural landscape. Unfortunately, this is not the case in Wisconsin and it is unlikely to change in the foreseeable future.

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INTRODUCTION

Effective habitat management techniques for northern bobwhites have been known for more than 50 years (Stoddard 1931) yet throughout their range, declining bobwhite abundance (Droege and Sauer 1990, Brennan 1991, Church et al. 1993) has been attributed to reduced habitat quantity and quality (Sorrow and Webb 1982, Brennan 1991, Church and Taylor 1992). Such a relationship is a paradox only if viewed from a 1930 perspective. Brennan (1991) presented a strong case for re-examining habitat management for northern bobwhites. He suggested that traditional habitat management prescriptions were designed for landscapes that were very different from the ones today. This opinion is reinforced when land managers consistently fail to restore bobwhite abundance with time-honored habitat practices. While some problems can be attributed to a lack of familiarity with the concepts outlined by Stoddard (1931) and Rosene (1969), there is little question that the intensification of agricultural and fiber management practices have undoubtedly altered habitat for northern bobwhites, and in turn, negatively impacted bobwhite numbers for >6 decades.

Historically, northern bobwhites in Wisconsin were numerous throughout much of the southern half of the state. During 1846–54, bobwhites became so numerous that it "ceased to be a sport to shoot them"—they were used in place of pigeons for trap-shooting and it was common to flush 3 coveys for every 10 acres (4 hectares) of land within the city of Milwaukee (Schorger 1946:81–82). Schorger (1946) noted that this extraordinarily high bobwhite abundance was due to a favorable ratio of agricultural lands set within a wild prairie landscape, combined with a series of exceedingly mild winters. Such bobwhite abundance has never been observed in Wisconsin since this time.

From a high during the mid-1850's, bobwhite numbers steadily declined through 1962. This decline was directly correlated with the loss of hedgerow cover. Kabat and Thompson (1963) documented a 90% loss in hedgerow cover on their Prairie du Sac Study Area between the mid-1800's and the mid-1900's. They found bobwhite numbers averaged 23 birds per mile (14 birds per kilometer) of hedgerow cover when hedge cover exceeded 1 mile per 450 acres (1 kilometer per 113 hectares) of land. When the amount of hedge declined to 1 mile per 650 acres (1 kilometer per 164 hectares) of land (a 45% loss), bobwhites disappeared altogether (Kabat and Thompson 1963:61). Surprisingly, while Kabat and Thompson noted precipitous hedgerow losses, they believed food supplies from waste grains were adequate during the early 1900's. The hunting season was closed from 1963–72 because of concern for low bobwhite numbers, and there was some effort to place the northern bobwhite on the songbird list, essentially de-listing the bobwhite as a game species. The bobwhite season was re-opened in 1973 with the departmental (Wisconsin Department of Natural Resources) mandate for the initiation of a bobwhite management program. This mandate also initiated the habitat management study for northern bobwhites on private lands (Dumke 1982). The experimental habitat study focused on improving cover and food availability for bobwhites during the winter months. Implementing this strategy suggested that habitat restoration would increase the carrying capacity for bobwhite on the study area (Dumke 1982). Winter months appeared to be the time of concern as short-term population fluctuations of Wisconsin bobwhites are influenced by a complex set of factors where winter weather appeared dominant (Kabat and Thompson 1963). Dumke (1982) reported on the early phases of this study, outlining the approaches used on this private lands program involving habitat developments during 1975–80, evaluations in dealing with landowners, and preliminary results. This paper reports on the long-term evaluation of the habitat restoration efforts, and offers suggestions and ideas regarding northern bobwhite management in the northern fringe of their range.

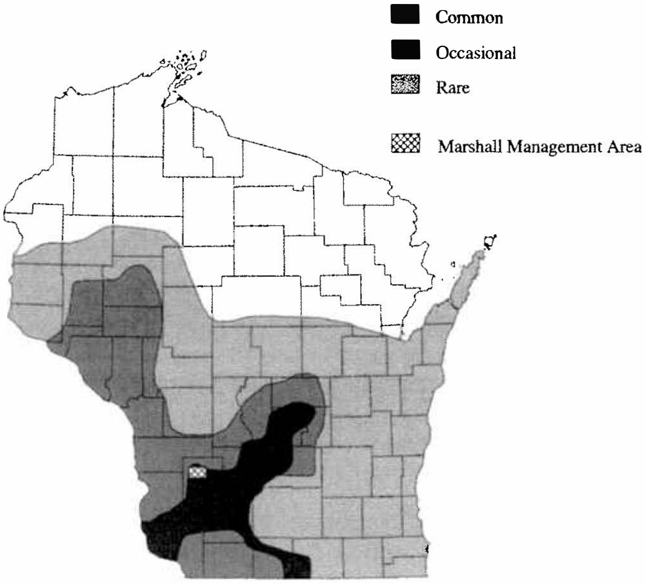

Fig. 1. Wisconsin northern bobwhite range and location of Marshall Management Area.

Background from the Earlier Work

A synopsis of the experimental habitat development work is presented to provide an understanding for the Quail Management Project (QMP) as it developed. For more detailed information, see Dumke (1982). A 60-mi^2 (155-km^2) study area, the Marshall Management Area (MMA), in Richland County was selected because it contained better-than-average northern bobwhite densities for Wisconsin and had a history of conservation-minded landowners (Figure 1). A 1972 preseason bobwhite survey indicated that Richland County residents had a genuine interest in the welfare of the northern bobwhite in Wisconsin. The topography of this region is rather rugged with a complex of narrow valleys and broad ridges. Land use was typical of southwest Wisconsin's driftless area (Table 1). Cropland was confined to the valley floors or ridge tops and the side slopes were mostly forest and pasture. The QMP was an interagency effort with active involvement from the USDA Soil Conservation Service (now know as the Natural Resources Conservation Service) District Conservationist, the Agricultural Stabilization & Conservation Service (now the Farm Service Agency) Executive Director, the University of Wisconsin Extension Specialist, and the Wisconsin Department of Natural Resources County Forester. A QMP Newsletter was developed and sent to all landowners on the MMA informing them of the project and its progress, basic bobwhite biology, and relevant resource issues.

The Marshall Management Area was divided into 26 management units of contiguous, physiographically similar habitats. Critical habitat components were identified from aerial photographs and collated with bobwhite sightings collected from landowner questionnaires (Figure 2). Both traditional and potential wintering sites were identified for bobwhites. Habitat prescriptions were written to improve food, cover, and dispersal elements of the habitat. The management concept was to provide a matrix of secure wintering sites that were connected by a series of continuous hedge, thereby promoting year-round use by bobwhites (see Guthery [1997] regarding the high value of year-round use of space for bobwhite). Some management units offered little opportunity for habitat restoration

Table 1. Land use in Richland County, Wisconsin 1977–92.[a]

Land use (area in mi²)	1978 Area (%)	1982 Area (%)	1987 Area (%)	1992 Area (%)
Cropland[b]	261 (53)	247 (53)	241 (53)	227 (54)
Corn	61 (12)	68 (15)	56 (12)	59 (14)
Hay	130 (26)	129 (28)	139 (31)	107 (25)
Oats	13 (3)	9 (2)	9 (2)	5 (1)
Idle Cropland	15 (3)	6 (1)	18 (4)	19 (5)
Pastureland[b]	56 (11)	46 (10)	40 (9)	49 (12)
Woodland[b]	161 (33)	156 (33)	155 (34)	134 (32)
Pastured woodland	100 (20)	99 (21)	85 (19)	65 (15)
Woodland not pastured	62 (13)	57 (12)	71 (16)	69 (16)
Number of farms	1,345	1,234	1,165	1,094
Average farm size (in acres)	236	242	250	248

[a] Data compiled from U.S. Department of Commerce, Bureau of the Census, 1982, 1992.

[b] Percents calculated from acres of land in farms.

[c] Percent land in farms based on total land in Richland County.

due to topography, land use, or landowner attitudes. As a result, habitat improvement was not promoted in units lacking potential for at least 3–4 wintering sites and 2–3 miles (3.2–4.8 kilometers) of fencerow hedge. Extensive habitat restoration was undertaken in 9 management units, 7 units received moderate work, 6 had little development, and the remaining 4 units received no development. From 317 property owners on the MMA, 117 landowners were initially selected to be contacted and 100 became cooperators, an 85% success rate. Seventy-two percent, or 228 of the 317 landowners, were residents, whereas only 54 of the 100 cooperators lived on the area.

Landowners controlling the most critical elements within the habitat plans for each unit were initially contacted to ascertain interest in program participation. If a field reconnaissance of their property verified initial interpretations, and landowner interest in the bobwhite program was demonstrated, a farm plan was developed. Whereas such plans focused on bobwhites, a comprehensive wildlife package was promoted as an additional incentive for participation. Desires and ideas of the property owners were incorporated into the farm plan and if agreed upon, a 10-year contract was signed, pledging the landowners' protection of the habitat improvements. The landowners' contribution was to take land out of production, whereas the WDNR's contribution was the planting materials, planting labor, and wildlife management advice.

During 1975–80, >465,000 shrubs and conifers were planted to create 32.2 miles (51.8 kilometers) of new or improved hedge, 6.5 miles (10.4 kilometers) of enhanced riparian corridors, 11.5 miles (18.5 kilometers) of improved woodland edge, and 191 plots of combined food and cover (i.e., sites with >4 rows of shrubs and conifers, often associated with sorghum and/or legume food patches). Plots were created to serve as activity centers for wintering bobwhites; they totaled 196 acres (79 hectares) and varied from a clump of spruce covering 1,350 square feet (126 square meters) to a 6.7 acre (2.7 hectare) plot with conifers, shrubs, brush piles, nesting cover, and food patches of legumes and sorghum. In addition, 130 brush piles were constructed from selectively removed trees and shrubs along areas where linear cover was developed and within plots (26 brush piles were placed in plots with food, 24 in shrub and conifer plots). The typical brush pile was 20 by 29 feet, and approximately 10 feet high (6x9x3 meters). Sorghum food patches were planted on 75 plots; 13 of these had legume patches as an auxiliary food source for early winter. Sorghum food patches averaged 8,283 square feet (770 square meters), while the mean legume plots was 1,950 square feet (181 square meters). The 3-row hedge of mixed shrubs and conifers was the predominate linear cover development installed on the MMA. Autumn olive (*Elaeagnus umbellata*),wild grape (*Vitis riparia*), ninebark (*Physocarpus opulifolius*), silky dogwood (*Cornus amomum*), gray dogwood (*Cornus racemosa*), and nannyberry (*Viburnum lentago*) were the principal shrubs planted; white spruce (*Picea glauca*) was the predominate conifer. Overall, 29 species of shrubs and 6 species of conifers were planted. Sorghum food plots were seeded to mixed grain and forage varieties (*Sorghum* spp.); legume patches consisted of lespedeza (*Lespedeza* spp.), crownvetch (*Coronilla varia*), or trefoil (*Lotus* spp.).

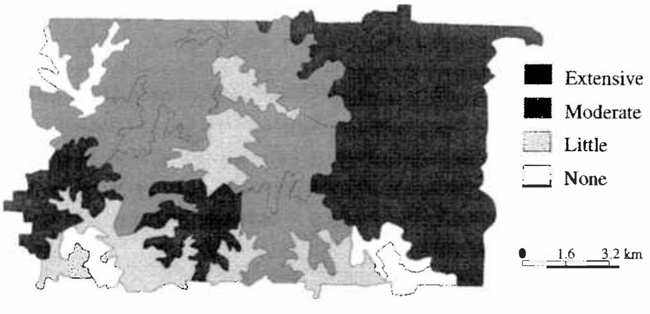

Fig. 2. Delineation of Marshall Management Area management units and intensity of habitat management undertaken.

The cost of installing habitat improvements on a typical cooperating farm was $1,610, and ranged from $250 to >$5,000. These costs included seed and tree/shrub stock, labor, and the planning and implementation of habitat developments and associated salaries, excluding costs for wildlife surveys, incidental field reconnaissance, and general land use mapping. Overall costs were kept low with extensive use of Federal work experience programs (Comprehensive Employ-ment Training Act, Community Action Program, WIN) for field work, and work study programs (e.g., internships) for landowner contacts. Wisconsin Department of Natural Resources equipment, or rentals from local implement dealers or farmers were used throughout the program.

Landowners did not participate in the QMP with equal involvement. Intensity of program participation varied with a number of factors: (1) intensity of land use was often related to the residency of the landowner (absentee landowners usually practiced less aggressive farming), (2) farm size (larger holdings offered greater opportunities), (3) compatibility of the landowner's long-range land use plan to wildlife habitat management needs, (4) agreement between the landowner and land renters regarding the intensity of land use, (5) agreement between owning partners regarding farm management, (6) interpersonal relationships between Department staff and participants (personality compatibility), (7) our perception of landowner willingness to participate, (8) the landowner's perception of total benefits and long-term gains, and (9) the landowner's interest in wildlife relative to other products of the land. In general, planned habitat restoration was largely accomplished on properties identified as potential cooperators.

Monitoring Efforts

Changes in northern bobwhite populations were documented on the Marshall Management Area and statewide. Both triangulation counts and 20-station transects of whistling males were conducted on the Marshall area, whereas regional surveys relied on transects only, following established procedures (Kabat and Thompson 1963, Dumke 1982). Triangulated counts of whistling males were taken from all suitable roads during 1 June to 5 July, three times annually. Population trends on the QMP were compared to regional trends to assess the success of habitat restoration efforts.

A Winter Severity Index (WSI) was used to objectively measure winter weather conditions. Seasonal values were calculated from minimum monthly temperature and daily snow depths during the period from December 1 through March 31 (Gates 1971, Dumke 1986). The winter severity index is more strongly influenced by snow depth than it is by minimum temperatures, and is reflective of earlier findings that Wisconsin bobwhite can often survive low winter temperatures as long as snow cover does not hamper their ability to find adequate food resources (Leopold 1931, Errington and Hamerstrom 1936, Kabat and Thompson 1963).

Hedges were monitored every 4–6 years to quantify growth and development, as well as plant survival. We visually judged growth and development, whereas survival was documented along measured intervals on randomly selected hedgerows (Woehler 1984, 1985). Wildlife use of food patches was monitored by periodic visits. A fall visit to subjectively evaluate the vegetation characteristics and seed production was followed by at least one winter visit to ascertain wildlife use.

SHORT-TERM RESPONSES

Habitat Changes

Changes on the landscape were dramatic. For example, on 6 intensive management units (a total of 6,560 acres, 2,656 hectares), 1 mile of new hedge was added for every 633 acres (1 kilometer for every 159 hectares) of landscape. Combined with existing hedge deemed adequate to serve bobwhite, the total of fencerow hedge then equaled 1 mile per 306 acres (1 kilometer per 77 hectares). If improved riparian corridors and woodlot edges also function as hedges (i.e., secure travel lanes, roosting and nesting sites), then total improved and unimproved edge cover was 1 mile per 88 acres (1 kilometer per 22 hectares) without adjusting for planting losses and growth problems. Kabat and Thompson (1963) estimated that 1 mile of hedge was needed for every 450 acres of land (1 kilometer per 113 hectares) to sustain a fall population of 1 bobwhite per 20 acres (8 hectares); they suggested this amount of hedge as a desirable management goal for bobwhite in Wisconsin. It was apparent that on some sites (i.e., intensive management units), habitat restoration efforts made monumental strides in changing habitat structure on a landscape scale.

It was routine to replace lost shrubs and conifers during the 6 years of habitat restoration. Over 50,000 shrubs and conifers were planted to replace losses due to adverse environmental conditions or accidental farming operations during 1975–80. A 1980 assessment of planting losses indicated a 31% mortality in shrubs and a 39% loss in conifers. After 1980, cooperators were offered free replacement shrubs and conifers if they would plant them. The restoration aspect of the bobwhite project was completed by then and the Department could no longer provide free labor. An average of 20,800 shrub and conifer replacement seedlings were provided to willing landowners during 1983–85. The number of seedlings actually planted as replacements for lost shrubs and conifers is unknown.

During the 1980 evaluation, severe competition from herbaceous and woody vegetation was observed from successional plant growth among the small shrubs and conifer seedlings. Negotiations with landowners were conducted to ask for their assistance in chemical or mechanical weed control. Cooperation among landowners was mixed. Survival and growth of individual species were highly variable. Site differences, year of planting, presence of competition, and quality of planting stock all contributed to the overall condition of the hedgerow. Autumn olive and ninebark developed better cover than all other shrub species, although autumn olive has an undesirable tendency to spread. Six-to-8 year old plantings of highbush cranberry (*Viburnum trilobum*), ninebark, and autumn olive produced fruit (Woehler 1984).

In Wisconsin, most cover development takes time to grow and become effective, therefore an evaluation of the habitat restoration was not believed possible until after 1990. Hedges were not considered "effective" until their growth forms overlapped, when planted shrubs and conifers formed a continuous overhead layer of protective cover (Woehler 1985, 1986). Since planted conifers were spaced 8 to 10 feet (2.4–3.0 meters) apart, it was anticipated that 8–10 years of growth was required before hedges became effective for bobwhite.

Effective Implementation with Cooperating Landowners

Whereas any judgement of the planted edges required more time, an evaluation of the techniques used to gain landowner cooperation, however, could be made. An 85% success rate in gaining cooperators reflected an adequate incentive program and an effective delivery system. The high level of landowner participation exceeded all expectations. Factors that contributed to this success rate included: (1) personal contacts, (2) early support by community leaders, (3) flexibility, (4) interpersonal cooperation, (5) administrative support from the Wisconsin Department of Natural Resources, and (6) an acceptable agreement. Of these factors, personal contacts and early support by community leaders were considered the most important. Three to 4 visits with the landowner were typically required to introduce the project and to negotiate a satisfactory farm plan. Listening to the landowner's objectives for the property, understanding their economic, cultural, and ecological constraints, and developing a sense of trust all played a role in the evolving relationship. Even issues such as chemical use during restoration work or a landowner's interest in northern bobwhite as a game species were considered. At least 5 cooperators held very strong opposition to other Department programs, and tense relations developed with another 6 cooperators due to other Department activities, yet these obstacles were overcome. Personal contacts built a close, working relationship and, when needed, restored trust.

A second factor contributing to the high level of cooperation was the active support of key landowners, the agricultural community leaders. As cooperators, these landowners were instrumental in spreading the "word" regarding the bobwhite project, and were able to address questions from other landowners and defend the project. Questions or concerns from landowners could be answered within the community, and when combined with occasional personal contacts by bobwhite project personnel and the Newsletter, little anti-project behavior developed.

Also, a major key to our success in soliciting landowners was flexibility. Every landowner and habitat plan was unique. Negotiations with cooperators included issues such as how much to plant, would the landowner play a role in planting the shrubs and conifers, would chemicals be used, would fences be installed to protect the plantings and who would build them, and even if it was necessary to gain permission to enter the property for evaluations. Such negotiations took longer to complete, but the resulting level of cooperation and its longevity more than compensated for the time spent negotiating.

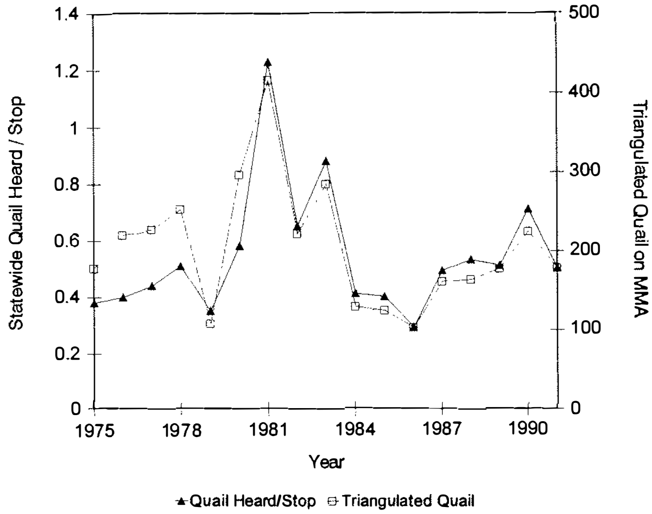

Fig. 3. Relationship of triangulated bobwhites from the treatment area to statewide transects used as controls, 1975–91.

Based on our preliminary experience from the bobwhite project, similar future efforts to improve bobwhite or other farmland wildlife species on private agricultural lands should include: (1) personal contacts to solicit landowner interest and negotiate an agreement: anticipate 5 hours per landowner contact, but inform the landowner with personal letters and a Newsletter about the project before the meeting; (2) agency personnel need to remain cognizant of the perceptions and needs of the individual landowner, and strive to remain flexible to accommodate any differences; (3) an interagency field staff needs to be involved to optimize efficiency, although a single project leader is essential; (4) key community leaders and county resource managers should be involved in the planning and implementation of the habitat development project; and (5) a simple agreement should be developed that protects the sponsoring agency's investment, yet provides flexibility in management for the landowners.

LONG-TERM RESULTS

Changes in Bobwhite Abundance

There was a strong correlation between the bobwhite counted on the Marshall Management Area and the bobwhite heard per stop on statewide transects ($n = 17$, $r = 0.86$, $P < 0.001$), indicating that the Bobwhite Management Project had no detectable impact on bobwhite densities (Figure 3). Statewide, routes were similar in their individual trends, suggesting a uniformity in factor(s) affecting bobwhites throughout Wisconsin. When winter severity was compared to triangulated bobwhite numbers on the Marshall area (Figure 4), the results suggested that over 60% of the annual variability in study area bobwhite numbers was due to winter weather conditions ($r^2 = 0.61$, $P < 0.01$).

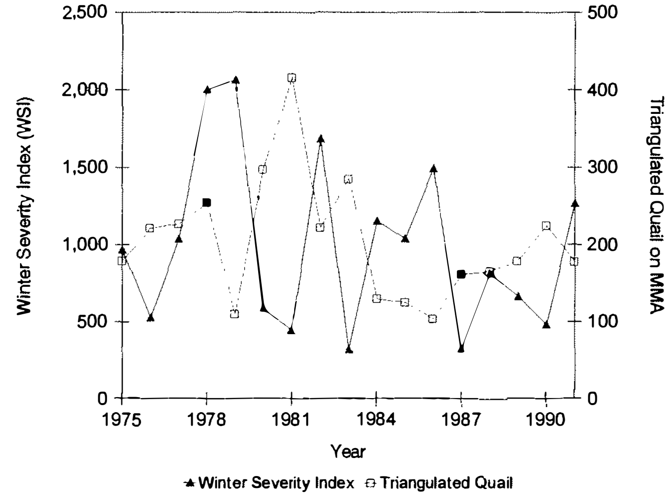

Fig. 4. Relationship of triangulated bobwhites from the Marshall Management Area to winter severity indices, 1975–91.

Table 2. Presence of habitat components of value to bobwhite on the Marshall Area, 1978–90.[a]

Cover type	1978	1990	Difference	Percent change
Area (acres/mi[a])				
Cropland	182.3	155.9	−26.4	−15.0
Conservation Reserve Program	—	25.2	—	—
Thickets[b]	0.9	1.3	0.4	44.0
Conifer clumps	3.4	6.3	2.9	85.0
Herbaceous cover	59.4	40.9	−18.5	−31.0
Brushy woodlands	32.1	49.3	17.2	53.0
Linear cover (yards/mi^2				
Herbaceous drainage[c]	176.0	616.0	440.0	250.0
Tree drainage	451.0	946.0	495.0	110.0
Herbaceous fencerow	2189.0	1617.0	−572.0	−26.0
Tree fencerow	605.0	770.0	165.0	27.0
Herbaceous woodlot edge	891.0	891.0	—	—
Brushy drainage	693.0	528.0	−165.0	−24.0
Brushy fencerow	1914.0	1199.0	−715.0	−37.0
Brushy woodlot edge	3388.0	1364.0	−2024.0	−60.0
Quail Management Program hedges[d]	—	454.0	—	—
All brushy edge	5995.0	3545.0	−2450.0	−41.0

[a] Compiled from a 16-mi^2 sample of the 60-mi^2 study area; sampled 5 of 26 management units, 3 intensively managed, 2 moderately manipulated units.

[b] Thickets defined as small areas of brush in herbaceous cover, pastures, cropland, or sites along a fenceline that are wider than the rest of the hedge. All thickets were a minimum of 500 ft^2.

[c] Only measured as herbaceous drainage when not pastured.

[d] Over 1815 yards/mi^2 of hedge originally planted during 1975–1980, 25%, or 454 yards/mi^2 judged effective after 12 years.

The impact of winter weather on spring bobwhite numbers came as no surprise. Past research on bobwhites in Wisconsin confirms the importance of winter conditions on subsequent spring numbers (Leopold 1931, Errington 1933, Errington and Hamerstrom 1936, Kabat and Thompson 1963). Kabat and Thompson (1963) documented that "normal" winter mortality for bobwhites varied from 37 to 77% of the fall population dependent upon winter severity, primarily snow depth. However, a stronger effect was expected on the Marshall area. Kabat and Thompson (1963) found that adequate food supplies through the 1950's enhanced weights and survival. Dumke (1984) suggested, however, that intensification of farming practices had drastically changed the availability of winter food stocks for bobwhites during the 1960's and early 1970's. Inadequate food resources should have resulted in an even stronger relationship between winter weather and spring bobwhite abundance. There are two factors present on the Marshall area that may have played a mitigating role: (1) the use of woodlands for pasture has declined between 1978 and 1992 (Table 1), offering additional wintering habitat (35% drop over 14 years), and (2) the practice of spreading barnyard manure remains common, offering a reliable source of winter food. Statewide, bobwhite transects for 1960–95 have suggested a declining trend (Dhuey 1997), implying factors effecting bobwhite trends in Richland County may be operating throughout Wisconsin, although BBS results from 1966–1996 show a stable trend for northern bobwhites in Wisconsin (Sauer et al. 1997).

Contributing Factors to the Poor Habitat Response

A number of factors are believed to be responsible for the lack of response by bobwhites to the extensive habitat restoration efforts. Most important was the survival and performance of hedges and other edge developments. The 1980 planting evaluation revealed substantial mortality, in spite of efforts to replant lost shrubs and conifers. In addition, the high density of white-tailed deer (*Odocoileus virginianus*) caused severe browsing damage on shrubs and conifers during 1975–85. Overwintering deer densities in Richland County were estimated at 19 to 26 animals per square mile (7.3 to 10.0 deer per square kilometer) of range, although the management goal was 15 deer per square mile (5.8 deer per square kilometer) of range (Wisconsin Department Natural Resources 1994). A sample of 14.6 miles (23.5 kilometers) of hedge examined in November 1983 and 1984 found that 39% of all shrub hedgerows suffered severe damage from browsing deer. Deer damage to planted shrubs was sufficient to cause mortality if browsing continued unabated (Woehler 1984).

An evaluation of linear brushy edge was made during 1990 to document changes since 1978. This evaluation was based on the original field maps and techniques employed by Dumke (1982). A sample of 5 management units, or 27% of the entire study area, was examined. All brushy edges along fencerows, drainages (riparian), and woodlot edges were tallied (Table 2); such types were believed to function as hedges as described by Kabat and Thompson (1963). These 3 types of linear brushy edge averaged 3.41 miles per square mile (2.53 kilometers per square kilometer) in 1978. By 1990, the same 3 types declined to 1.76 miles per square mile (1.31 kilometers per square kilometer), a 48% loss over a period of 12 years. Annual rate of loss was 4% per year. The existence of bobwhite project hedges (0.26 miles per square mile, 0.19 kilometers per square kilometer) kept the amount of brushy edge to a respectable figure (2.01 miles per square mile, 1.50 kilometers per square kilometer). Only 25% of the original project hedge was judged effective (25% of the 1.03 miles per square mile, 0.77 meters per square kilometer planted). The net loss of brushy edge cover was 1.39 miles per square mile (1.03 kilometers per square kilometer) over the 12-year time span (41% loss; 3.4% per year).

These changes can be described another way. Kabat and Thompson (1963) call for 1.42 miles of hedge per square mile (1.05 kilometers per square kilometer) as a management goal in Wisconsin. When the amount of hedge declined to 1.00 miles per square mile (0.74 kilometers per square kilometer) of land, bobwhites ceased to exist. Brushy linear edge on the MMA in 1978 was 3.41 miles per square mile compared to 2.01 miles per square mile in 1990 including project hedge. Whereas brushy linear edge is still in excess of the established management goal, the rate of decline is a cause of great concern. If the rate continues as such, the future existence of bobwhites in Richland County is in question within the foreseeable future.

Severe competition without periodic chemical or mechanical control of surrounding herbaceous and undesirable woody vegetation continued to be a problem. It was believed that once the plantings became established and became taller than surrounding vegetation, such competition would be of minor consequence. Conifers planted along woodlot edges varied in height from 2 to 10 feet (0.6–3.0 meters), reflecting differences in soil fertility, soil moisture, and competition that seriously impaired their growth and development. Even with extensive cutting and weed control, it was doubtful that these plantings would ever have any favorable influence on bobwhites (Woehler 1985,1986). Woehler (1985, 1986) felt that the variability in conifer growth, fragmentation of the conifer edge due to plant losses, and excessive competition from surrounding vegetation would not allow the conifer woodlot edge to develop as intended.

The Conservation Reserve Program (CRP) represented 16% of the cropland, but only 4% of the total land area. Subjectively, it appeared that the CRP tended to be clustered in certain areas and in some small drainages where cropland was less than ideal. In such small valleys with heavy CRP enrollment, calling male bobwhites were seldom detected within 2–3 years after retirement. The addition of CRP during the habitat restoration program may have compromised our efforts to improve habitat conditions for bobwhites on some portions of the Marshall area. Elsewhere, CRP has not been associated with improved bobwhite habitat conditions, and has been implicated in declining bobwhite abundance (King and Savidge 1995, Harr 1996). Bobwhites require semi-open areas with exposed ground and herbaceous vegetation for nesting (Stoddard 1931, Rosene 1969). They avoid fields with heavy, dense cover (Roseberry and Klimstra 1984). Over 86% of the CRP established in Richland County was cool-season grass-legume mixtures, predominately smooth brome (*Bromus inermis*) and alfalfa (*Medicago sativa*). After 3–4 years, the alfalfa was essentially gone, which left a monotypic stand of smooth brome. Smooth brome is a sod-forming grass (Carlson and Newell 1985). Without periodic disturbance such as fire, it will become dense with little or no bare ground. Over time, it will develop a thick layer of grass litter unsuitable for bobwhites (King and Savidge 1995).

Building brush piles and planting sorghum food patches were two habitat practices that were thought to provide immediate positive habitat changes for bobwhites on the Marshall area. Unfortunately, these practices had limited benefits for bobwhites. Sorghum plots are annual undertakings, whereas brush piles compacted and lost their usefulness to bobwhites over time. Brush piles compacted approximately 20% the first year and nearly 8% per year thereafter. Without periodic restoration, the brush piles would be reduced to nearly 40% of their original size in 10 years and be of little value to bobwhites. Brushy linear edge was designed to provide safe travel lanes for bobwhites. Winter movements and home ranges of bobwhites in Wisconsin are small (typically <0.25 mile radius) even during the best of times (Errington and Hamerstrom 1936, Kabat and Thompson 1963). Unless a covey was within 0.25 miles (0.4 kilometers) of a food plot or brush pile, its use was unlikely. The winter covey density on the Marshall area during 1975–1979 was only 1.6 coveys per square mile (0.6 coveys per square kilometer), suggesting that there were large areas (presumably much of which was restored habitat) without wintering bobwhites.

Throughout the intensive phase of habitat restoration in 1975–80, 75 sorghum food plots were annually seeded. Thirteen legume patches were planted near selected sorghum plots to provide an auxiliary food source. From 1984 to 1990, planted winter bobwhite food resources were: 12 to 19 sorghum plots, 18 perennial Natob lespedeza plots, and 2–3 corn parcels purchased from cooperating landowners. This reduction of food plots was due to fiscal and personnel constraints. It reduced the number of managed food plots by half compared to earlier efforts. By 1991, the Department stopped planting sorghum plots and purchasing of corn parcels all together. Periodic checks of food plots in 1984–90 to ascertain use by wintering bobwhites were disappointing. Bobwhite visits of the sorghum plots varied annually from 0 to 30%, and only a single covey of bobwhites visited a Natob lespedeza patch during a single winter over the 7-year period. A variety of wintering songbirds did, however, extensively use these food plots. Over 75% of the corn parcels were used, although they were originally purchased because of the existence of a nearby covey of bobwhites. In addition, the lespedeza was susceptible to top growth die-backs during cold weather, and the resulting growth form and seed production were poor. Natob seed was also invariably gone by the end of December.

Changes in Observed Farms and Farming Patterns

While CRP increased, and grazing of woodlots decreased in Richland County, other, more subtle land-

Table 3. Agricultural chemicals used on Richland County farms, 1978–90.[a]

Chemicals used (acres treated)[b]	1978	1982	1987	1992
Cropland fertilizer	65,638	65,708	71,069	70,288
Pastureland fertilizer	1,951	2,334	1,424	2,392
Insecticides on hay & crops	25,379	21,349	21,944	17,794
Herbicides on pastures & crops	33,017	31,997	31,980	33,449

[a] Data from U.S. Department of Commerce, Bureau of the Census, 1982, 1992.

[b] Total harvested cropland: ~126,000 acres, pastured cropland: ~30,000 acres, and total harvest cropland and hay: ~200,000 acres.

scape and bobwhite habitat changes were noted. The number of farms as a whole, and the amount of land in farms, decreased in Richland County, although farm size remained relatively unchanged (Table 1). The increase in the amount of non-farm lands is believed to be due to urbanization. The number of bobwhite project cooperators declined by about 4% per year, reflecting changes in farm ownership. By 1996, only 39 of the original 100 cooperators remained, and 2 of these had destroyed bobwhite project plantings. New landowners received the QMP Newsletter until 1991 when it was discontinued. No systematic efforts at personal contacts were made to promote the bobwhite project. As a result, some excellent bobwhite habitat improvements were destroyed by grazing or other farming activities. However, this project was not designed to continue indefinitely. As agency personnel slowly shifted their attention to other duties, it was hoped that the inherent attributes of the habitat improvements would encourage landowners to maintain them. This apparently did not always happen.

Changes in corn harvesting methods also had negative impacts on bobwhite habitat. During the 1950's, it was still common to find corn shocks in Richland County. Over the last decade, however, picker-sheller harvesters became common place, and the shelled corn is stored in sealed bins. This makes it unavailable to any wildlife. Corn stalks previously left in the fields as organic matter are now chopped and blown into large stacks, hauled out of the fields and fed to dry stock or beef cattle. The resulting corn fields have virtually no waste corn nor shelter, and offer very little, if any, benefits to wintering bobwhites. Between half to three-quarters of all corn fields used as grain are now treated in this fashion. Soybeans are not common on the Marshall area (<2% of harvested cropland) and, therefore, corn is believed to be the most important agricultural grain available to wintering bobwhites. This trend is likely to continue and it is difficult to see how wintering bobwhites can derive any benefits from corn fields.

Changes in agricultural chemicals used in Richland County were examined using data from the Census of Agriculture (U.S. Department of Commerce 1983, 1994; Table 3). During 1978–92, use of fertilizers and herbicides on crops and pastures changed very little, although there was a decline (30% drop) in the use of insecticides on hay and crops. Whereas the effect of agricultural chemicals on bobwhites in Wisconsin is unknown, the decreased use of insecticides in Richland County does not appear to be a source of concern (Sotherton et al. 1993).

Lessons Learned from the Bobwhite Management Project

Whereas the results of the intensive bobwhite habitat management efforts on the MMA did not produce the desired outcome, there are lessons that can be gleaned from our efforts. First and foremost is the original assumption that lack of hedges limits bobwhite abundance in Wisconsin cannot be answered from our efforts, yet there is also no compelling reason to discount this belief. Only 25% of all managed hedge row cover was judged effective for bobwhites by 1990, certainly far less than what was hoped. This was not a fair test of the hedge row habitat prescription developed by Kabat and Thompson (1963) and implemented by Dumke (1982).

However, the approach used by Dumke (1982) to develop a bobwhite habitat management strategy on a landscape scale, gain landowner cooperation, implement extensive habitat restoration on the land at minimal costs, and maintain this effort over time (albeit a short period of time) was remarkably successful. Habitat management designed for individual farms can be beneficial to bobwhites residing on that farm, but will hardly benefit bobwhites on a regional or landscape scale. The 85% level of cooperation among landowners exceeded all expectations. Whereas one might say that this high level of cooperation was only achieved because the Department essentially did all the planning, provided all the planting stock, and did all the work may be true, this level of participation was much higher than anticipated at the beginning of the project.

If there was a major flaw in our overall approach, it was that restored bobwhite habitat on private agricultural lands requires continuous attention and maintenance over time to remain effective. Some sorghum food plots and most brush piles were used immediately by bobwhites, but they need frequent, continuous management to maintain their usefulness. Sorghum plots need to be planted annually, while brush piles need to be restored every 3–5 years. Shrub and conifer hedges take 10–15 years to become effective for bobwhites, but attention must be made to replace lost plants or provide protection from farming operations (accidental or otherwise) if the resulting hedge is to make a contribution. Competition from surrounding vegetation must also be controlled by mechanical or chemical means. Landowners on the Marshall area were essentially required to provide little of their own resources to this project, consequently, we feel that they possessed little desire to make sure these developments were protected or maintained over time. Had the Marshall area landowners invested some of their time or resources into this project, the level of initial participation would have been lower, but those participating may have had a stronger commitment. Habitat management projects on private lands typically have shown better long-term results when the property owners develop a vested interest in the program (Deknatel 1979, Applegate 1981).

Where does this leave us with respect to bobwhite habitat management in Wisconsin and elsewhere in the northern fringe of their range? Edminister (1954) suggested that bobwhite habitat management on the northern fringe of their range is ineffective because winter weather overwhelms any habitat change or improvements. With restricted resource agency funding, the use of any dollars for bobwhite habitat management would appear to be a waste of financial resources. However, in Wisconsin, we are also on the northern edge of ring-necked pheasant (*Phasianus colchicus*) and on the southern fringe of ruffed grouse (*Bonasa umbellus*) range, yet these two species enjoy great popularity, high agency interest, and extensive habitat management programs. Management dollars are frequently tied to harvest levels, in which case, it would be difficult to secure substantial funding for bobwhite management in Wisconsin.

Any habitat management program for bobwhites in the northern fringe of their range requires careful planning and implementing. Bobwhites are a by-product of the agricultural land use and, therefore, require effective cooperation with private landowners if we have any hope of making an impact. Madsen (1981) suggested the widespread failure of most private land wildlife programs has resulted from concentrating on implementation, rather than first working to obtain a favorable attitude among the potential participants. Personal contacts and support from community leaders greatly influenced landowners attitudes towards bobwhites and state agencies. Also, recent approaches using geographic information systems (GIS) to map suitable habitat on a statewide basis have greatly improved our ability to identify where habitat management dollars can be most effectively used (Donovan et al. 1987, Mladenoff et al. 1995, Deelen 1996). Dumke (1982) originally examined the treatment area from a landscape-scale viewpoint, delineated critical bobwhite habitat and deficiencies, and then mapped out a treatment plan. Such an approach mirrors using GIS and a habitat suitability model to manage bobwhite habitat in today's world.

Perhaps the greatest lesson to be gleaned from this experimental management effort is that it was a classic example of what Walters and Holling (1990) describe as "passive adaptive" management. Past research indicated that hedgerow cover was the factor limiting bobwhites in Wisconsin, and that the other critical habitat components were essentially in place. We assumed that simply adding hedgerows would reverse the longstanding stagnation of bobwhite abundance. When years of hedgerow work failed to produce the anticipated results, we struggled for answers. Walters and Holling (1990) suggest that passive adaptive management not only fails to lead to sound conclusions, but often confounds or clouds existing policy, leaving the researchers with few, if any alternatives. They suggested that an "active adaptive" experimental approach, involving the developing and testing for a variety of alternative hypotheses, would have produced better results. An active approach can be costly and complex in monitoring, but so is spending 15 plus years on a single hypothesis, only to find few definitive answers.

MANAGEMENT RECOMMENDATIONS AND IMPLICATIONS

Brennan (1993), Capel et al. (1993) and others are developing strategic plans that attempt to deal with two issues related to bobwhite habitat in the agricultural sector: (1) general habitat loss and strategies for habitat development and improvement, and (2) agricultural programs and policies. Efforts must continue to develop and enhance this strategic plan into a working document. In Wisconsin, intensive grazing systems and rotational grassland dairy farming are new techniques that are receiving great interest. Their potential for altering bobwhite habitat is unknown, but merits study. Also, the 1996 federal farm bill (Federal Agriculture Improvement and Reform Act) offers wildlife more opportunities through the existence of some new rules: the Wildlife Habitat Improvement Program (WHIP) and the Environmental Quality Incentives Program (EQIP). Even on new CRP lands, part of the annual payment will include a maintenance fee allowing light disking of established cover to promote growth of annuals, prescribed burning to remove litter and expose more bare ground, and the establishment of food plots. Some less desirable cool-season grasses (e.g., tall fescue, *Festuca arundinacea*) will receive a zero wildlife multiplier in calculating the overall environmental index, severely reducing the chances that such cover will receive a minimum entrance score. Such activities will benefit bobwhites. Fortunately, mandatory mowing of CRP no longer happens.

Private land management is now being recognized as an integral part of the wildlife program in Wisconsin and elsewhere. With adequate resources, opportunities for economic incentives and technical advice to private landowners can be enhanced. Every landowner is different in the way they approach their land and what attributes they are seeking to gain. Any private lands management program must therefore be aware of these differences and offer a variety of options and a continuum of opportunities that allow the property owner to pick the program that best fits their needs. At the same time, we must also work to change the attitudes of landowners towards bobwhite and other farm wildlife. The property owner must have an interest in wildlife and be willing to invest his resources if bobwhite habitat management is to be a success. Whereas much bobwhite habitat has been lost or severely fragmented in the last several decades, there are still opportunities to restore habitat for this important upland game bird in the Upper Midwest.

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EFFECTS OF FILTER STRIPS ON HABITAT USE AND HOME RANGE OF NORTHERN BOBWHITES ON ALLIGATOR RIVER NATIONAL WILDLIFE REFUGE

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ABSTRACT

Lack of breeding habitat for northern bobwhites (*Colinus virginianus)* on agricultural landscapes is a factor that limits populations. Therefore, we examined how the addition of filter strips around crop fields and along crop field drainage ditches impacted northern bobwhites. Our study focused on habitat use, home range and brood-rearing range of bobwhites, from April through September 1993–94. Two farms on Alligator River National Wildlife Refuge were sub-divided into filter strip (FS) and non-filter strip (NFS) sections. More bobwhites were found on FS sections than on NFS sections based on flush counts (4.3x more on FS areas; $P = 0.02$). We used log-linear analysis to examine the distribution of telemetry locations ($n = 1796$) of radio-marked bobwhites ($n = 218$) across 5, 4.6m bands parallel to drainage ditches. Bobwhite locations were skewed towards ditches, particularly on FS sections before soybeans matured to a size that was sufficient to provide canopy cover for bobwhites. Bobwhites captured on FS sections had significantly smaller breeding season ranges than those captured on NFS sections ($P = 0.001$). Adult and sub-adult breeding season (May–Aug) ranges ($n = 23$) averaged 32 ha (SE = 26) and 182 ha (SE = 41) on FS and NFS sections, respectively. Brood ranges to 14 days ($n = 9$) ranged from 0.8 ha to 2.2 ha depending on habitat and calculation method. Presence of filter strips shifted habitat use patterns, especially during spring and early summer, and improved crop fields as habitat for breeding bobwhites.

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INTRODUCTION

The continental bobwhite population has declined 2.4% per year since 1966 (Church et al. 1993). Biologists largely agree that one reason for this decline has been habitat loss related to agricultural modernization (Brennan 1991, Minser and Dimmick 1988, Burger et al. 1990). Much of the habitat lost in agricultural settings has been nesting and brood-rearing areas. Such breeding habitat components are critical to quail population recovery after a period of typically high fall-spring mortality (Stoddard 1931, Rosene 1969, Roseberry and Klimstra 1984, Burger et al. 1995, Puckett et al. 1997).

In today's modern agricultural ecosystems, strategies for reversing habitat loss and quail population declines must be practical and affordable. Filter strips and field borders may meet these criteria because they are easily incorporated into row crop agriculture and can be economically feasible for producers to establish (Bromley, unpublished data). Potential for addressing habitat loss through the use of filter strips and field borders exists in federally sponsored conservation programs, such as the Conservation Reserve Program, as well as individual state programs. The U.S. Department of Agriculture's (USDA) National Conservation Buffer Initiative goal of 2,000,000 miles of field borders and filter strips by the year 2000 suggests field borders will become important habitat elements on some agricultural landscapes. However, the biological

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value of filter strips to quail and other wildlife are not known.

For these reasons, we investigated the potential of drainage ditch filter strips to serve as components of bobwhite breeding habitat on modern soybean and small grain farms. Using telemetry and flush counts, we tested the null hypotheses that bobwhite habitat use and home range size during the breeding season would be identical in farming systems with and without drainage-ditch filter strips.

STUDY AREA

Our study areas were 2 farming units (Western Study Area, WSA, and Eastern Study Area, ESA) on Alligator River National Wildlife Refuge (ARNWR) in Dare County region of the northeastern coastal plain in North Carolina. The study areas were separated by a 5 km buffer zone comprised of moist soil waterfowl management units and farm fields. The area surrounding the study areas was uninhabited pocosin and mixed-pine/bottomland hardwood (approximately 80,000 hectares). Bobwhite hunting was prohibited on the study areas.

The study areas were further divided to create one filter strip (FS) and one non-filter strip (NFS) section on each area. FS and NFS sections within study areas were separated by approximately 10 m wide drainage canals. The WSA's FS section (WSFS) and NFS section (WSNFS) were 282 ha and 219 ha, respectively, for 1993 and 1994. The ESA's FS section (ESFS) was 640 ha. The ESA's NFS section (ESNFS) was 217 ha and 411 ha in 1993 and 1994, respectively. Each study section (*n* = 4) was partitioned by parallel drainage ditches (range, 41 to 84 per section) at 100 m intervals. Mean ditch length was 0.9 km (range: 0.3–1.3 km). Mean field size within sections was 6 ha (range: 4–10 hectares), and mean number of fields per section was 50 (range: 30–81). Habitat categories for all sections included: crop, wooded (peninsulas of wooded land jutting into the farming units), filter strip, road/levee, and fallow (land out of production > 1 year) (Table 1).

Filter strips were designed for the primary purpose of filtering runoff from precipitation. They were heterogeneous buffers of planted and natural vegetation along agricultural drainage ditches. The filter strips were planted with a mixture of kobe lespedeza (*Lespedeza striata*), ladino clover (*Trifolium repens*), and sericea lespedeza (*Lespedeza cuneata*) between 1989–1992. Naturally occurring vegetation (*Solidago* sp., *Aster* sp., *Paspalum* sp., *Eupatorium* sp.) dominated most filter strips.

Mean width of filter strips was 9.2 m (*n* = 99, SE = 0.14) from edge to edge including the ditch itself. Width of cover from edge to edge along non-filter stripped ditches averaged 2.5 m (*n* = 99, SE = 0.05) including the ditch width. Filter strips accounted for 4.9–9.4% of treatment sections. While filter strips were not mowed during the study, canal banks and road/levees on FS and NFS areas were mowed during winter.

Table 1. Classification of habitat types during 1993 and 1994 on all sections of the Alligator River National Wildlife Refuge study areas, Dare Co., North Carolina.

1993	Crop	Wooded	Filter strip	Road/ levee	Fallow
WSA[a]	60%	12%	4%	1.8%	22.2%
ESA[b]	63%	1.9%	4.9%	2.2%	28%
WSFS[c]	58%	14%	5.5%	1.7%	20.8%
WSNF[d]	64%	8.8%	2.2%	2%	23%
ESFS[e]	60.5%	2.5%	5.7%	2.3%	29%
ESNFS[f]	70%	0%	2.4%	1.6%	26%
1994					
WSA	77%	12%	6%	1.8%	3.2%
ESA	69%	2.6%	9.4%	2.3%	16.7%
WSFS	73%	14%	8%	1.7%	3.3%
WSNFS	82.8%	8.8%	2.7%	2%	3.7%
ESFS	69%	2.6%	9.4%	2.3%	16.7%
ESNFS	75%	0%	2.3%	1.4%	21.3%

[a] Western Study Area.
[b] Eastern Study Area.
[c] WSFS = WSA filter strip area.
[d] WSNFS = WSA non-filter strip area.
[e] ESFS = ESA filter strip area.
[f] ESNFS = ESA non-filter strip area.

Crop production enterprises on the study areas included continual full season broadcast-planted soybeans (not drilled in rows on 8" centers, but spin seeded behind a tractor and disked into the soil) and winter wheat (*Triticum* sp.), or conventional drill-planted soybeans and winter wheat with little use of corn (*Zea mays*) in the rotation. Additionally, U.S. Department of the Interior, Fish and Wildlife Service (USFWS) regulations prohibited the use of "restricted-use" pesticides.

METHODS

Bobwhites were captured from February–July using funnel entrance traps similar to those described by Stoddard (1931). Bobwhites (*n* = 218, 68% female in 1993, 63% female in 1994), were aged (Rosene 1969) and fitted with 6.1 g necklace transmitters. Radio-marked bobwhites were located daily by triangulation or homing with 3-element hand-held YAGI systems (White and Garrott 1980). Observers were tested to determine average bearing error by locating 30 transmitters that were hidden at varying distances from 10 telemetry stations. The average bearing error was + 6.4 degrees. Bobwhites estimated to be within 50 m or beyond 300 m from nearest telemetry stations were located through homing. Approximately 30% of all locations were determined by homing. Hens with broods were located 2–4 times daily the first 14 days post-hatch to define the brood-rearing range prior to substantial chick fight capability.

Flush Counts

We conducted flush counts along drainage ditches during June and early July to compare quail use of habitat along ditches with and without filter strips. Different sub-sections, representing 10–20 ditches, of the FS and NFS sections were surveyed in pairs on each

Table 2. Number of northern bobwhites counted per km of drainage ditches, with and without filter strips, during flush counts conducted during June, July, and August of 1993 on Alligator River National Wildlife Refuge, Dare Co., North Carolina.

Date	FS[a] quail/km	NFS quail/km
1993		
15 June (WSA)	1.16	0.38
29 July (WSA)	2.95	0.29
14 August (ESA)[b]	0.78	0.19

[a] FS = filter strip area, NFS = non-filter strip area, WSA = western study area, ESA = eastern study area.

[b] Not used in analyses.

Table 3. Number of northern bobwhites flushed per km along drainage ditches, with and without filter strips, during flush counts conducted during June and July, 1994 on Alligator River National Wildlife Refuge, Dare Co., North Carolina.

	Western Study Area		Eastern Study Area	
Date	FS[a] Quail/ km	NFS[b] Quail/ km	FS Quail/ km	NFS Quail/ km
7 June	4.17	0.53	0.54	0.33
16 June	4.30	0.48	0.99	0.33
17 July	0.19	0.66	0.50	0.44

[a] Filter Strip.

[b] Non-Filter Strip.

day. In 1993, 4 sections were surveyed, but surveys were conducted on different days for the 2 study areas (i.e., ESA or WSA). In 1994, flush counts were conducted simultaneously on FS and NFS sections of both study areas. Observers walked along all drainage ditches within each sub-section counting flushed quail. Observers were instructed to avoid counting flushed quail more than once. The number of bobwhite flushed per km of drainage ditch for each section surveyed (n = 16) were compared using t-tests for independent samples, pooling across month. Data from 1994 were analyzed using ANOVA with study area, month and FS treatment as factors. Ratios of quail flushed per km were log-transformed to meet test assumptions.

Brood Range Vegetation

Brood ranges ($n = 9$) were demarcated in the field from maps of telemetry locations. Coverage by grass, forbs, debris, woody, and bare ground at ground level in brood ranges was measured by randomly placing 5 to 10 two meter line transects. Vegetation height was measured at 3 points, 3 m apart, in the 4 cardinal directions along transects perpendicular to line transects. An additional 2 m line transect was placed above vegetation to determine percent canopy closure.

Vegetation data were analyzed using nested factorial ANOVA (SAS PROC GLM, SAS Inst., 1985). Differences in structure between crop and fallow brood ranges were tested using t-tests (Steel and Torrie 1980).

Additional Analytical Methods

Telemetry locations ($n = 5083$), pooled across years, were incorporated as layers in Atlas GIS study area maps (Strategic Mapping, Inc. 1989). All locations ($n = 1796$) within 23 m of a drainage ditch, excluding the initial 23 m along the ditch from a main canal or road, were categorized by their proximity to the ditch center (Atlas, GIS BUFFER Function) into 5, 4.6 m bands, which was the average width of filter strips. Each band category was discrete from all others. Locations within these bands were analyzed using multi-way log-linear independence analysis by band, study area (WSA, or ESA), section (FS, or NFS), and period (early, < 15 July, or late, > 15 July).

Adult and brood range sizes of bobwhite chicks >14 days after hatch were calculated using Harmonic Mean and Minimum Convex Polygon estimators in McPAAL version 1.2 (Stuwe and Blohowiak 1985, Dixon and Chapman 1980, Mohr 1947). Bobwhites included in home range analyses were captured in March, April, or May and survived from capture until 30 September. Home range size, area, and month of initial capture interactions were examined using ANOVA (SAS PROC GLM, SAS Inst., 1985). Differences in brood range size between crop and fallow primary habitat types were tested using t-tests for means with equal variances (Steel and Torrie 1980).

RESULTS

Effects of Filter Strips on Habitat Use

Flush Count Surveys

Flush count surveys (n = 16) were conducted along 232 km (113 FS, 119 NFS) of drainage ditches. Over all flush counts, we flushed an average of 1.5 quail/km on FS bordered ditches and 0.4 quail on ditches without filter strips ($t = 2.6$, df = 7.3, $P = 0.02$). Though there were more quail flushed per km of FS ditches, the more substantial effect of filter strips was noted on the WSA (Tables 2 and 3). In 1994, analysis of variance indicated more quail were flushed on FS sites ($F = 30.5$, $df = 1,4$, $P = 0.017$), during surveys conducted in June than in July ($F = 41.9$, $df = 1,4$, $P = 0.003$) and on the WSA ($F = 25.8$, $df = 1,4$, $P = 0.007$). A filter strip treatment × month interaction ($F = 64.9$, $df = 1,4$, $P = 0.001$) resulted from greater declines in quail flushed per km on FS ditches from June surveys to July surveys. An area × month ($F = 33.7$, $df = 1,4$, $P = 0.004$) interaction resulted from greater declines in quail flushed per km on the WSA than the ESA from June surveys to July surveys. Finally, a treatment × area × month interaction ($F = 35.6$, $df = 1,4$, $P = 0.004$) resulted from greater numbers of quail being flushed per km of drainage ditch on FS sections of both study areas in June and on the ESA during July, but slightly more quail flushed per km on the western study areas NFS section than FS section in July. Reduced numbers of bobwhites flushed during July can probably be attributed to increased flushing difficulty as summer progressed. Once crops matured and provided cover, quail may have been more likely to run into standing soybeans rather than fly out of the filter strips.

Telemetry Locations and Filter Strips

Categorization of bobwhite locations by band, study area, section, and period resulted in 40 data analysis cells. Number of observations per cell ranged from 8 to 231, with a mean of 45.97 (SE = 6.39). Log-linear analysis demonstrated no 4-way interaction, and indicated only one significant 3-way interaction, section*study area*period (log-linear model deleting section*study area*period $G = 4.34$, $P = 0.037$). Further analysis was conducted to examine the strengths of factors involved in location distribution. Of particular interest were the effects of deleting the 2-way interaction terms band*period, band*section, and band*study area from the saturated model. These deletions were examined under the assumption that bird locations (band categorizations) were by-products of the interaction between period, section, and study area, and could therefore be considered dependent variables. The data suggest these deletions were logical choices.

The largest change in the likelihood-ratio chi square occurred with the deletion of band*period (log-linear $G = 34.2$, $P = 0.000$), followed by band*section (log-linear $G = 14.5$, P = 0.006), and band*study area (log-linear $G = 11.3$, $P = 0.023$). It is important to note in this analysis that large numbers of observations in many cells may have complicated efforts to sort out lack of significance.

Filter Strip Effects on Range Size

Overall mean nesting season range ($n = 23$, pooled 15 FS captured and 8 NFS captured) was 53 ha (SE = 11) and 101 ha (SE = 33) for Harmonic Mean (HM) and Minimum Convex Polygon (MCP) estimators, respectively.

Adult bobwhite nesting season HM estimated ranges differed ($F = 14.4$, $df = 1{,}17$, $P = 0.001$) based on capture section [FS ($n = 15$) captured versus NFS ($n = 8$) captured], but not among months of capture ($F = 2.9$, $df = 2, 17$, $P = 0.08$). We observed no capture month/capture section interaction ($F = 2.16$, $df = 2{,}17$, $P = 0.15$). Minimum convex polygon estimated ranges demonstrated significant effects of capture month ($F = 9.7$, $df = 2, 17$, $P = 0.01$), capture section ($F = 9.6$, $df = 1{,}17$, $P = 0.007$), and capture month/capture section interaction ($F = 4.9$, $df = 2, 17$, $P = 0.02$). Using either estimator, presence of filter strips was most significant, with FS section captured bobwhites having the smaller ranges. Using the HM estimator and pooling across capture months, mean NSR's were smaller for bobwhites captured on FS sections (28 ha, $n = 15$, SE = 9) than for bobwhites captured on NFS sections (89 ha, $n = 8$, SE = 14). Using the MCP estimator and pooling across capture months, mean NSR's were 32 ha (SE = 26) and 182 ha (SE = 41) for quail on FS areas and quail captured on NFS sections, respectively.

There were differences in NSR sizes using both HM and MCP estimators based on capture month. Least squares means indicated that quail captured in May had significantly greater home ranges than quail captured in April or June ($P < 0.10$). Using the HM estimator, ranges for quail captured in March, April and May pooled across capture areas were 46 ha ($n = 9$) (SE = 11), 84 ha ($n = 7$) (SE = 12), and 46 ha ($n = 7$) (SE = 17), respectively. Using the MCP estimator, ranges for March, April and May captured bobwhites were 54 ha (SE = 34), 211 ha (SE = 37), and 55 ha (SE = 53), respectively.

Brood Range Size

Brood ranges ($n = 9$) of bobwhites > 14 days after hatch averaged 1.1 ha (SE = 0.4) and 2.2 ha (SE = 0.5) using HM and MCP estimators, respectively. Brood ranges were in either crop (broadcast-planted soybeans) or fallow fields. There was no overlap. Crop brood ranges ($n = 5$) averaged 1.4 ha (SE = 0.8) and 2.2 ha (SE = 0.6) using HM and MCP estimators, respectively. Fallow brood ranges ($n = 4$) averaged 0.8 ha (SE = 0.3) and 2.2 ha (SE = 0.9) using HM and MCP estimators, respectively. There were no significant differences between crop and fallow range sizes using either HM ($t = 0.13$, $df = 7$, $P = 0.9$) or MCP ($t = 1.12$, $df = 7$, $P = 0.3$) range averages for comparison. Using the MCP method, seasonal adult ranges ($n = 23$) averaged 101 ha (SE = 33) and were 46× larger than the average 14 day brood range.

Brood Range Vegetation

Vegetation in brood ranges of hens using fallow areas and soybeans was very similar in height and canopy closure. Mean cover heights were 67.7 cm ($n = 780$) (SE = 1.39), 69 cm ($n = 480$) (SE = 2.12), and 64.8 cm ($n = 300$) (SE = 1.52) for pooled, fallow, and crop range categories, respectively. Mean length of openings at canopy level were 13.6 cm ($n = 177$) (SE = 1.02) and 15.5 cm ($n = 299$) (SE = 1.25) for crop and fallow ranges, respectively. Mean distances between openings in the canopy were 6.8 cm (SE = 0.76) and 5.9 cm (SE = 0.71) for crop and fallow ranges, respectively. Mean total amounts of opening per 200 cm transect at canopy level were 130 cm (65% of transect) (SE = 8.59) and 150 cm (75% of transect) (SE = 7.44) for crop and fallow ranges, respectively. Bare ground averaged 46% in crop fields and 31% in fallow brood ranges ($P = 0.0001$). Forbs were a greater component of vegetation in fallow brood ranges, averaging 11.3%, than in crop fields where forbs averaged 2.6% of the vegetation ($P = 0.014$). Grasses were more prominent in fallow brood ranges, averaging 30%, than brood ranges in crop fields which averaged 18% grasses ($P = 0.0006$). There was no significant difference in amount of debris between brood ranges in crop fields and fallow habitats ($P = 0.072$), 33% versus 27% coverage, respectively.

DISCUSSION

The smaller nesting season ranges of bobwhites using FS areas, the greater number of quail flushed along filter stripped drainage ditches, and the disproportionate use of drainage ditches with filter strips, particularly prior to crop maturation, indicate that filter strips influenced how quail used the farmed landscape during the breeding season. Filter strips may have been attractive to bobwhites during spring, because little residual herbaceous vegetation from the previous growing season other than filter strips was available to quail on these farms. Filter strips provided travel and escape cover during spring and early summer when crop fields were devoid of cover or nearly so.

Both flush counts and telemetry analysis indicated that FS drainage ditches were used more than NFS ditches. Drainage ditches without filter strips also affected quail movements, however, not to the degree of FS ditches. By the late season, both FS and NFS ditch habitat use declined. As summer progressed, crops provided a habitat alternative to both filter strips and fallow habitats. However, presence of FS appeared to attract quail to farm fields at the beginning of the nesting season; bobwhites remained on FS areas throughout the nesting season. This pattern of quail use of the farmed landscape, in association with presence of more nesting cover at the beginning of the nesting season, resulted in much greater nest production on FS areas than NFS areas. Most (83%) of the 53 incubated nests located during the study occurred on FS areas (Puckett et al. 1997). There were 1 nest per 3 radio-marked quail and 1 nest per 8 radio-marked quail on FS and NFS sections, respectively. On NFS areas, quail remained in wooded areas, habitat along roads and canal banks during spring and exhibited large movements to nesting areas. These movement patterns, and the lack of early nesting cover, resulted in fewer incubated nests and larger nesting season ranges for quail captured on areas without filter strips.

While filter strips served as nesting areas for quail, nest success was low (Puckett et al. 1997) during the early nesting season. As soybeans matured, weedy sections in the crop fields were used for nesting. Klimstra and Roseberry (1975) found that nearly two-thirds of the variation in spring to fall population increases during the course of their study could be attributed to number of chicks produced per hen. In addition, the number of chicks produced per hen was almost equally dependent on both total number of nests per hen and their success rate (Klimstra and Roseberry 1975). Dimmick (1975) found that, of all variables tested, total number of nests constructed was most strongly correlated with December bobwhite densities. The above examples suggest that, though nesting success was low in filter strips, the contribution to the fall bobwhite population may have been positive.

The smaller nesting season ranges of bobwhites inhabiting FS areas compared to those inhabiting NFS areas suggest that habitat quality was enhanced by filter strips. Guthery et al. (2000) recently challenged wildlife managers to think in terms of increasing "usable space" rather than simply thinking about improving habitat quality. In addition, Guthery et al. (2000) pointed out that, within a given boundary, usable space could be maximized with a number of different habitat patch arrangements. The addition of filter strips within a relatively simple farm ecosystem apparently increased usable space during the spring and early summer when the habitat provided by filter strips allowed quail to use portions of farm fields away from "hard" edges that were less "available" to quail on areas without filter strips.

The presence of filter strips may have also improved the suitability of crop fields as brood-rearing cover for bobwhites. In terms of productivity, all but one brood confirmed alive at 14 days after hatching inhabited FS sections. The one occurring on a NFS section inhabited an area where mature soybeans bordered fallow land. All brood ranges ($n = 5$) found in soybean fields incorporated filter strips. Quail brood survival (percentage of quail chicks surviving to 28 days) in FS sections was high (0.68–0.85), and brood range sizes were small (Puckett et al. 1997). Vegetation analysis within soybean/filter strip brood ranges demonstrated them to be markedly similar to fallow field brood ranges in structure. Similar habitats in small grain agrisystems in Great Britain increased insect abundance and grey partridge (*Perdix perdix*) →chick survival (Potts 1986, Sotherton et al. 1993).

Recent research has revealed that northern bobwhite reproductive potential is higher than biologists previously believed. Monogamy among bobwhites is the exception rather than the rule (Curtis et al. 1993). The importance of the male bobwhite to overall recruitment is greater than previously believed (Curtis et al. 1993, Suchy and Munkel 1993, Burger et al. 1995). Renesting and double clutching among bobwhite hens can contribute significantly to overall chick production (Curtis et al. 1993, Suchy and Munkel 1993, Burger et al. 1995). Late season recruitment can be limited by reduced clutch sizes characteristic of the period and a reduction in the proportion of available hens initiating clutches after mid-summer (Puckett et al. 1997). It is hypothesized that rates of male incubation, female renesting and female double clutching are a function of early season nesting success of hens (Burger et al. 1995). This emphasizes the importance of the availability of nesting and brood rearing cover throughout the breeding season (Burger et al. 1995, Puckett et al. 1997). Researchers in Kansas recently concluded that bobwhite managers should emphasize increasing both quantity and quality of nesting and brood-rearing cover (Taylor et al. *this volume*).

While filter strips may not be the panacea that will solve all problems faced by bobwhites on the modern industrial agriculture countryside, they have the potential to increase quail recruitment by providing what is often the only available nesting and brood-rearing cover during spring and early summer. They may also improve the quality of brood-rearing habitat throughout the breeding season. In a study conducted by Stinnett and Klebenow (1986) in Nevada, California quail (*Callipepla californicus*) were found to prefer filter strip habitats during all seasons.

MANAGEMENT IMPLICATIONS

For any effort at restoring bobwhite populations to be effective, it must first be simple, practical and affordable. Additionally, any effort to reverse the bobwhite decline must be directed at privately owned land. Currently, 50% of our nation, or 907 million acres, is privately owned pasture, range and crop land (USDA 1996). Private landowners may be more willing to accept filter strips than other more restrictive conservation practices such as the idling of entire crop fields.

After years of exclusion from federal farmland conservation programs, legislation in the 1996 farm bill made wildlife a 1/3 partner in our nation's 3 major conservation programs, the Conservation Reserve Program, the Wildlife Habitat Incentives Program and the Environmental Quality Incentives Program. In each program there are provisions for cost-sharing wildlife friendly practices including filter strips and field borders. Most recently, USDA is promoting a "Buffers for Bobwhite" initiative with a goal of 2 million miles of buffer by the year 2000. All these programs have the potential to provide many acres of usable bobwhite habitat. It is up to professional biologists and quail managers, however, to insure they are implemented in the bobwhite's best interest.

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VEGETATION RESPONSE TO DISKING ON A LONGLEAF PINE SITE IN SOUTHEASTERN LOUISIANA

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ABSTRACT

The effects of season (November vs February vs May) of disking on plant composition were evaluated on a longleaf pine (*Pinus palustris)* site in southeastern Louisiana during 1986--1990. Almost 150 species of plants were recorded in the fallow disked plots during 3 sampling years. Disked plots, compared to native upland pine sites, had a lower abundance of broomsedges (*Andropogon* spp.) and wiregrasses (*Aristida* spp.), more bare ground, and more early seral plants such as 3-seeded mercury (*Acalyphya* spp.) and poor-joe (*Diodia teres*). Legumes were reduced or stable under all disking regimes and disking did not increase the quantity of partridge pea (*Cassia nictitans* and *C. fasciculata*) or ragweed (*Ambrosia artemisiifolia*), as frequently reported.

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INTRODUCTION

Northern bobwhite (*Colinus virginianus*) populations in Louisiana have declined since they peaked shortly after the turn of the century (Louisiana Department of Wild Life and Fisheries [LDWF]1948); populations are perceived to be at all-time lows. Farmlands in Louisiana historically supported the densest populations, but now generally offer marginal to very poor quality habitat due to large-scale clean farming, intensively managed improved pastures, and overgrazing. Pinelands, though not as productive for bobwhites as they were 40 years ago, presently support the majority of the quail (Louisiana Department of Wildlife and Fisheries unpublished data, W-55-10, V-I) and, as such, offer the greatest recreational opportunities.

Fallow disking in pine woodlands has long been acknowledged as a beneficial bobwhite food management technique. However, managers do not agree on the optimum timing for this activity. Stoddard (1931: 365) stated that disking should occur from November through mid-March. Rosene (1969:318) suggested disking after 15 September but before April. In Louisiana, Brunett (1975) advised to disk as soon as possible in the spring until 15 August, while Prickett (1981) indicated that disking "should be completed by late winter before spring growth begins." The objective of this investigation was to evaluate vegetation response to disking in different seasons.

STUDY AREA

The Sandy Hollow Quail Research and Development Area (hereafter Sandy Hollow), located in Tangipahoa Parish in southeastern Louisiana, is a 1,234 ha longleaf pine site that was purchased by the LDWF in 1986. Most of the area was clearcut during the 1970's and early 1980's, but longleaf regeneration (grass stage to sapling) occurs across the area. Like many southeastern pinelands, the area also had a long history of cattle grazing. Nevertheless, the herbaceous cover on Sandy Hollow is considered to be representative of a quality longleaf pine system due to the absence of large-scale site disturbance associated with agriculture and a long history of annual burning (by prescription and by arson) (Louisiana Department of Agriculture, Office of Forestry, personal communication). Upland pine and upland drain vegetation dominate Sandy Hollow and are where most bobwhites are located. Common grasses and sedges include broomsedge, panic grasses (*Panicum* spp.), nut rushes (*Scleria* spp.) and wiregrass (LDWF unpublished data, W-55, VI-I Final Report). Pencilflower (*Stylosanthes biflora*) is the predominant legume. The topography of the area is characterized by gently to moderately rolling hills. Soils are mostly sandy and silt loams of low fertility and mild to moderate acidity, with strongly acid subsoils.

Since it was acquired by the LDWF, Sandy Hollow has been managed intensively for northern bobwhites to accommodate quail hunting and bird dog field trials. Most of the area continued to be prescribed burned annually with 0.5–2 ha "cover islands" about every 40 ha. However, because the area is an example of native and mostly undisturbed longleaf pine flora, development was somewhat restricted until the extent of rare plants was better understood. With this in mind, a goal of only 5–10% disturbance was initially established for the area. Within the upland pine habitat, approximately 250 rectangular food plots totaling 25 ha and 50 km of strip food plots totaling about 15 ha were planted. Food plots were generally a mixture of 6 parts Egyptian wheat (*Sorghum vulgare*), 3 parts browntop millet (*Panicum fasciculatum*) and 1 part Kobe lespedeza (*Lespedeza striata* var. *striata*) planted at about 10 kg per ha.

METHODS

Study Design

The effect of disking in different seasons (November, February and May) was evaluated for a 3-year period. Three sets of 3 disking plots, each 20 m × 50 m (0.1 ha), were established on 1 section of Sandy Hollow. Within each block, a disking month was randomly assigned to each plot the first year and maintained throughout the study. Plots were thoroughly disked (approximately 5 times) the first year with a 2.1-m offset disk. In subsequent years, plots were double-disked.

Vegetation Sampling

Vegetation was sampled using 2 methods. The first method closely followed that used by Walker and Peet (1983) to determine vegetation composition. Ground cover vegetation presence was recorded on 10 0.5-m × 0.5-m subplots located at random distances along either side of the plot centerline. The potential locations of the ground cover subplots were determined by dividing the centerline into 200 0.5-m long segments (100 along each side of the centerline) and randomly selecting a sample from among these potential subplots. The second method consisted of sampling vegetation along either side of the centerline using the loop intercept method (Parker 1951). A 2-cm diameter loop was placed at 200 randomly selected points. Only vegetation at the ground level was recorded as within the sample loop. Vegetation sampling was conducted in early July. Data from another study on Sandy Hollow conducted during 1987 and 1988 provided comparative data (LDWF unpublished data, W-55, VI-I Final Report). The same techniques were used in that study to sample 6 randomly located upland pine plots managed by annual prescribed burning.

Data Analysis

Analysis of variance was performed on loop sampling data (count data) with SAS software using a split plot in time design to determine the impact of disking period on quail food plants and non-food plants collectively. Treatments (disk date) were applied to plots within blocks (whole plot) and the split plot effect was years. The model was reduced when possible ($P < 0.05$) and the mean square error used to test the disk date and year responses in the final model were disk date by block and the full model, respectively. Least square means and associated standard errors were used to determine differences among treatments and years when appropriate. A quail food plants list was developed using Reid and Goodrum (1979), Wycoff (1964), Rosene and Freeman (1988) and unpublished LDWF data.

RESULTS AND DISCUSSION

The initial study design was to treat plots for 3 consecutive years. However, due to wet weather in the fall of 1988, no disking was conducted that period. As a consequence, plots were disked in 1986–87, 1987–88 and 1989–90. Almost 150 species of plants were recorded in the fallow disked plots during the 3 sampling periods (July 1987, 1988 and 1990) and 26 species/genera were recorded in $\geq$20% of the species composition plots (Table 1). Disked plots, compared to the native vegetation plots, contained a lower abundance of grasses such as broomsedge and wiregrass, an increase in bare ground, and more early seral plants such as 3-seeded mercury and poor-joe. Nevertheless, broomsedge occurred in about 65% of the November and February disked composition plots. Panic grasses were the most frequently recorded species in disked and native upland composition plots ($\geq$90%).

Table 1. Percent occurrence for plant species commonly found on composition plots sampled in July on the Sandy Hollow Quail Research and Development Area, Tangipahoa Parish, Louisiana.

Species	Month of disking			Native upland
	November	February	May	
Acalyphya spp.	70	56	24	4
Andropogon spp.	64	62	22	92
Aristida spp.	7	11	3	52
Aster spp.	88	77	18	71
Boltonia spp.	32	26	0	22
Crotalaria spp.	54	29	2	22
Croton spp.	22	7	14	22
Cuphea carthegensis	22	7	14	0
Desmodium spp.	22	20	8	33
Diodia spp.	47	68	52	12
Eupatorium spp.	49	62	12	32
Gnaphalium spp.	32	36	2	4
Helianthus spp.	29	60	4	32
Hypericum spp.	43	23	2	9
Hypoxis spp.	30	32	42	43
Lespedeza spp.	28	14	2	24
Linum spp.	37	6	0	2
Panicum spp.	90	98	90	95
Paspalum spp.	58	61	21	20
Polypremum spp.	22	34	28	1
Rhus copilliana	9	22	1	3
Rubus spp.	33	39	11	17
Scleria spp.	54	66	23	56
Solidago spp.	37	27	22	40
Stylosanthes biflora	61	67	32	75
Strophostyles spp.	9	32	6	17

Three taxa (panic grasses, 3-seeded mercury, and aster [*Aster* spp.]) occurred in the November disked plots $\geq$70% while panic grasses and aster and panic grasses were recorded in $\geq$70% of the February and May disked plots, respectively. Four taxa (panic grasses, broomsedge, pencilflower, and aster) were present in $\geq$70% of the native upland pine plots.

Loop sampling data were collectively analyzed as food plants and non-food plants because of the sparseness of the data set. Disk date (F = 11.69, 2,4 d.f., P = 0.021) and year (F = 7.59, 2,26 d.f., P = 0.005) were significant for food plants. Quail food plants were greater ($P < 0.03$) on November ($\bar{x}$ = 44.9, SE = 4.7) and February ($\bar{x}$ = 35.7, SE = 4.7) disk plots than May disk plots ($\bar{x}$ = 13.7, SE = 4.7) (Figure 1). Grasses (sedges included) predominated in loop sampling regardless of disk date. Grasses accounted for at

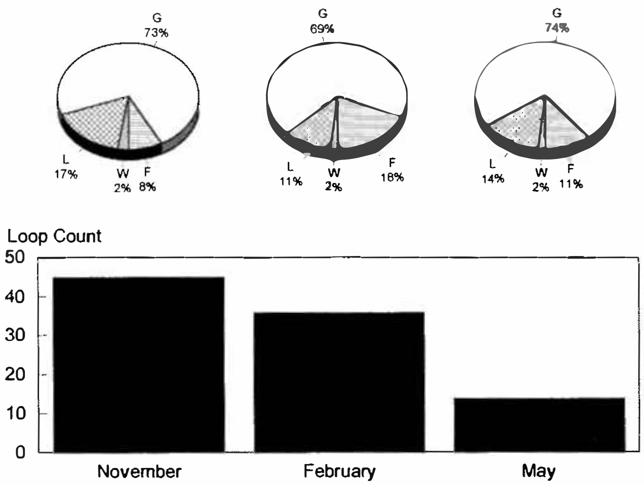

Fig. 1. Loop sampling count data for quail food plants in disked plots by month and percent contribution by plant groups (F = Forbs, G = Grasses, L = Legumes, and W = Woody) on the Sandy Hollow Quail Research and Development Area, Tangipahoa Parish, Louisiana.

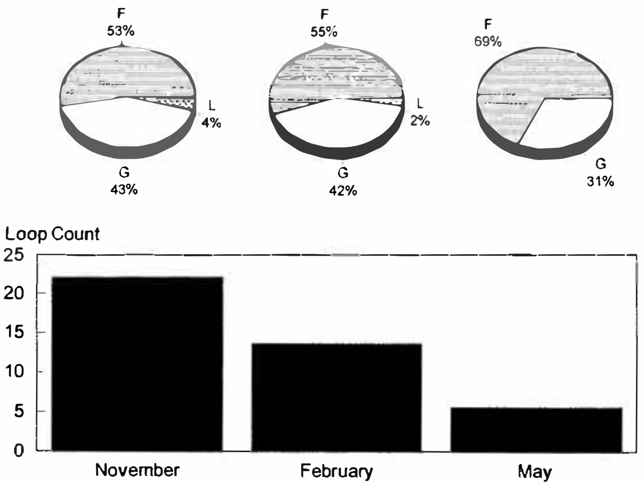

Fig. 2. Loop sampling count data for quail non-food plants in disked plots by month and percent contribution by plant groups (F = Forbs, G = Grasses, L = Legumes, and W = Woody) on the Sandy Hollow Quail Research and Development Area, Tangipahoa Parish, Louisiana.

least 66% of the loop counts (range 69%-74%). Legumes were present in 11–17% of the counts while forbs represented 8–18% of the loop sample vegetation and woody food plants averaged <3%.

Disk date (F = 19.26, 2,4 d.f., P = 0.009) and year (F = 3.63, 2,26 d.f., P = 0.050) were significant for non-food plants. Forbs outnumbered grasses and legumes regardless of disk date (Figure 2). Non-food forbs accounted for 53–69% of the loop counts. Non-food grasses accounted for 31–43% of the loop counts while legumes represented 0–4% of the samples. No woody non-food plant was recorded.

A somewhat unexpected result of disking was the apparently stable to reduced abundance of quail foods as compared to native upland pine plots. Of particular note was the lack of response by legumes. Prevalence based on composition data suggests that only wild bean (*Strophostyles* spp.) increased while lespedezas (*Lespedeza* spp.), beggarticks (*Desmodium* spp.), pencilflower and milk pea (*Galactia* spp.) decreased, or at best were stable. Partridge pea and ragweed were not recorded in either the loop or composition sampling in disk plots. However, they also were not detected by either method during upland pine sampling. Landers and Mueller (1989:23) indicated that the percent coverage on Tall Timbers Research Station's December disk plots was about 10% for partridge pea and 30% for ragweed.

Stoddard (1931:365) stated that vegetation response to fallow disking was dependent on season of disking. He further reported that seed bank on the site was also extremely important in determining the response. Seed sampling on Sandy Hollow indicated that partridge pea was largely absent from upland pine plots (LDWF unpublished data, W-55-VI-I Final Report). Fallow disking has not been as effective as initially expected on some pine sites in Mississippi (W. Burger, Department of Wildlife and Fisheries, Mississippi State University and L. Brennan, Tall Timbers Research Station, personal communication). They hypothesized that the lack of agrarian history and past overgrazing on the sites may have resulted in a limited seed bank of desirable plants. Not only does Sandy Hollow not have a history of agriculture, it likely had a history of overgrazing. In addition, soils at Sandy Hollow are generally characterized by slightly to moderately acid soils with strongly acid subsoils. As a rule, low pH soils support fewer legumes than higher pH soils, such as those frequently associated with many of the better quail areas in the Southeast. The lower pH of Sandy Hollow soils may have also contributed to the lower natural seed bank.

MANAGEMENT IMPLICATIONS

The lack of expected legume response does not negate the benefits of fallow disking. Fallow disking created edge, travel lanes and generally more open conditions for northern bobwhite habitat use. Competition reduction may also enhance seed production of desirable plants and seeds produced should be more readily available because of the limited dead leaf litter on the ground. November and February provided the greatest overall benefits. Fallow disking can be incorporated into a site's prescribed burning program with disked strips serving as firebreaks. In this instance, the season of burning may dictate the season of disking.

Quail managers are encouraged to develop similar trials on their areas to further the understanding of fallow disking. Results of this study and those observed on at least 1 site in Mississippi suggest that impacts of fallow disking may differ significantly from those reported from the Thomasville-Albany, Georgia area. As a consequence, traditional food plots and plantings may be more important in habitats with little history of agriculture, a long history of overgrazing or lower pH soils than in traditional quail plantation regions of the Southeast because of the lack of legume and ragweed response to fallow disking. DeVos and Mueller (1993) found managed old field sites with an abundance of legumes to be important brood rearing areas. With this in mind, managers on areas with intact native forest ground cover may want to incorporate legumes into food plots, particularly partridge pea, to facilitate conversion to fallow disking management regimes.

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INFLUENCE OF FOOD PLOTS ON NORTHERN BOBWHITE MOVEMENTS, HABITAT USE, AND HOME RANGE

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ABSTRACT

Natural resource managers at the Fort Riley Military Reservation in Kansas have established plantings to provide winter food for northern bobwhites (*Colinus virginianus*) since 1959. These food plots have the potential for reducing movements and home range sizes of bobwhites during winter because birds should apparently need to forage over less area to obtain sufficient food. To determine if this was occurring, we conducted a 3-year radio telemetry study of bobwhites on Fort Riley. We equipped 511 bobwhites with radio transmitters and followed their movements and habitat use from October through March, beginning in 1994.

Daily movements of bobwhites near food plots varied by field season and study site, but generally did not differ significantly between food plot and non-food plot areas. Home ranges of bobwhites did not differ significantly between food plot and non-food plot areas, study site, or field season. Prairie habitat always was used significantly less than its proportional availability by bobwhites. Food plots were used significantly more than their proportional availability during 2 of 3 field seasons. Habitat use by bobwhites on the 2 study sites differed between food plot and non-food plot areas.

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INTRODUCTION

The availability of food has been demonstrated to influence the movement and home ranges of many wildlife species. For example, the presence of food patches reduced daily movements of ring-necked pheasant (*Phasianus colchicus*) in Wisconsin during the fall and winter (Gatti et al. 1989). Supplemental food reduced home range sizes relative to individuals without access to supplemental food among red squirrels (*Tamiasciurus hudsonicus*) and deer mice (*Peromyscus maniculatus*) in British Columbia (Sullivan 1990 and Taitt 1981, respectively), and chipmunks (*Tamias striatus*) in Pennsylvania (Mares et al. 1976). Wildlife using food plots may also reduce their predation risk by decreasing exposure when foraging (Martin 1992).

Natural resource managers at the Fort Riley Military Reservation, Kansas, began establishing food plots to supplement winter food supplies for bobwhites in 1959 (Joselyn 1965). These food plots were effective at improving body condition of bobwhites during winter (Robel et al. 1974) and increasing their overwinter survival (Robel and Kemp 1997). Natural resource managers at Fort Riley have also observed that hunters concentrate their efforts near food plots. Intense hunting pressure is known to affect the movements of bobwhites. Rosene (1969) observed that bobwhites disturbed repeatedly by hunters moved to different locations to avoid such hunting activity. When regularly disturbed, bobwhites are known to become more elusive (Kellogg et al. 1982) and shift their home range or increase their movements to avoid the disturbance (Dimmick and Yoho 1972).

The effect of food plots on bobwhite movement patterns and home ranges during winter is unknown. We initiated this study to examine the influence of food plots on the daily movements, home ranges, and habitat use of bobwhites on the Fort Riley Military Reservation. We also examined whether hunting activity affected bobwhite movements relative to food plots.

STUDY AREA

The Fort Riley Military Reservation is a 40,740 hectare area approximately 22 kilometers west of Manhattan, Kansas. It is located within the Flint Hills region of Kansas, which is a rolling landscape dominated by tall-grass prairie (Kuchler 1974). Natural resource managers at Fort Riley currently manage 160 food plots across the military reservation. These food plots vary in size from 1–5 hectares, are generally lo-

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cated adjacent to woody cover, and are planted with grain sorghum (*Sorghum bicolor*) or soybeans (*Glycine max*).

We selected a study site in the western area of Fort Riley and another in the eastern area of Fort Riley to conduct this study. These 2 study sites were separated by 10–15 kilometers, and their habitat composition significantly differed ($P \leq 0.001$); the eastern study site was 44% forested and 40% prairie, whereas the western site was 67% prairie and 13% forested.

We choose 6 food plot and 6 non-food plot areas within each of the 2 Fort Riley study sites to conduct trapping and radio telemetry activities. A food plot area was defined as any area ≤600 meters from a food plot and a non-food plot area as any area >900 meters from a food plot, based on Robel et al. (1974). The eastern ($P \leq 0.038$) and western ($P \leq 0.006$) study sites differed between food plot and non-food plot sites in habitat composition. In eastern Fort Riley, food plot sites were 32% prairie and 63% wooded cover, whereas non-food plot sites were 48% prairie and 52% wooded cover. Food plot sites were 52% prairie and 45% wooded cover in western Fort Riley, whereas non-food plot sites were 74% prairie and 26% wooded cover. This was an artifact of the method used by the natural resource managers at Fort Riley when they selected locations for establishing food plots. They selected areas where the food plots would border large stands of wooded cover.

METHODS

Bobwhites were captured from October through December during 1994, 1995, and 1996 at each study site. We attempted to capture all birds prior to the beginning of the hunting season (second weekend in November). Walk-in funnel-traps baited with grain sorghum were used to capture all bobwhites.

Captured bobwhites were sexed and aged. All adult bobwhites and juveniles ≥ 58 days of age (based on primary feather replacement) (Larson and Taber 1980) were fitted with a necklace radio transmitter, banded, and released. The radio transmitter weighed 7.5-8.0 g and contained a mortality switch.

Bobwhites were tracked using radio telemetry 4–5 days per week from October through March, depending on the intensity of military activities. The location of radio-marked bobwhites was determined by triangulating their position from as close as possible (50–200 meters), while attempting to minimize disturbance to the covey. Bobwhite locations were categorized into 4 habitat types: forested, woody thicket, prairie, and food plots.

Daily movement was estimated by determining the distance between locations on consecutive days based on the Universal Transverse Mercator (UTM) coordinate system. The effect of hunting on daily movements of bobwhites was estimated by dividing each field season into 3 periods: pre-hunting (prior to the second weekend in November), hunting, and post-hunting (after 31 January). Home range was estimated using the adaptive kernel method (Worton 1989) with a 90% confidence interval. Habitat preferences and avoidance were estimated using a χ^2 analysis with a Bonferonni z-test (Neu et al. 1974). Differences in habitat use between food plot and non-food plot areas were determined using χ^2 analysis (Christensen 1990). Analysis of variance was used to test for differences and interactions in daily distance moved and home range size (Steele and Torrie 1980). A least significance difference mean comparison test was used to delineate differences between main effects. These data were analyzed as a split-plot design with repeated measures (Milliken and Johnson 1992) at an $\alpha = 0.10$. Means are presented ± 1 standard error.

RESULTS

We captured 551 bobwhites and fitted them with radio-transmitters during this study; 140 during the 1994–1995 field season, 211 during 1995–1996, and 200 in 1996–1997. Overall, we monitored 26 coveys near food plots and 26 coveys in non-food plot areas. We recorded 2,454 telemetry locations across study sites and field seasons, of which 1,260 locations were collected on consecutive days.

Daily Movements

Daily movement of bobwhites varied according to study site and field season ($P \leq 0.001$). Daily movements of bobwhites in the western study sites averaged 227 ± 9 meters per day, which was greater ($P \leq 0.101$) than those in the eastern study site (218 ± 8 meters per day). Daily movements were also greater ($P \leq 0.059$) in the 1995–1996 field season (242 ± 13 meters per day) and 1996–1997 field season (221 ± 7 meters per day) than in the 1994–1995 field season (195 ± 11 meters per day). During the 1995–1996 field season in western Fort Riley, movements near food plots were significantly greater than bobwhite movements in non-food plot areas (Table 1). Across all other field seasons and study sites, there were no differences between the daily movement of bobwhites near food plots and those in non-food plot areas. The maximum daily movement observed in the eastern study site across field seasons was 1.1 kilometers in a food plot area and 1.2 kilometers in a non-food plot area. In the western study site, the maximum movement was 1.3 kilometers in a food plot area and 1.0 kilometer in a non-food plot area.

There were sufficient data only in the pre-hunting, hunting, and post-hunting periods of the 1996–1997 field season to test for hunting effects. The majority of bobwhites were captured after the start of the hunting season in the 1994–1995 field season and most bobwhites had died by the post-hunting period in the 1995–1996 field season. During the 1996–1997 field season, there was a significant difference in daily movements between each period ($P \leq 0.003$), but it did not differ between food plot and non-food plot areas ($P \leq 0.733$) or study sites ($P \leq 0.511$). Bobwhites moved an average of 271 ± 17 meters per day

Table 1. Average daily movement (meters per day) and standard error (S.E.) of bobwhites between food plot and non-food plot areas in eastern and western Fort Riley, Kansas, study sites by field season.

Field season	Study site	Food plot n	Food plot x̄	Food plot S.E.	Non-food plot n	Non-food plot x̄	Non-food plot S.E.
1994–1995							
	Eastern Ft. Riley	22	257 a[1]	44	34	220 a	27
	Western Ft. Riley	73	181 a	18	87	181 a	17
1995--1996							
	Eastern Ft. Riley	102	194 a	16	108	205 a	24
	Western Ft. Riley	84	320 a	28	57	250 b	30
1996–1997							
	Eastern Ft. Riley	254	235 a	12	135	209 a	14
	Western Ft. Riley	187	204 a	14	111	233 a	19

[1] Rows with the same letters are statistically similar at $\alpha = 0.10$.

during the pre-hunting period, which was significantly greater than the daily movement within both the hunting (212 ± 9 meters per day) and post-hunting (181 ± 14 meters per day) periods.

Home Range

There was no difference ($P \le 0.769$) between home range sizes of bobwhites near food plots (40.6 ± 5.0 hectares) and those in non-food plot areas (42.7 ± 4.7 hectares). Home ranges of bobwhites near food plots ranged from 10 to 126 hectares; home ranges of bobwhites far from food plots was 7 to 117 hectares. Home ranges of bobwhites did not vary with field season ($P \le 0.829$) or study site ($P \le 0.758$), nor was there an interaction between field season and study site ($P \le 0.223$). Bobwhite home ranges also did not differ significantly between food plot and non-food plot areas within each field season ($P \le 0.216$), study site ($P \le 0.131$), or field season and study site ($P \le 0.134$).

Habitat Use

There was a difference in the habitat use by bobwhites between field seasons ($P \le 0.001$) and study site ($P \le 0.001$). Therefore, habitat use by bobwhites in food plot and non-food plot areas was analyzed within field season by study site.

Tall grass prairie was always used by bobwhites less than its proportional availability across field seasons, study sites, and food plot and non-food plot areas (Tables 2 and 3). Food plots were always used by bobwhites greater than their proportional availability among food plot areas across field seasons and study sites. However, during the 1994–1995 field season, the preference for food plots was not statistically significant in either the eastern or western study sites (likely due to low sample size).

The use of thickets and forests by bobwhites relative to availability varied between field seasons and food plot and non-food plot areas in the eastern study site (Table 2). During the 1994–1995 field season, bobwhites in both food plot and non-food plot areas used thickets and forests greater than their proportional availability. Thickets were used less than their proportional availability in both food plot and non-food plot areas in the 1995–1996 field season. Forests were used greater than their proportional availability by bobwhites in non-food plot areas, but equal to their proportion in food plot areas. During the 1996–1997 field season, bobwhites near food plots used thickets equal

Table 2. Percentage of bobwhite locations habitat composition, and habitat use in proportion to availability by habitat type, within food plot and non-food plot areas, by field season, in eastern Fort Riley, Kansas.

Field season	Habitat type	Food plot n	Food plot Locations %	Food plot Composition %	Food plot Used	Non-food plot n	Non-food plot Locations %	Non-food plot Composition %	Non-food plot Used
1994–1995									
	Food plot	12	11.1	5.0	=[1]	Not applicable			
	Prairie	11	10.2	33.6	<	19	22.3	71.0	<
	Thicket	19	17.6	20.5	>	33	37.9	8.5	>
	Forest	66	61.1	40.9	>	32	36.8	20.5	>
1995–1996									
	Food plot	46	24.3	5.3	>	Not applicable			
	Prairie	12	6.4	26.4	<	30	14.8	48.2	<
	Thicket	19	10.1	16.0	<	12	5.9	10.1	<
	Forest	112	59.3	52.4	=	161	79.3	41.7	>
1996–1997									
	Food plot	67	18.3	4.6	>	Not applicable			
	Prairie	90	24.5	31.2	<	42	21.7	36.9	<
	Thicket	83	22.6	21.5	=	53	27.3	10.3	>
	Forest	127	34.6	42.7	<	99	51.0	52.8	0

[1] A ">" indicates the habitat was used in a greater proportion than available; a "<" indicates the habitat was used in a lesser proportion than available; and a "=" indicates the habitat was used in the same proportion as available.

Table 3. Percentage of bobwhite locations habitat composition, and habitat use in proportion to availability within food plot and non-food plot areas, by field season, in western Fort Riley, Kansas.

		Food plot				Non-food plot			
Field season	Habitat type	*n*	Locations %	Composition %	Used	*n*	Locations %	Composition %	Used
1994–1995									
	Food plot	16	9.5	4.8	=[1]		Not applicable		
	Prairie	24	14.3	54.4	<	78	35.1	72.8	<
	Thicket	58	34.5	11.2	>	101	45.5	23.4	>
	Forest	70	41.7	29.5	>	43	19.4	3.8	>
1995–1996									
	Food plot	35	15.2	5.1	>		Not applicable		
	Prairie	48	20.9	60.4	<	33	22.3	66.5	<
	Thicket	109	47.4	15.3	>	90	60.8	28.6	>
	Forest	38	16.5	19.2	=	23	15.5	4.9	>
1996–1997									
	Food plot	59	17.6	5.1	>		Not applicable		
	Prairie	47	14.0	56.7	<	22	10.8	76.5	<
	Thicket	114	34.0	14.9	>	156	76.9	20.4	>
	Forest	115	34.3	23.0	>	25	12.3	3.1	>

[1] A ">" indicates the habitat was used in a greater proportion than available; a "<" indicates the habitat was used in a lesser proportion than available; and an "=" indicates the habitat was used in the same proportion as available.

to, and forests less than, their proportional availability. Bobwhites in non-food plot areas used thickets more often than forests.

Habitat use by bobwhites in the western study site did not vary as greatly as it did in the eastern study site. Thickets were always used greater than proportionally available in both food plot and non-food plot areas across field seasons (Table 3). Forests were used by bobwhites in non-food plot areas greater than their proportional availability across field seasons. Bobwhites in food plot areas also used forests greater than their proportional availability, except during the 1995–1996 field season.

DISCUSSION

Researchers in Missouri observed that bobwhites moved no more than 410 to 810 meters during the entire winter (Lewis 1954, Murphy and Basket 1952). We recorded occasional daily movements > 1 kilometer. Williams (1996) observed that daily movements of bobwhites during winter in Kansas ranged from a mean of 81.9 to 271.3 meters per day, and total mean movement was 1,216 meters. Bobwhites in our study area had mean daily movements of 180 to 320 meters per day, which was generally greater than most movements reported by other researchers.

The home range sizes we observed near (40.6 ± 5.0 hectares) and far from (42.7 ± 4.7 hectares) food plot areas on Fort Riley were also generally greater than home ranges observed by researchers elsewhere (4.4 hectares, Wiseman and Lewis 1981; 9.6 hectares, Roseberry 1964; 12.6 hectares, Hunt 1991; 16.7 hectares, Dimmick and Yoho 1972; 4.2 to 33.0 hectares, Dixon et al. 1996). Williams (1996) observed home ranges of bobwhites in central Kansas averaged 19.5 hectares, half that observed for bobwhites on Fort Riley. Bell et al. (1985) did observe home range sizes similar to those on Ft. Riley. They observed home range sizes of 18.4 to 58.4 hectares in Louisiana pinelands. They postulated that the marginal habitat quality of pinelands for bobwhites caused the large home range sizes. There is evidence that home range sizes and daily movements may be linked to habitat quality, where movements and home range sizes are generally greater in areas with poorer quality habitat (Brennan 1999). For example, Lee (1994) observed home range sizes for bobwhites as large as 282 hectares in an area in Mississippi where habitat had deteriorated.

The presence of food plots on Fort Riley did not significantly influence the daily movements of bobwhites or their use of habitat types. Daily movements and home range sizes of bobwhites generally were similar between food plot and non-food plot areas across field seasons and study sites. The only exception was that during the 1995–1996 field season in the western study site, daily movement of bobwhites near food plots was greater than bobwhites in non-food plot areas. Bobwhites near food plots in this study site tended to have a bimodal home range, in that more than one central area was utilized. Several coveys interchanged between the food plot and an alternate area that was > 500 meters from the food plot on successive days. The reason for these shifts in their location was unknown. Dimmick and Yoho (1972) observed shifts in bobwhite home ranges due to human disturbance, but we observed no specific disturbance that could be linked to the shifts in home ranges during our study.

The presence of supplemental food has been documented to reduce the movements or home ranges of several wildlife species. Robel and Kemp (1997) observed that bobwhites near food plots spent less time foraging and bobwhites in non-food plot areas had longer foraging movements. Several factors may have led to our observation of no differences in daily movements and home ranges between food plot and non-food plot areas. Robel and Kemp (1997) determined that food plots had their greatest impact on overwinter survival during severe winters (10–12 consecutive days of temperatures ≤ 5° C in January). During the 3 field seasons of this study, no winter had > 5 consecutive days of ≤ 5° C temperatures in January. Therefore, winter weather during our study may not have been severe enough to impact the behavior of bobwhites near food plots. The daily movements of bobwhites near and far from food plots may be similar during mild winters, but during more severe winters, bobwhite movements may decrease near food plots.

Predators may also be affecting the daily movements of bobwhites near food plots. Predator density is known to be greater in areas where the prey base is high (Clark 1972, Robinson and Bolen 1984). Foraging time of many avian species has been documented to increase when predation risk is elevated (Grub and Greenwald 1982, Lima 1986). We did not measure predator or prey densities in this study, but if predators are concentrated near food plots, their presence may influence bobwhite foraging time (movements and home ranges) near food plots.

We observed that hunting did not affect the daily movements of bobwhites between food plot and non-food plot areas. Daily movements were greatest prior to the beginning of hunting season and progressively decreased through the winter. Williams (1996) observed a slight increase in daily movements of bobwhites in Kansas during November and December, which he attributed to the onset of hunting season. Smith et al. (1982) concluded that the impacts of hunting on bobwhite movements in Florida were insignificant. Dimmick and Yoho (1972) determined that when coveys were repeatedly disturbed during field trials in Tennessee, they tended to shift their home range. However, coveys receiving only moderate disturbance did not exhibit changes in their home range. During the opening weekend of the 1996–1997 hunting season on Fort Riley, hunter numbers averaged 0.53 hunters per 100 hectares and decreased to 0.08 hunters per 100 hectares one month after the start of hunting season. These numbers of hunters probably did not constitute heavy enough hunting pressure to alter bobwhite movement patterns for extended periods of time.

Habitat use by bobwhites near and far from food plots was similar, particularly in the western study site of Fort Riley. Prairie always was used less than proportionally available. Wiseman and Lewis (1981) and Williams (1996) observed that pastures were used less than proportionally available by bobwhites during winter. Grasslands are an integral component of bobwhite habitat (Casey 1965), but open grasslands are avoided. Food plots always were used greater than their proportional availability within food plot areas substantiating Robel (1969), i.e., a majority of bobwhites < 300 meters from food plots fed in those plots. Bobwhites on Fort Riley also used woody cover. Such habitat provides protection and escape cover for bobwhites across their North American range (Schroeder 1985, Wiseman and Lewis 1981).

In summary, we found few differences between the daily movements, home ranges, and habitat use between food plot and non-food plot areas during our study. Food plots were utilized by bobwhites, but daily movements and home ranges of bobwhites were not reduced near food plots, as we had expected. Mild winter weather and potential influences of predators near food plots may have limited the influence of food plots on bobwhite movements and home ranges.

Future research on the influence of food plots on the daily movements, home ranges, and habitat use by bobwhites should focus on assessing the impact of habitat quality and predator populations. Habitat quality, rather than the presence or absence of food plots, may better explain fluctuations in home range sizes and movement patterns. This would likely involve sampling bobwhite densities near and far from food plots, which is known to reflect habitat quality. In addition, the densities of both avian and mammalian predators could be estimated to determine if predators appear to be congregating near food plots. Experimental manipulations of the predator populations could further determine the impact of their presence on the movements, home ranges, and habitat use of bobwhites.

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THE STATUS OF MASKED BOBWHITE RECOVERY IN THE UNITED STATES AND MEXICO

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ABSTRACT

The masked bobwhite (*Colinus virginianus ridgwayi*) is an endangered species currently numbering <1500 individuals and restricted to 2 locales in southeastern Arizona and northcentral Sonora, Mexico. The subspecies' endangered status is attributed to overgrazing of Sonora savanna grassland that began during the late 1880's and continued well into the 20th century. This overgrazing resulted in the conversion of many native grass pastures to the exotic bufflegrass (*Cenchrus ciliaris*). The Arizona masked bobwhite population was extirpated around the turn of the century, and the Sonoran population was thought to have disappeared during the 1940's until a small remnant population was discovered on a ranch near Benjamin Hill, Sonora, in 1964. Masked bobwhite recovery efforts have a dynamic, long history of nearly six decades. Current masked bobwhite recovery efforts focus on reestablishing a self-sustaining population on the Buenos Aires National Wildlife Refuge (BANWR) in the United States, as well as 2 remnant wild populations located on privately owned ranches in northcentral Sonora.

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INTRODUCTION

The masked bobwhite is currently the only federally listed endangered quail in North America. The species was listed as endangered in 1968. It was among the fauna originally designated as endangered by the United States Government after the passage of the Endangered Species Conservation Act (Public Law 91-135; 83 Statute 275). The Endangered Species Conservation Act was superseded by the Endangered Species Act of 1973 (Public Law 93-205; 87 Statute 884) and the legal and biological status of the masked bobwhite remain "endangered".

Masked bobwhites remain endangered today throughout their current ranges in Arizona, U.S.A., and Sonora, Mexico. A recovery plan was first completed for the species in 1978 (U.S. Fish and Wildlife Service 1978), was revised in 1984 (U.S. Fish and Wildlife Service 1984), and underwent a second revision in 1995 (U.S. Fish and Wildlife Service 1995). Current masked bobwhite recovery goals, strategies, and efforts are outlined in detail in the second revision of the recovery plan and are being adhered to by the various Federal, State, and private organizations involved in the recovery process. The objectives of this paper are to provide: (1) a brief description of masked bobwhite distribution, taxonomy, and life history; and, (2) a history of past recovery efforts.

DESCRIPTION

Distribution

Historic accounts and scientific collections indicate that the masked bobwhite was restricted to level plains and river valleys in Sonora and extreme south-central Arizona, between 150 and 1,200 m elevation (Brown 1885, 1900, Van Rossem 1945, Ligon 1952, Tomlinson 1972a) (Figure 1). Consequently, masked bobwhites inhabited the grassy savanna habitats (llanos) within Shreves' (1942, 1951) Plains of Sonora, which are subdivisions of the Sonoran Desert. These biotic communities have a mean rainfall ranging from 250 to >500 mm, of which more than 70% occurs from July through September (Shreve 1951, Tomlinson 1972b).

The eastern and southern distribution of masked bobwhites is limited by the merging of Sonora savanna grassland with the more structurally dense Sinaloan thornscrub where bobwhites are replaced by elegant quail (*Lophortyx douglassi*). Masked bobwhite occurrence south or east of the Rio Yaqui has not been documented. To the west and northwest, a decrease in summer precipitation excludes masked bobwhites from the desert scrub communities of the Central Gulf Coast, Lower Colorado River, and Arizona Upland

Fig. 1. Historic range of the masked bobwhite in Arizona including areas considered most suitable for masked bobwhite recovery activities.

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subdivisions of the Sonora Desert. Northward and above 1,200 m in elevation, the subtropical scrub and grass understories of Sonora savanna grassland give way to sod-forming perennial grasses and shrubs, and leaf succulents characteristic of warm temperate desert grassland. At the northern limits of masked bobwhite range in the Altar and Santa Cruz valleys of Arizona, semidesert grassland replaces Sonoran savanna grassland and the masked bobwhite is supplanted by scaled quail (*Callipepla squamata*). Reports of masked bobwhites outside this range are unsubstantiated by specimens or other corroborating evidence.

The current distribution of masked bobwhites is limited to 2 sites. One population of <500 birds occurs on the Buenos Ares National Wildlife Refuge (BANWR) in southeastern Arizona, while 2 populations exist in northcentral Sonora on privately-owned ranches. One of the Sonoran populations is located on Rancho El Carrizo approximately 120 km south of the BANWR, and numbers <1000 individuals. The existence of the second Sonoran population, located on Rancho Grande 20 km south of Rancho El Carrizo, was reestablished in 1995; population estimates were not made. Despite recent surveys (Dobrott 1990), no other wild population of masked bobwhite is known to occur in Sonora, Mexico. Considering the widespread deterioration of subtropical grasslands throughout Sonora, existence of any heretofore unrecorded population is unlikely. However, because large segments of the historic range have not been searched, and given the secretive habits of the bird as well as the difficulty of locating small, isolated populations, it is possible that additional masked bobwhite populations persist in remote areas of Sonora. For example, two masked bobwhites were reported to have been live-trapped on a ranch approximately 400 km southwest of the Rancho El Carrizo area during the winter of 1992–1993, and several birds were killed by hunters in the same area the previous winter (R. Engel-Wilson, unpublished data).

Taxonomic Classification

Masked bobwhites are one of 4 quail species endemic to Arizona. The other 3 species include Gambel's quail (*Callipepla gambelii*), scaled quail, and Montezuma quail (*Cyrtonyx montezumae*). Masked bobwhite males are very distinctive in appearance and are characterized by a brick red breast and black head and throat. A varying amount of white is usually present on the head, particularly above the eye and occasionally on the throat (Banks 1975). Johnsgard (1973) speculated that a link existed between masked bobwhites and the black-headed bobwhite (*Ortyx graysoni*) of the Pacific slope of southwestern Mexico because the males closely resemble one another. Females, however, closely resemble other bobwhite subspecies; they are essentially indistinguishable from the Texas bobwhite (*C. v. texanus*) found in subtropical Texas and Tamaulipas, Mexico (Ridgway 1887).

Recent work tends to support the early conclusions of Ridgway (1887). For example, Banks (1975) examined a series of 60 specimens from most portions of the masked bobwhite's presumed range, and concluded that all populations were of a single, although highly variable subspecies. He found no evidence that masked bobwhite integrated with other races in historical times. The genetic analysis conducted by White et al. (*this volume*) supports Bank's conclusion regarding the subspecific status of masked bobwhites. However, their results also suggested that masked bobwhites and Texas bobwhites from southern portions of the state are more closely related to one another than either subspecies is related to eastern subspecies of northern bobwhite. This seems plausible as masked bobwhites and bobwhites from south Texas occupy similar habitats and it is possible that evolution of both subspecies was similar. White et al. (*this volume*) believed that Texas bobwhites might serve as valid research models for masked bobwhite recovery in Arizona and Mexico.

Life History

Little quantitative information has been collected regarding masked bobwhite life history. Most of what is known comes from the observations of field biologists. However, masked bobwhite life history seems to closely resemble that of Texas bobwhites. The limited evidence available from studies in Sonora (Brown 1989) indicate that the incubation period, as well as average clutch and brood sizes of masked bobwhites, are very similar to those of other races of bobwhites. Moreover, the food habits of masked bobwhites are thought to be very similar to those reported for south Texas bobwhites by Lehmann (1984), Guthery (1986), and Koerth et al. (1986). Forb seeds and leafy material and invertebrates, chiefly insects, are probably the most important dietary items, although grass seed such as Johnsongrass (*Sorghum halepense*) and vinemesquite (*Panicum obtusum*) are consumed on a seasonal basis as well. The contents of approximately 20 fresh crops of chicks killed by a raptor at a release site on the BANWR were examined in 1995. Insects and forb material were the dominant food items identified.

Annual mortality rates for the masked bobwhite, though little studied, are believed similar to the rates (about 70%) for other northern bobwhite subspecies (Rosene 1969). Raptors are the most important masked bobwhite predators (Goodwin 1982). The telemetry studies done by Gall et al. (*this volume*) on the BANWR clearly demonstrated that raptor predation is the primary source of mortality among radio-marked masked bobwhites. Red-tailed hawks (*Buteo jamaicensis*) and northern harriers (*Circus cyaneus*) accounted for most of this predation. Mammalian predation is another important mortality factor. Goodwin (1982) attributed 4 mortalities out of 18 recorded (22%) to mammals, and Simms (1989) likewise reported 5 mammal-induced mortalities (21%) compared to 21 caused by raptors. Undoubtedly coyotes (*Canis latrans*) and bobcats (*Felis rufus*) account for a few mortalities each year, and raccoons (*Procyon lotor*) and skunks (*Mephitis mephitis, M. macroura, Spiolgale* *gracilis, Conepatus mesoleucus*) are probably responsible for some nest destruction.

Behavioral patterns exhibited by masked bobwhites are also similar to those of eastern races of northern bobwhites. The reports of biologists who have studied wild masked bobwhites indicate that pairing activity, breeding, nesting and brood-rearing behavior, as well as covey formation, follow patterns similar to those reported for northern bobwhite populations elsewhere in the U.S. (Stoddard 1931, Lehmann 1984, Roseberry and Klimstra 1984). Despite these general similarities, masked bobwhites also exhibit seasonal behavioral patterns that are unique to the subspecies and seem to be a manifestation of the environments they inhabit. The most striking behavioral feature that differentiates masked bobwhites from eastern subspecies involves the onset of breeding activity. Masked bobwhite breeding activity is closely associated with the onset of summer precipitation in both Arizona and Sonora. Humidity levels must exceed 90% in order for breeding activity to commence (G. Gee, unpublished data). The captive masked bobwhite population at BANWR will not begin breeding unless biologists artificially elevate relative humidity levels in the propagation building by wetting the floors several times daily. Therefore, because high humidity is required, masked bobwhites remain in coveys until late June (Tomlinson 1972b) and do not display breeding behavior until rainfall commences in mid-to-late July (Tomlinson 1972b, Brown 1989). Peak breeding activity generally occurs in August and then terminates as humidity levels decrease in September (Brown 1989, Camou et al. 1998).

Breeding activity may also occur during early spring during years of above average winter precipitation. Masked bobwhite chicks have been observed during late March and early April following wet winters. This indicates that chicks were produced during late February or early March. Though spring breeding activity probably does not occur every year, and recruitment rates are smaller than those of summer, its periodic occurrence is likely of demographic importance. Modeling work conducted by F. S. Guthery (unpublished data) demonstrated that 60 days of breeding activity, the average length of a summer masked bobwhite breeding season, is insufficient to sustain a masked bobwhite population. Though the majority of the chicks produced each year are produced during summer, additional recruitment is necessary, even on an intermittent basis. Such recruitment is probably critical to the continued persistence of a masked bobwhite population. Early breeding activity is also probably constrained by photoperiod, but it is unlikely to occur in the absence of a wet winter. Therefore, masked bobwhites seem to exhibit a bimodal breeding season initiated and maintained largely by precipitation.

Masked bobwhites are associated with grassy river bottoms, broad level valleys, and plains. Habitat in Sonora is relatively open, subtropical, savanna grassland within dry-tropic scrub. The scrub components are characteristic of Sinaloan thorn-scrub and Sonoran desert-scrub (Shreve 1942, 1951). On the Sonora savanna grassland of the BANWR, the extreme northern edge of the masked bobwhite range (Figure 1), scrub components include a mixture of Sonoran species and dry-subtropical species of warm temperate semidesert grassland (Shreve 1942). Abundant grass cover is seasonal, along with a variety of summer-active forb and weed species. Typical masked bobwhite habitat in both Sonora and Arizona is characterized by lush and diverse herbaceous species interspersed with semi-arid shrubs (U.S. Fish and Wildlife Service 1996). Habitat preference studies indicate that ample herbaceous cover and diversity, as well as a shrub overstory of 15–30% total cover, are essential to masked bobwhite survival (Goodwin 1982, Simms 1989). In fact, Goodwin (1982) reported that several coveys emigrated from home ranges when the grass-forb understory was reduced (by grazing) to 400 kg per ha and 12–15 cm height. Reducing herbaceous cover to 12–15 cm in occupied masked bobwhite habitat probably represents at least a 50% reduction in total cover.

Reasons for Listing as Endangered

The rangelands of southeastern Arizona were described by early visitors to the region as some of the most lush and beautiful in the southwestern U.S. (Arrington 1942). Destructive land use practices were introduced by Anglo colonialists when they first visited southeastern Arizona during the 15th and 16th centuries, when livestock were first introduced (Bahre 1995). The earliest Anglo visitors were Spanish explorers (Bahre 1995) and Catholic clergymen whose goal was the conversion of Native Americans to Christianity (Whetstone 1994). Many overgrazed areas probably recovered between the late 1700's and the early 1800's because most Spanish missions were abandoned due to Apache hostilities (Bahre 1995). More extensive damage to grasslands transpired when Mexican Land Grants were awarded during the 1830's, and vast ranches, supporting huge herds of cattle, were established in portions of southeastern Arizona (Officer 1987). Nonetheless, the damage to grassland ecosystems due to livestock mismanagement was thought to be minimal, restricted to certain locales and temporary in nature (Bahre 1995). It is probable that large areas of many grassland ecosystems remained relatively undisturbed until after the Civil War.

Serious grassland destruction began during the latter part of the 19th century as a result of the subjugation of the Apaches and the advent of the Arizona cattle industry (Whetstone 1994). It is estimated that southeastern Arizona's productive grasslands were severely damaged in only two decades (Bahre 1995). By the 1880's hundreds of thousands of cattle, and over a million head of livestock including sheep, inhabited southeastern Arizona (Hollon 1966). Hollon (1966) reports that there were approximately 5,000 cattle in Arizona in 1870; 135,757 in 1880; and by 1890, there were 927,880. Wilson (1976) estimated that over 1,500,000 cattle were on Arizona rangelands, primarily in southern Arizona, at the beginning of 1891. A serious drought during the early 1890's exacerbated grassland deterioration and almost destroyed the cattle industry (Brown 1900). The Chairman of the Livestock Sanitary Commission, C. Cameron, said that if the drought of 1891 to 1893 had continued 60 days longer, all the cattle in southern Arizona would have perished (Wilson 1976).

In 1901 D.A. Griffiths, an early University of Arizona agricultural scientist, noted that the rangelands of southern Arizona were the most degraded of any he had observed in the West. A few years later J.W. Toumey, another University of Arizona scientist, stated that suitable herbarium specimens of perennial grasses were almost impossible to locate (Bahre 1995). The extirpation of masked bobwhites from Arizona coincided with Mr. Griffith's observations of grassland conditions at the turn of the last century. The last masked bobwhite specimens from Arizona were those taken for Brown at Calabasas on 29 December 1897 (Phillips et al. 1964).

The arrival of Europeans and their livestock in Sonora predates colonization of Arizona. However, the settlement of Sonora was slow and areas away from river valleys remained uninhabited by Europeans until the late 1880's. With the elimination of nomadic Apache and Yaqui Indian populations (1850 to 1900), settlement of Sonora accelerated. Accompanying settlement was the expansion of the livestock industry and the concomitant destruction of Sonoran grasslands.

Masked bobwhites apparently persisted in Sonora through the late 1880's as Benson and Cahoon separately collected birds in and around Cumpas and Bacoachi in 1886 and 1887 (Stephens 1885, Brewster 1887, Van Rossem 1945). Nevertheless, populations in Sonora were probably declining as habitat was lost. The subspecies was thought to have been extirpated from Sonora, and therefore extinct in the wild, by the early part of the 20th century (Tomlinson 1972b, Brown 1989). However, a small population was rediscovered on Rancho El Carrizo in 1964 (Gallizioli et al. 1967) thereby stimulating interest in saving the subspecies. It was obvious to those concerned that rigid protective measures were necessary to prevent extinction. The masked bobwhite was consequently listed as an endangered species in 1968.

RECOVERY OBJECTIVES AND CRITERIA

The primary objective of masked bobwhite recovery is to increase populations of the subspecies to the point where they can be removed from the endangered species list. Recovery criteria state that the masked bobwhite will be considered for reclassification from endangered to threatened status when 4 separate, viable populations are established (consisting of 2 populations in the U.S. and 2 more in Mexico) and have been maintained for 10 consecutive years. A viable population is considered to consist of 200 calling males (500 individuals) which, without supplementation, maintains these numbers for at least 5 years and never falls below 50 calling males (U.S. Fish and Wildlife Service 1995).

RECOVERY EFFORTS

1930 to 1950

The rangeland abuse that occurred during the late 1800's in southeastern Arizona and Sonora continued unabated well into the 20th century. After the Mexican revolution (1911 to 1927), establishment of "ranchos" in Sonora was again accelerated through the development of permanent water. By the late 1920's and early 1930's, ornithologists were concerned that the masked bobwhite might be extinct (Bent 1932). However, Ligon (1952) reported that birds were "still fairly numerous locally as late as 1937 in central and southern Sonora, Mexico."

When Ligon returned to Sonora in 1949 and 1950, the situation had changed. As cattle ranching expanded as an industry throughout Sonora after 1930, masked bobwhite populations continued to decline. Ligon's (1952) report of trips in 1937 and 1950, and Wright's experiences between 1931 and 1950, indicate that the once luxuriant grassy plains were denuded within that time span (Tomlinson 1972a). Sonoran ranchers, who had formerly known of the presence of the birds, stated that masked bobwhites seemed to have vanished overnight (Ligon 1952). Competent observers familiar with masked bobwhites also reported seeing birds through the 1930's in the Altar Valley of Arizona, and Ligon (1942) stated that reports of masked bobwhite observations persisted around the town of Arivaca and on the Baboquivari range west of the Altar Valley in Arizona. However, these sightings were neither confirmed by other observers nor substantiated by specimens.

It was obvious to ornithologists that monitoring programs, and recommending habitat protection to disinterested ranchers, would not save the few remaining masked bobwhite populations that still existed in Sonora. Therefore, while monitoring programs continued, several early attempts were made to reintroduce masked bobwhite to Arizona and to restore or bolster populations in Sonora. Ligon initiated 3 expeditions to Sonora to obtain wild stock for reintroduction and propagation in 1937, 1949, and 1950 (Ligon 1942, Lawson 1951, Ligon 1952). In 1937, 132 bobwhites were captured and another 25 were obtained in 1950. Restocking efforts following the 1937 trip resulted in the initial release of about 200 birds (including wild and propagated stock) in 6 areas of Arizona and southwestern New Mexico.

Most of these releases were well outside the presumed historic range of the masked bobwhite (Figure 1). Evidently, little effort was devoted to acclimating birds to the new environmental conditions associated with the release site. Thus, each reintroduction attempt was unsuccessful as masked bobwhites rapidly disappeared from release sites. Areas within the bird's known range were not selected as release sites because Arrington and Ligon believed range conditions in historic habitat were totally unsuitable for masked bobwhites (Arrington 1942). The most recent collections and reports of masked bobwhites in Arizona at that time (Ligon 1942, Phillips et al. 1964) were at the upper elevational limits of the bird's habitat, consequently Ligon (and others) may have erroneously concluded that the bird's historic range included higher elevation desert grasslands (>1200 m). Additionally, these early biologists did not have accurate information about critical components of masked bobwhite habitat. Consequently, their reintroduction attempts probably occurred in habitats that lacked essential components such as tall, dense herbaceous cover, which further doomed the reintroduction efforts to failure. Early attempts to reintroduce masked bobwhites to Arizona and Sonora effectively ceased after the 1950 translocation to the Gardner Canyon area of the Huachuca Mountains in Arizona.

1964 to 1985

After the 1950 reintroduction effort failed, no attempts were made to recover masked bobwhite populations until 1964 when Steve Gallizioli, an Arizona Game and Fish Department (AGFD) Biologist, and Naturalists Jim and Seymour Levy documented a population between Benjamin Hill-Carbo and Hermosillo, Sonora (Gallizioli et al. 1967). The rediscovery of this population again prompted interest in saving the masked bobwhite from extinction. The Levys, with assistance from the AGFD, attempted to convince a Sonoran landowner to designate a portion of his ranch a masked bobwhite management area. Despite some initial encouragement, their efforts failed as the rancher ultimately refused to manage the area properly. Clearly protective measures alone would not suffice.

Accordingly, in 1964 the Levy brothers and personnel at the Arizona Sonora Desert Museum in Tucson began separate studies of the masked bobwhite using breeding stock obtained from Ligon (Walker 1964, Gallizioli et al. 1967). The latter study was terminated when vandals entered the breeding pens and destroyed the remaining propagated birds. In 1966 the Levys donated 4 pairs of pen-reared masked bobwhite to the U.S. Department of the Interior, Fish and Wildlife Service (USDI, FWS). These birds, and 57 wild birds captured near Benjamin Hill-Carbo, Sonora, in 1968 and 1970, were the original breeding stock sent to the USDI, FWS's Patuxent Wildlife Research Center (PWRC) in Laurel, Maryland where a captive masked bobwhite population was soon developed. The descendants of these 61 birds, with occasional supplementation of wild birds from Sonora, were then used for propagation and release projects in Arizona and Mexico for the next 30 years. Another important event regarding masked bobwhite recovery that occurred during the 1960's was the passage of the Endangered Species Conservation Act in 1968. When this act became Federal Law the USDI, FWS received a legal mandate to implement recovery efforts for the masked bobwhite.

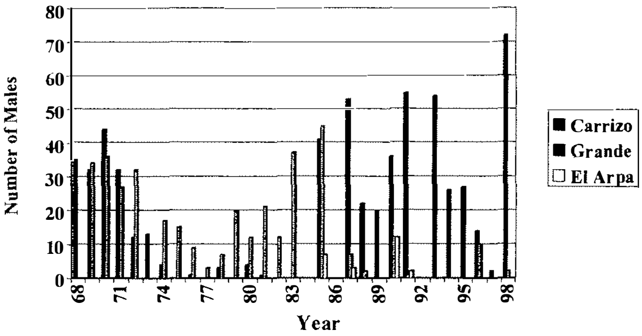

Fig. 2. Number of masked bobwhite males breeding on Rancho El Carrizo, Rancho Grande and Rancho El Arpa, Sonora, Mexico from 1968 to 1998.

Sonora

From 1967 through 1970, Tomlinson (1972b) conducted extensive surveys in Sonora to determine the distribution and status of masked bobwhites. He visited published localities and collection sites, and interviewed hundreds of Mexican citizens. During the fall and winter, areas thought to harbor masked bobwhites were searched on foot with a dog. Cactus wren (*Campylorhynchus brunneicapillus*) and verdin (*Parus* spp.) nests (which are frequently lined with feathers of other birds) were inspected for masked bobwhite feathers. The distinctive roosts of masked bobwhites were also sought. During the summer breeding season, Tomlinson listened for bobwhite calls, and used taped female calls to elicit male responses. His investigations concentrated on 8 general areas in Sonora. Masked bobwhites were located at 2 sites in the Benjamin Hill-Carbo area, Rancho Grande-El Arpa and Rancho El Carrizo, and a very limited region east of Mazatan (Tomlinson 1972b). Tomlinson therefore established call-count survey routes on both Rancho El Carrizo and Rancho Grande in 1968 (Figure 2).

Population trends were subsequently monitored on both ranches for the next several years. During the early 1970's it was apparent that both populations were declining and USDI, FWS biologists were unable to locate masked bobwhites on the Mazatan site when they revisited the area in 1974. By 1977, the trend in peak counts of calling males (Figure 2) suggested that the Rancho El Carrizo population was near extinction and that the Rancho Grande population, though still persisting, was in danger of disappearing as well (Ellis and Serafin 1977). These declines coincided not only with continued overgrazing by livestock, but dry weather as well. Fortunately, the drought ended during the summer of 1977. Despite continued overgrazing, both populations began to increase. The populations then experienced a combination of moderate declines and increases until 1983, when both populations contained more than 40 males (Figure 2). Like the increase in 1977, this increase again coincided with abundant summer precipitation in 1982. Habitat conditions improved as a function of increased moisture and the masked bobwhite populations responded accordingly. From 1980 to 1982, USDI, FWS biologists released approximately 2000 captive-reared masked bobwhites on 3 additional areas in Sonora where extensive brush-clearing had occurred. These reintroduction attempts apparently failed due to excessive livestock grazing on cleared areas. Nevertheless, by 1985, masked bobwhite populations on Rancho El Carrizo and Rancho Grande appeared to be at the highest levels recorded since call-count surveys were instituted in 1967.

Other than establishing call-count surveys, monitoring populations, conducting several releases and establishing dialogues with the ranch owners, USDI, FWS biologists could do little to improve the masked bobwhite situation in Sonora. The population increases documented during the surveys indicated that the quail were responding to precipitation-induced habitat improvement. Livestock management practices were not altered significantly during the 1970's and 1980's. Goodwin (1981) was initially hopeful that the habitat situation would improve on Rancho Grande when owners implemented an extensive brush removal program and then planted thousands of acres to buffelgrass (*Cenchrus ciliaris*). Biologists believed that masked bobwhites would respond positively to the increased herbaceous cover. However, this did not occur because the buffelgrass formed extensive monocultures that replaced native grasses and such habitat was not suitable for masked bobwhite production. The future of masked bobwhites in Sonora therefore remained dependent on the management decisions of ranch owners, and their future remained tenuous at best in 1985.

Arizona

In 1969, the USDI, FWS, in cooperation with the AGFD, began surveying southern Arizona for suitable masked bobwhite reintroduction sites. Biologists conducting the surveys were unable to perform definitive habitat evaluations because Tomlinson's life history studies had just begun and little was known about specific masked bobwhite habitat requirements. Criteria used for selecting release areas were range condition, historic distribution, land status and availability, amount and composition of ground cover, recent land use practices, and elevation. Although little was known about masked bobwhite food habits, an effort was made to choose reintroduction areas believed to contain an adequate food supply.

Four areas in the Altar Valley were eventually selected as release sites in 1970, although none of these areas were comparable to occupied habitats in Sonora. The Altar Valley habitat was higher (730 to 1,300 m) than the Sonoran habitat (300 to 800 m), the soils were generally more shallow and the terrain more rugged, and subtropical vegetation of Sonora was less abundant. However, like the occupied habitat in Sonora, much of the land had been, and was currently being abused by livestock. Although the Altar Valley habitats were less than ideal, they were judged to represent the best available release sites in the U.S. Biologists released captive-reared birds on lands owned by cooperative ranchers; however, all releases failed. Though cattle grazing rendered habitats unsuitable for masked bobwhite survival and contributed to the failure, poor physical conditions of the birds being released was also a contributing factor to reintroduction failure. These birds were fed, watered, and held for only 24 hours before being released. Many of the birds suffered deformities from excessive debeaking and confined rearing. Release protocols were thus altered after the 1971 releases and birds were held in Tucson for 3 months prior to release.

In an effort to alleviate concern about poor habitat on release sites the USDI, FWS leased 745.2 ha of the Las Delicias Ranch (Altar Valley) from the Arizona State Land Department in 1972 as a masked bobwhite management area. The pastures comprising this lease were within the historic range of the masked bobwhite, and would provide undisturbed nesting cover as cattle were removed from all pastures soon after the site was leased. Biologists immediately began releasing captive-reared stock on the leased pastures. Nevertheless, like the 1970 and 1971 releases, the early Las Delicias releases also failed. Most of the masked bobwhites that were released during this period received little wild conditioning and, as a result, most of them disappeared within 2 months of release. Abnormally high mortality rates due to coyote predation were documented immediately after most releases (Ellis and Tomlinson 1974, Goodwin and Hungerford 1977). A screening program was therefore initiated in 1974, and only those birds thought capable of surviving in the wild were released (Ellis and Serafin 1977). Two reintroduction techniques were developed which resulted in release-worthy stock (Ellis et al. 1978). One is a modification of the foster parent-adoption methods described by Hart (1933), Stoddard (1931), and Stanford (1952). The most promising foster parents were wild male Texas bobwhites sterilized by bilateral vasectomy (Ellis and Carpenter 1981). The second technique was a modification of the call-box or call-pen conditioning program originally proposed by Hardy and McConnell (1967).

These techniques were developed in 1974 and 1975, and tested with hundreds of birds between 1974 and 1977. This shift toward prerelease training produced captive-reared birds that were thought to be better prepared for survival in the wild (Ellis et al. 1978). Many of the birds released during the spring and summer of 1976 survived into winter, and by the onset of the 1977 summer rains, a population estimated at 30 birds was found near 1976 release sites in Altar Valley on the Buenos Aires Ranch. Several pastures of this ranch (465 ha) were included as release sites in 1975 because habitat conditions were deemed more suitable here than on the Las Delicias lease, which was terminated in 1976. The decision to move reintroduction efforts to the Buenos Aires Ranch was justified on 4 October 1977 when a USDI, FWS biologist observed a pair of wild masked bobwhites with at least three chicks. This observation was significant because it conclusively demonstrated that captive-reared birds could survive the winter and produce wild progeny.

Annual releases of masked bobwhites on the

Buenos Aires Ranch eventually produced a wild population by 1978. Natural productivity was documented, and winter survival was good. The number of calling males increased from 21 in 1977, to 54 in 1978, and eventually to a peak of 74 in 1979 (Goodwin 1982). Thereafter intensive grazing, combined with summer drought, sharply reduced the population (Goodwin 1981). Only 9 birds were detected in 1984 (Levy and Levy 1984, Ough and deVos 1984). It was evident that the reestablished population was again in danger of disappearing.

Much was learned from the reintroduction research conducted during the 1970's; previously unknown habitat requirements were identified, and new techniques were developed and applied that improved the postrelease survival of captive-reared birds. Most importantly research indicated it may be possible to reestablish masked bobwhites to historic habitats. Despite this increased knowledge, the masked bobwhite decline of the early 1980's demonstrated that the birds remained vulnerable to even moderate grazing pressure. Clearly, an area managed exclusively for masked bobwhite was needed to assure the future of the subspecies in the wild.

1985 to 1994

Sonora

The masked bobwhite populations on Rancho El Carrizo and Rancho Grande were not monitored between 1985 and 1987 because a USDI, FWS biologist was not assigned to the Recovery Project. However, 9 males were documented by an observer who conducted a call-count on Rancho El Arpa (a ranch adjacent to Rancho Grande) in 1985 (Figure 2). This small population was subsequently added to the monitoring program. After the BANWR was established in 1985, the USDI, FWS hired a biologist in 1986 to resume masked bobwhite recovery efforts in Arizona and Sonora. When call-count surveys resumed in 1987 the Rancho El Carrizo population appeared to have increased whereas the Rancho Grande and El Arpa populations had experienced a serious decline (Figure 2). Results of the 1988 and 1989 surveys indicated that not only were the Rancho Grande and El Arpa populations continuing to decline, but the Rancho El Carrizo population had suffered an alarming decline as well. In fact, it appeared that all 3 populations were in imminent danger of extinction. However, the 1990 survey revealed that the 3 populations had begun to increase, though the Rancho Grande and El Arpa populations again declined in 1991 while the Rancho El Carrizo population increased to the highest level recorded in almost 30 years (Figure 2). A bird dog survey conducted during the winter of 1991 yielded an estimate of 1000 birds (Carroll et al. 1994). The Rancho El Carrizo population appeared to occupy higher quality habitat than the other 2 populations. Habitat destruction caused by overgrazing and buffelgrass establishment were the norm on Rancho Grande and El Arpa because the owners were not interested in conserving masked bobwhites. Conversely, the owners of Rancho El Carrizo were interested in masked bobwhite recovery and therefore expended efforts to protect important habitat. Nevertheless, the USDI, FWS felt that additional measures were necessary to protect the few masked bobwhites that remained in Sonora.

Therefore, a final effort to avert extirpation of the masked bobwhite in Sonora was initiated in 1991 when The Nature Conservancy, The Center for Ecology of Sonora (CES), the USDI, FWS, and private Sonoran landowners identified and protected approximately 20,000 ha of critical habitat. Management strategies were developed to enhance and expand masked bobwhite habitat, thereby providing additional areas for population expansion (Dobrott 1991). Members of the Camou family, the historical owners of Rancho El Carrizo, became more interested in masked bobwhite conservation and implemented habitat improvement measures on major portions of Rancho El Carrizo. Between 1992 and 1994, the Camous chained and range-disked >20,000 ha of the ranch in an effort to improve masked bobwhite habitat (Kuvlesky 1993, 1994). During the winter of 1993, USDI, FWS biologists initiated line transect surveys and covey-call counts and obtained a population estimate of 1500–2000 birds (Carroll et al. 1994). Also, in 1994 the Camou family agreed to cooperate with the USDI, FWS, Texas A&M University, and CES to initiate a Ph.D. research project that would examine masked bobwhite habitat preferences on the ranch. This study represented the first intensive effort to quantify masked bobwhite habitat needs in Sonora. The cooperating parties also attempted to interest Sonoran cattlemen in masked bobwhite recovery in particular, and wildlife management in general, by cosponsoring an Educational Seminar in Hermosillo during the early fall of 1994.

Despite these efforts, the population declines continued due to habitat deterioration, overgrazing, and a severe drought that began during late spring of 1992. The Rancho Grande and El Arpa populations appeared extinct by summer 1993, while the Rancho El Carrizo population continued to decline (Figure 2). Line transect surveys conducted during the winter of 1994 indicated that the population had decreased by more than 50%. Habitat conditions remained poor and overgrazing continued. Therefore, USDI, FWS biologists were surprised the following summer when they conducted the call-count survey and discovered that the number of calling males had increased (Figure 2). The drought, however, progressed through the breeding season and few chicks were produced. Habitat conditions continued to deteriorate during fall and winter as the drought worsened. It began to appear that the Rancho El Carrizo masked bobwhite population would share the fate of the other 2 Sonoran populations.

Arizona

Unlike Sonora, significantly more effort was directed at masked bobwhite recovery in the U.S. during the mid 1980's. In 1985, after nearly 2 years of controversy and public debate, the Buenos Aires Ranch was acquired by the USDI, FWS in an effort to restore the Sonora savanna grassland and provide suitable habitat for a self-sustaining masked bobwhite population. The new refuge assumed the name of the former ranch and eventually consisted of almost 48,564 ha of grassland, riparian, and desert mountain habitats. Acquisition of the BANWR accomplished a major objective of the 1984 recovery plan. One of the first things accomplished after the BANWR was established was to remove all livestock and construct a perimeter fence around the entire property. The refuge manager also implemented a vegetation monitoring program to document vegetation dynamics in the absence of grazing. He hired a range conservationist in 1986 to install almost 40 permanent transects throughout the Refuge. Data from these transects have been recorded at approximately 3-year intervals. USDI, FWS officials believed that masked bobwhites reestablishment could be accomplished rather easily in the absence of grazing pressure. This assumption later proved naive.

Although reports of masked bobwhites in the Altar Valley persisted at the time of BANWR establishment, none could be verified (Brown 1989). It appeared that the birds introduced during the 1970's had disappeared despite moderate- and above-average summer precipitation between 1981 and 1984. Obviously, captive-reared stock produced by the captive population at the PWRC in Maryland would have to be released on the Refuge in order to restore a free-ranging wild population. Therefore, the techniques developed for the release work conducted during the 1970's were again applied on the BANWR. The standard protocol utilized involved the foster parent-adoption technique developed by Ellis et al. (1978). Between 1985 and 1996 an average of 2,500 2-week-old masked bobwhites were produced by PWRC and flown to the BANWR each summer for release to the wild. Of the almost 25,000 chicks delivered to the BANWR, >20,000 (80%) survived transport and prerelease conditioning and were ultimately released.

Propagation and release protocols utilized and developed between 1985 and 1994 are discussed in detail by Gall et al. (*this volume*). They evaluate the techniques utilized and discuss the presumed fate of chicks released during this period and the high postrelease mortality that seemed to be occurring each year. Though some survival and natural reproduction was documented each year (Dobrott 1990), the overall poor results became apparent to refuge officials by the late 1980's. The USDI, FWS provided financial support to the Arizona Cooperative Fish and Wildlife Research Unit (ACFWRU) to conduct research on the habitat requirements of captive-reared masked bobwhites on the BANWR in hopes of learning what habitats the quail prefer and applying this knowledge to the release program. The results of this research (Simms 1989) yielded previously unknown information regarding masked bobwhite habitat requirements and homerange sizes, and proved useful in selecting future release sites. However, postrelease survival among chicks did not improve. It was obvious that simply removing cattle and maintaining undisturbed grassland did not provide habitat conditions conducive to the postrelease survival rates necessary to establish a self-sustaining masked bobwhite population.

The BANWR manager therefore implemented a prescribed burning program in 1988. Numerous studies in the southeastern U.S. and Texas indicated that prescribed burning produced suitable habitat conditions for bobwhites and that populations performed well on burned areas (Stoddard 1931, Rosene 1969, Wilson and Crawford 1979, Koerth et al. 1986). A fire management officer, along with a fire crew, were subsequently hired and instructed to ignite prescribed burns on a 4-year rotational cycle. By 1992, 11,000 ha had been burned by prescription. Numerous prescribed burns were conducted, and a few wildfires occurred during the late 1980's; dry weather, however, caused a deterioration in habitat conditions. Insufficient brood habitat and a lack of winter food were thought to be critical limiting factors until summer rains in 1990 improved habitat conditions. In 1990, refuge biologists estimated a wild population of 300–500 birds using trained bird dogs. Similarly, winter and spring surveys in 1991 estimated an over wintering population of 31 coveys (333 bobwhites) within a 4,000 ha study area (Dobrott 1991). However, without supplementation from captive-reared chicks, this population began to disperse and decline in 1992 (Dobrott 1992). Winter food limitation was considered responsible for the decline.

Since scarcity of winter food was thought to be a limiting factor, botanists from the University of Arizona were invited to establish two plots of whiteball acacia (*Acacia angustisima*) on the BANWR. Whiteball acacia seeds are an important food item for masked bobwhites in Sonora. The plant is prolific on Rancho El Carrizo, particularly on areas where soil has been disturbed. The Levy brothers were unable to live-trap masked bobwhites on the ranch during the 1960's until they began using whiteball acacia seeds (S. Levy, personal communication.). USDI, FWS biologists suspected that the presence of whiteball acacia played an important role in maintaining masked bobwhite populations on areas where herbaceous food and cover were sparse on Rancho El Carrizo during drought. The BANWR lies within the historic range of whiteball acacia; however, it is presently rare. Refuge management believed that the poor winter food situation could be improved if whiteball acacia abundance could be improved on the BANWR. Generally, the plantings were successful and a seed source was established. However, seeds were not planted on any additional areas frequented by masked bobwhites so the presence of whiteball acacia on the BANWR did not really benefit masked bobwhites in any measurable way. Permanent vegetation transect monitoring conducted during 1993, however, indicated that the species appeared to be reestablishing itself on selected sites. Consequently, masked bobwhites may potentially benefit as whiteball acacia abundance increases on the BANWR.

There was little doubt that the elimination of grazing and the prescribed burning program were improving BANWR grasslands. Still, it was believed that additional measures could be utilized to create better habitat conditions for masked bobwhites. Consequently, in 1992, arrangements were made for the refuge biologist, the manager, a CES biologist, and member of the Camou family to tour several south Texas ranches that were being actively managed for bobwhite production. During the tour they observed a number of management techniques employed to improve quail habitat, and discussed habitat management with numerous quail managers. Refuge officials returned from their visit determined to establish food plots and implement a range-disking program to improve masked bobwhite habitat on the BANWR. A limited amount of disking was accomplished during the summer of 1992 on selected areas of the refuge. Mechanical habitat improvements, along with the prescribed burning program, were temporarily terminated due to the presence of an endangered plant, the Pima pineapple cactus (*Coryphantha scheeri* var. *robustispina*), which was discovered by the refuge biologist in 1991. Field personnel were required to search an entire potential habitat management site for cacti and protect individual cacti before habitat management could proceed. As a result of these limitations, only 800 ha were burned between 1992 and 1994, and no mechanical habitat management was performed. It was clear that a compromise was necessary to maximize protection of the cacti yet still apply habitat management on a scale that would benefit masked bobwhites. A biologist from the USDI, FWS Ecological Services Phoenix Field Office (PFO) visited the BANWR during late spring of 1994 and concluded a temporary agreement with the refuge manager that would permit prescribed burning until a formal agreement could be achieved. Formal intra-service consultation under Section 7 of The Endangered Species Act was scheduled with the PFO for winter of 1995.

Along with efforts to improve habitat conditions on the BANWR, refuge biologists attempted to improve postrelease survival of chicks by strengthening adoptive behavior of foster parents. In 1991, they participated in a study designed to determine if supplemental injections of testosterone and antiandrogens enhanced alloparental behavior of Texas males (Vleck and Dobrott 1993). Athough initial results appeared promising, postrelease survival among chicks did not seem to improve. Another method attempted to increase the density of masked bobwhites on the BANWR involved releasing older captive-reared chicks during winter. Biologists thought that older chicks released during the covey season would perform better than younger chicks released during summer. The results of these releases were, however, inconclusive. A line-transect survey was initiated during late winter 1993 to determine how many masked bobwhites inhabited the BANWR. Surveys were conducted on most areas judged to be good habitat for masked bobwhites. Less than 10 observations were obtained, precluding precise estimation of population density.

In 1993 refuge biologists started using the flight-pens constructed in 1992, to better prepare chicks for the environmental conditions they would be confronted with upon release to the wild (Gall et al. *this volume*). Native grass seed was planted in each pen and watered daily to promote vigorous growth and encourage insect utilization. Biologists also began utilizing radio telemetry to monitor the fate of released chicks. The telemetry results indicated that, despite the use of flight pen conditioning, postrelease survival remained poor. Biologists could generally locate a radio-marked foster parent and brood a day or 2 after a release. However, within 5–7 days very few chicks were observed with foster parents, and often foster parents were found alone. Biologists suspected that postrelease survival was >2%. Nonetheless, the 1993–1994 winter line transect survey yielded a total population estimate of 1000 individuals. Refuge biologists believed that the abundant winter and fair summer rainfall of 1993 improved habitat conditions and resulted in a population increase. An increase in natural productivity seemed the most likely explanation, although some chicks released during the summer likely survived over winter. Live-trapping was conducted during the winter of 1993–1994, and though only 25 masked bobwhites were captured, 88% of the individuals captured were chicks released the previous summer, indicating that over winter survival did occur. Additionally, 2 adults released during 1992 and a chick produced in the wild were captured. Evidently, the long-term survival and natural reproduction that were documented several years earlier were still occurring in 1994.

In addition to the habitat research that was initiated on Rancho El Carrizo in 1994, refuge biologists succeeded in securing funding from the AGFD to conduct similar research on the BANWR. This project was administered by the ACFWRU at the University of Arizona, and involved hiring a Master of Science (M.S.) candidate to complete the research. The principal investigators involved in these 2 projects decided that data would be collected in an identical manner on both sites to compare habitat preferences between masked bobwhites on the BANWR and those on Rancho El Carrizo. The USDI, FWS had always assumed that habitat deficiencies existed on the BANWR because of its location at the extreme northern limit of the masked bobwhite's historic range. In contrast, the Rancho El Carrizo population exists near what is thought to be the core of the historic range, with therefore fewer potential habitat deficiencies. Biologists hoped that the 2 projects would illuminate habitat deficiencies on the BANWR if deficiencies exist.

1995 to 1997

Sonora

The status of the masked bobwhite population on Rancho El Carrizo remained perilous through the late winter, spring, and early summer of 1995. During a late winter bird dog survey, only 7 coveys were located on the ranch, and masked bobwhite observations were becoming more difficult to obtain as the Ph.D. research project progressed. The presence of masked bobwhites was, however, verified on a small pasture on Rancho Grande during a call-count survey in August when 9 males were recorded (Figure 2). This population was believed to be much smaller than the 1 inhabiting Rancho El Carrizo, although the population had not been extirpated as USDI, FWS officials had feared. Another positive result of the rediscovery of the Rancho Grande population was that the ranch owner displayed remarkable enthusiasm relative to masked recovery when he was informed that 1 of the 2 last truly wild populations of this endangered species relied on his property for its continued survival. He expressed interest in managing important habitat if the USDI, FWS would contribute financial assistance.

The discovery that masked bobwhites continued to persist on Rancho Grande, together with improved summer rainfall on Rancho El Carrizo, resulted in increased optimism among recovery collaborators. Optimism increased further during July 1995 when the Turner Foundation, Inc. informed the Camou family and USDI, FWS biologists that they would fund a proposal to install short-duration grazing systems (SDG) on 4000 ha of critical habitat on Rancho El Carrizo. Mr. Beau Turner, a Foundation Trustee, toured the ranch in August and was impressed with what had been accomplished on behalf of masked bobwhites. As a result he pledged to support future recovery efforts. Biologists also discovered that the masked bobwhite population did not suffer the severe over-winter decline that they feared would occur. The August call-count survey revealed a slight decrease. The number of calling males was slightly lower (13) than the number recorded during the 1994 survey (19) (Figure 2).

Dry weather continued during the fall and winter on both Rancho El Carrizo and Rancho Grande. Habitat conditions over the winter of 1995–1996 deteriorated somewhat on Rancho El Carrizo while conditions on Rancho Grande deteriorated substantially. USDI, FWS biologists encountered difficulty in locating birds with dogs during a January visit to both ranches. One covey of 12 birds was found on Rancho El Carrizo while only a single hen was sighted on Rancho Grande. Despite the low numbers of birds observed, ranch vaqueros insisted that more birds remained on both ranches. The assurances of ranch personnel slightly assuaged the worries of biologists. Nevertheless, recovery collaborators remained concerned that installation of the SDGs had not yet begun by early spring 1996. Habitat conditions continued to deteriorate due to the combined effects of livestock grazing and drought. It was feared that all that had been accomplished during past years would be for naught.

Installation of one 1600 ha SDG was completed by the end of August 1996. The 5-year drought ended when the Rancho El Carrizo received over 50 cm of rainfall between July and September. Additionally, the 1996 call-count survey indicated that the number of males (10) remained similar to that of 1995 (13) (Figure 2). By fall, habitat conditions over much of the ranch were the best observed in almost 6 years. Moreover, the installation of at least 1 SDG would ensure that a sizable amount of critical habitat would be managed properly for masked bobwhites in the future and improved livestock management would begin under high quality herbaceous vegetation conditions. Recovery collaborators received additional good news during the summer of 1996 when the National Fish and Wildlife Foundation awarded the Camous supplementary funding toward installation of a second grazing system. Alejandro Camou, the owner of the portion of Rancho El Carrizo where the second grazing system was to be located, indicated that instead of using the funds to install the grazing system, he would remove cattle from 2000 ha of critical habitat designated by BANWR officials. Completely resting critical habitat from grazing was deemed a better alternative than implementing a different grazing system. Therefore, the BANWR accepted Mr. Camou's offer and for perhaps the first time in a century, critical masked bobwhite habitat would not be disturbed by cattle.

Habitat conditions remained excellent on the functioning SDG through fall and winter 1996. Ranch personnel reported observing masked bobwhites on almost a daily basis, and documented several broods during summer 1997. The 1997 call-count survey results, however, initially alarmed BANWR biologists because only 2 males were recorded (Figure 2). Ranch vaqueros assured biologists that masked bobwhites were abundant despite the call-count results; surveys were simply being conducted too early. Camou et al. (1998) analyzed 30 years of call-count data, as well as 40 years of Rancho El Carrizo rainfall data, and found that peak breeding activity occurs during mid August.

By the late winter of 1997 it was estimated that at least 5 masked bobwhite coveys used the SDG. This is significant because few masked bobwhites, if any, were thought to occur on this area in 1995. SDG habitats had been recolonized and additional birds were thought to have moved into the grazing system from surrounding areas with poorer habitat conditions during the spring and summer. During the summer of 1997 BANWR biologists and scientists from Oklahoma State University secured funding to begin a research project aimed at evaluating the effects of the SDG on masked bobwhite habitat. The primary objective of this study was to determine grazing management strategies that best met masked bobwhite habitat needs. Data collection began in 1997 and screening cover was measured in each pasture of the grazing system. The study will terminate during winter 1999.

Unlike Rancho El Carrizo, the masked bobwhite situation on Rancho Grande remains tenuous at best. A low density population may still exist on the ranch. Mr. Fimbres remains interested in masked bobwhites and it is obvious that he enjoys the fact that they inhabit his property. He initiated a native shrub restoration program on his property during the summer of 1996 which may benefit the masked bobwhite population as the shrubs mature. The USDI, FWS pursued habitat improvement funding for the past 2 years but has been unsuccessful in obtaining the finances necessary for Mr. Fimbres to implement habitat improvement on his property.

Arizona

Like Sonora, the prospects for masked bobwhite recovery in Arizona also improved between 1995 and 1997. Formal intra-Service Section 7 consultation between BANWR staff and biologists representing PFO were convened on the Refuge in April 1995 to discuss the prescribed burning program and Pima pineapple cactus welfare. After lengthy discussions, an agreement was reached that permitted normal prescribed burning operations to resume. One aspect of the agreement was to expand the permanent vegetation monitoring program that has been ongoing since BANWR establishment in 1985. It was agreed that expansion of the current project and continued long-term monitoring of the BANWR grassland would provide insight about how prescribed burning influences the dynamics of grasslands not exposed to livestock disturbance. This information will undoubtedly benefit not only masked bobwhite recovery efforts, but Pima pineapple cactus recovery efforts as well. During the spring of 1996, refuge biologists and a fire ecologist at the University of Arizona received funding for a 4-year GIS-based study that should quantify the effects of recurring fires on BANWR grasslands, and by association, masked bobwhites and Pima pineapple cactus.

An event that threatened to impede masked bobwhite recovery on the BANWR occurred during the fall of 1995. The Southern Arizona Cattlemen's Protection Association (SACPA) mounted an assault on the "no grazing" policy of BANWR Management. The refuge manager hosted a meeting for members of the SACPA in October to explain and clarify refuge policy, and to answer any questions. Refuge biologists also explained that masked bobwhite recovery and traditional cattle grazing were not compatible because the quail require dense herbaceous cover to survive. Little was resolved during the meeting, and SACPA representatives soon launched a relentless public relations and political campaign to force the USDI, FWS to permit ranchers to graze cattle on the BANWR. Masked bobwhite recovery was attacked in the news media and in January 1996 the SACPA succeeded in convincing ABC News to air a segment about masked bobwhite recovery as part of its weekly "Fleecing of America" broadcast. The segment prompted outrage among citizens throughout the U.S. who support the National Wildlife Refuge System and conservation in general. Though the national publicity seemed to increase public awareness and galvanized support for recovery efforts, the SACPA continued a campaign to open the BANWR to livestock grazing. Nevertheless, they have not yet succeeded in opening the BANWR to livestock grazing.

During the spring of 1995, the BANWR hosted a Population-Habitat Viability Analysis Workshop along with a Recovery Committee Meeting to evaluate the recovery process. Participants included most of the Federal and State Agencies in the U.S. and Mexico that had been active participants during the past several years (U.S. Fish and Wildlife Service 1996). A Conservation Biologist from the Conservation Breeding Specialists Group (CBSG), Species Survival Commission of International Union for the Conservation of Nature (ICUN) conducted the workshop. Participants developed goals to be achieved during the course of the workshop, fulfilled these goals at workshops end, and made several recommendations relative to enhancing recovery efforts (U.S. Fish and Wildlife Service 1996).

One important recommendation from this workshop was that habitat improvement continue in both Sonora and Arizona, with special emphasis on improving grazing management in Mexico. Translocation of wild masked bobwhites from Rancho El Carrizo to the BANWR as soon as sufficient numbers are present on the ranch was also endorsed. Additionally, workshop participants recommended that traditional captive propagation and release protocols be altered on the BANWR in an effort to improve postrelease survival of chicks. In this regard, termination of the use of the Texas bobwhites as foster parents was a major recommendation. Refuge biologists have known for years that sterilized Texas males pair with masked bobwhite hens during the breeding season. Hens that pair with Texas males cannot be fertilized and they are essentially lost from the masked bobwhite breeding population for that breeding season. Demographic modeling scenarios produced during the workshop demonstrated very clearly that the loss of as few as 25 hens from the breeding population could have serious negative impacts on masked bobwhite population dynamics. Therefore, for this and other reasons discussed in more detail in the workshop proceedings (U.S. Fish and Wildlife Service 1996), refuge officials terminated the Texas male foster parent program during summer 1995.

Refuge biologists immediately implemented protocol alterations discussed in detail by Gall et al. (*this volume*) during the 1995 release season. Follow-up monitoring via radio telemetry conducted after each release, as well as the field observations obtained by the M.S. candidate conducting habitat research, indicated that the protocol changes appeared to have improved postrelease survival rates (Gall et al. *this volume*). Survival among radio-marked birds averaged about 2.5 days in 1994 whereas survival increased to 12 days in 1995 (Gall et al. *this volume*). Moreover, in 1995 larger groups of masked bobwhites were observed for longer periods of time than in years past. Improved postrelease survival also occurred during a very dry winter (1995–1996), so habitat and environmental conditions were not conducive to good quail survival. BANWR biologists did not receive the funding necessary to purchase new radios in 1996. Nevertheless, though only 4 radios were available, postrelease survival of these radioed birds averaged 28 days (Gall et al. *this volume*). Recovery committee members were optimistic that the new propagation and release protocols would contribute significantly to achieving recovery goals on the BANWR.

Meanwhile, during the fall of 1995, U.S. Department of the Interior's policy makers decided that the PERC would no longer house and maintain the captive masked bobwhite population. USDI, FWS, Region 2 officials subsequently initiated the process of assuming responsibility of caring for the captive population and housing it on the BANWR. With the assistance of PERC Scientists a "state of the art" captive propagation facility was designed and construction commenced on the BANWR during December 1995. The facility was completed by the end of March 1996 and the captive population was moved to the BANWR in April. Refuge officials believed that housing the captive population in Arizona would improve propagation and release efforts because BANWR biologists could now immediately implement alterations to chick production protocols to improve the release program.

Moving the captive population, however, did create some difficulties relative to the 1996 release season. Since the captive birds did not arrive until April, and needed at least a month to acclimate to their new surroundings, the captive breeding season was delayed for almost 6 weeks. Breeding behavior was not stimulated until the third week of May, and although egg production was similar to what the PERC achieved each year, young chicks were released later than they had been in the past. Chicks were thus exposed to cooler temperatures and prerelease survival rates suffered significantly as a result. Consequently, substantially fewer chicks were released during the late summer and fall of 1996. Nevertheless, refuge biologists continued following the new protocols developed in 1995 and again, postrelease over-winter survival among chicks released appeared to be at least as good as what was achieved in 1995 (Gall et al. *this volume*).

Though results of the improved propagation and release protocols are preliminary, refuge biologists are now confident that these protocols improve postrelease survival. The focus of 1997, and the future, was to begin captive breeding earlier, by April 1, and to maximize chick production each year. Biologists will also consider initiating breeding activity in January during wet winters in order to release a group of chicks in late March. Wild masked bobwhites probably produce a limited number of chicks in late March or early April following a wet winter. If this does occur, supplementing natural chick production with captive-reared chicks may bolster the wild population on the BANWR. The new captive propagation and release protocols also might improve post-release survival among wild birds translocated from Rancho El Carrizo.

1998 to 1999

Sonora

Herbaceous habitat conditions continued to improve throughout Rancho El Carrizo due to a reduced grazing pressure and above average precipitation. During the summer of 1998, ranch vaqueros told BANWR biologists that many masked bobwhite breeding whistles could be heard every morning on a 800 ha pasture that was designated as critical habitat by Alejandro Camou in 1996. Call-counts were conducted during the third week of August in 1998 (Camou et al. 1998), and a record number of males were recorded (72) (Figure 2). In fact, an additional 60 males were recorded on new survey routes installed that summer. The ranch vaqueros also said that they had observed more broods during the late summer and early fall of 1998 than the previous 5 years. It was clear that the Rancho El Carrizo masked bobwhite population had recovered from the drought of the mid 1990's.

Like Rancho El Carrizo, masked bobwhite habitat conditions improved on Rancho Grande during 1998. Mr. Fimbres constructed 4 SDGs on approximately 3500 ha of the ranch. He also asked BANWR biologists for guidance in managing grazing on each of the SDGs, and indicated that he wants to manage these grazing systems in a manner that benefits masked bobwhites. Mr. Fimbres also emerged as a strong proponent of wildlife conservation in general, and masked bobwhite recovery in particular, in Sonora. He is a prominent rancher in the state, and is considered a leader by his Sonoran cattlemen peers. During fall 1998, he and Gustavo Camou, convinced 2 fellow ranchers, who control thousands of acres of masked bobwhite habitat, to consider joining the masked bobwhite recovery effort. Mr. Fimbres arranged for BANWR officials to meet the prospective cooperators at a meeting on his ranch. BANWR biologists were invited to tour the 2 new ranches (during summer 1999) and conduct a masked bobwhite survey as a result of this meeting.

Since masked bobwhite recovery in Sonora was proceeding in such a positive direction in 1998, and record numbers of birds were recorded during the summer survey, recovery cooperators in the U.S. and Mexico decided it was appropriate to attempt a major recovery goal. During the fall of 1998 they began the permitting process necessary to translocate 40 masked bobwhites to Rancho Grande and 100 masked bobwhites to the BANWR. Permits were issued in March 1999. During the first week of April, 37 wild masked bobwhites were live trapped and transported to the BANWR. Some of these birds will be used to improve the genetic quality of the captive population. However, over half of the wild masked bobwhites from Sonora will be released on the refuge. This release will represent the first time wild masked bobwhites have inhabited the U.S. since they were extirpated in the late 1890's. Biologists will attempt to capture the additional 103 wild masked bobwhites during the summer and fall of 1999. However, habitat conditions have deteriorated due to a drought that began during the fall of 1998, and the Rancho El Carrizo masked bobwhite population is currently declining. If the drought persists through the summer of 1999, chick recruitment will likely be poor and the population will continue to decline. Removal of additional individuals from the masked bobwhite population will therefore have to be postponed until the population increases again.

Despite present concerns about the drought in Sonora, the prospect of masked bobwhite recovery has improved since 1995. Better grazing management, and increased interest in recovery among U.S. conservation foundations and prominent ranchers, should improve the probability of achieving additional recovery goals on both Rancho El Carrizo and Rancho El Grande in coming years.

Arizona

Masked bobwhite abundance on the BANWR continued to improve through 1998. Summer call-counts documented an increase in calling males as 32 birds were recorded whereas 19 males were recorded on the same routes during summer 1997. Precipitation between the summers of 1997 and 1998 was average-to-above average. Habitat conditions were therefore good, and it is likely that increased survival and chick recruitment contributed to the population increase observed. Additionally, biologists are confident that the modified propagation and release protocols adopted in 1995 also contributed to increased abundance. Nevertheless, prerelease chick survival remains a problem because only 15 % of the chicks that are produced by the captive population survive and are released (Gall et al. *this volume*). At least 80% of the mortality occurs among week old chicks. Refuge biologists have yet to resolve the problem(s) responsible for the high mortality rate, but continue to work on isolating the cause(s). They are confident, however, that the chicks that survive the rearing process are strong, healthy and well suited for life in the wild. When survival among very young chicks improves, hardier juvenile masked bobwhites will be released each fall, and the refuge population should increase as a result.

In 1998, the two graduate students working on masked bobwhite habitat ecology finished their respective projects. Analyses of their data revealed aspects of masked bobwhite habitat ecology that were previously unknown. For example, earlier observations from biologists working on masked bobwhites indicated that masked bobwhites required relatively open grasslands (5–10% woody cover) consisting of predominantly native herbaceous species to survive and persist in a self-sustainable manner (Tomlinson 1972a, Goodwin 1982, Brown 1989, Simms 1989). In contrast, Guthery et al. (2000) found that woody cover was a much more important habitat variable than previously thought. Masked bobwhites on both Rancho El Carrizo and the BANWR, selected habitats with more woody cover than was randomly available because operative temperatures and exposure to aerial predators were lower in these habitats (Guthery *this volume*). Masked bobwhite habitat should consist of at least 20–25% woody cover, and ideal shrub height is about 1-m. Moreover, masked bobwhites on the BANWR did not display a preference for either native grass cover or exotic grass cover (King 1998). Both herbaceous habitat types were used indiscriminately. The results of these studies have already impacted BANWR management. The prescribed burning program had to modified in deference to the importance of woody cover to masked bobwhites. The previous burning cycle of 4 years had to be modified on portions of the BANWR important to masked bobwhites, to 6 years to ensure that sufficient woody cover is available to the birds.

During the summer of 1999, about 2 dozen of the wild masked bobwhites translocated to the BANWR in March, will be released on the refuge. Two groups, representing the original coveys trapped in Sonora, will be released during the summer shortly before the masked bobwhite breeding season begins in late July. USDI, FWS officials hope that these wild birds will survive to produce and raise chicks during the 1999 breeding season.

Like masked bobwhite recovery in Sonora, recovery in Arizona continued to progress during 1998 and 1999. Additional time will be needed to achieve all of the masked bobwhite recovery goals on the BANWR; however, recovery appears to be proceeding in a positive direction.

SUMMARY

Masked bobwhite recovery has a long history and it has been a dynamic process. Early efforts focused on identifying remnant populations in Sonora, live-trapping individuals from these populations, and releasing them in the U.S. Despite the failure of these attempts, sufficient interest remained among ornithologists to conduct periodic surveys for masked bobwhites in Sonora. These efforts yielded dividends when a small population was rediscovered in north-central Sonora in 1964. Interest in preventing extinction increased as a result of the rediscovery. Conservation prospects further improved when masked bobwhites were listed as endangered in 1968. Essential financial support was made available to pursue recovery and as a result, a captive population was established and aggressive reintroduction research was implemented during the 1970's and into the 1980's. Establishment of the BANWR in 1985 was viewed as the most important accomplishment of recovery efforts at the time. However, increased interest and cooperation among Sonoran ranchers and conservation officials, as well as innovative habitat and propagation and release research that occurred over the next decade, proved to be as important as refuge establishment to the eventual recovery of masked bobwhites. The recent interest and financial support of conservation funding organizations, and a general increase in public support for masked bobwhite recovery, have also furthered recovery efforts in both Arizona and Sonora.

The masked bobwhite recovery program has weathered numerous set-backs. The recovery objective and associated criteria have not yet been fulfilled. However, aspects of the program improved dramatically over the past 3 decades. The deep sense of commitment and cooperation that existed, and still exists, among the various Federal and State Agencies in the U.S. and Mexico, as well as among private citizens in both countries, has prevented the extinction of masked bobwhites. Maintaining this sense of commitment and spirit of cooperation is essential to the future of recovery. These qualities are particularly important in

Sonora where the continued welfare of the masked bobwhite depends largely on cooperation of the people who manage the land. Great progress has been made in developing positive management attitudes among Sonoran ranchers whose activities directly influence masked bobwhite survival. It remains important that these individuals feel they continue to be an important part of the decision-making process. Those interested in masked bobwhite recovery must also do a better job of educating the public about not only the plight of the masked bobwhite and quail in general, but about the threats special interest groups pose to ecosystem protection. Masked bobwhite recovery remains an attainable goal, and those involved in current recovery efforts are optimistic it can eventually be achieved. Nevertheless, continued commitment to innovative research and public education are essential to achieving masked bobwhite recovery in the U.S. and Mexico.

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VEGETATION AND THERMAL CHARACTERISTICS OF BOBWHITE NOCTURNAL ROOST SITES IN NATIVE WARM-SEASON GRASS

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ABSTRACT

Native warm-season grass (NWSG) has been widely promoted as wildlife habitat, but little empirical evidence is available to support its value for most wildlife species. One justification for a conversion to NWSG is the high thermal quality of cover resulting from the height and structure of the vegetation. Because vegetation cover is an important factor contributing to bobwhite winter survival, we predicted that they should select roost sites with superior thermal characteristics during winter when energy requirements for thermoregulation are greatest. In this 3-year study we used data derived from roost sites ($n = 166$) obtained from radio-marked quail to compare the relative use of NWSG and 5 other habitat types, and the micro-habitat characteristics of winter roost and random sites on an area intensively managed for quail in Missouri. Of the 6 habitats used for roosting, most locations (51.2%) were in old-field habitats. NWSG ranked third with 17% of the locations. Our findings indicated that roost site selection may be influenced to a greater extent by the micro-habitat characteristics of a site rather than by habitat type. Two micro-habitat features that were of particular importance in habitats used most by quail were litter cover and canopy cover. These habitat features are valuable in reducing conductive and convective heat loss.

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EFFECTS OF DISKING VERSUS FEED PATCH MANAGEMENT ON NORTHERN BOBWHITE BROOD HABITAT AND HUNTING SUCCESS

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ABSTRACT

More than 60 years ago, Herbert Stoddard (1931:376) wrote *"there is little doubt that such methods* [i.e., disking and harrowing] *are more practical for Southeastern quail preserves than artificial plantings, which are costly on a large scale and not always effective."* Incredibly, this statement, and testing it as an hypothesis, has been ignored by the bobwhite research community until the past 10 years. Therefore, we designed a pilot study to compare measures of northern bobwhite (*Colinus virginianus*) brood habitat (vegetation composition and arthropod biomass) and direct measures of hunting success (covey finds per half-day hunt) to test whether feed patches were really necessary for bobwhite habitat management in southern Georgia and northern Florida. We applied experimental treatments (disk only versus feed patch planting) by using shooting courses (150–250 ha each) on 2 southeastern shooting plantations during 1994, 1995 and 1996. Overall, results were equivocal between the feed patch and disking treatments; no consistent pattern or difference in brood habitat composition or hunting success was observed. One factor responsible for this pattern may be the relatively fine-grained scale (only 1–3% of the shooting courses were planted or disked) at which treatments were applied were insufficient to significantly influence bobwhite abundance. Further research using increased amounts of ground disturbance and planting (5%, 10%, 20%, etc.) will be required before the actual need for agricultural plantings can be determined in the context of their efficacy for bobwhite management. One potential result of these findings is that significant cost savings can be realized by disking rather than planting agricultural crop plants because at least 70% of the costs of planting are a function of seed, fertilizer and cultivation, whereas only about 30% are attributed to disking.

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INTRODUCTION

Stoddard (1931:376) wrote *"there is little doubt that such methods* [i.e., disking and harrowing] *are more practical for Southeastern quail preserves than artificial plantings, which are costly on a large scale and not always effective."*

Despite this admonition, widespread use of artificial plantings (i.e., "feed patches") for northern bobwhite habitat management persists throughout the southeastern and midwestern United States. In the midwestern U.S. feed patches may provide winter food for bobwhites, and thus enhance their physiological condition and reduce their need to wander over large areas to find food (Robel et al. 1974). However, in the southeastern U.S. there seems to be a blind acceptance that feed patches are an essential component of successful bobwhite management, despite the widespread lack of data to support this belief (Guthery 1997).

Because of the widespread declines in northern bobwhite populations during the past 3–4 decades (Brennan 1999), economical management techniques are now more important than ever. If researchers can

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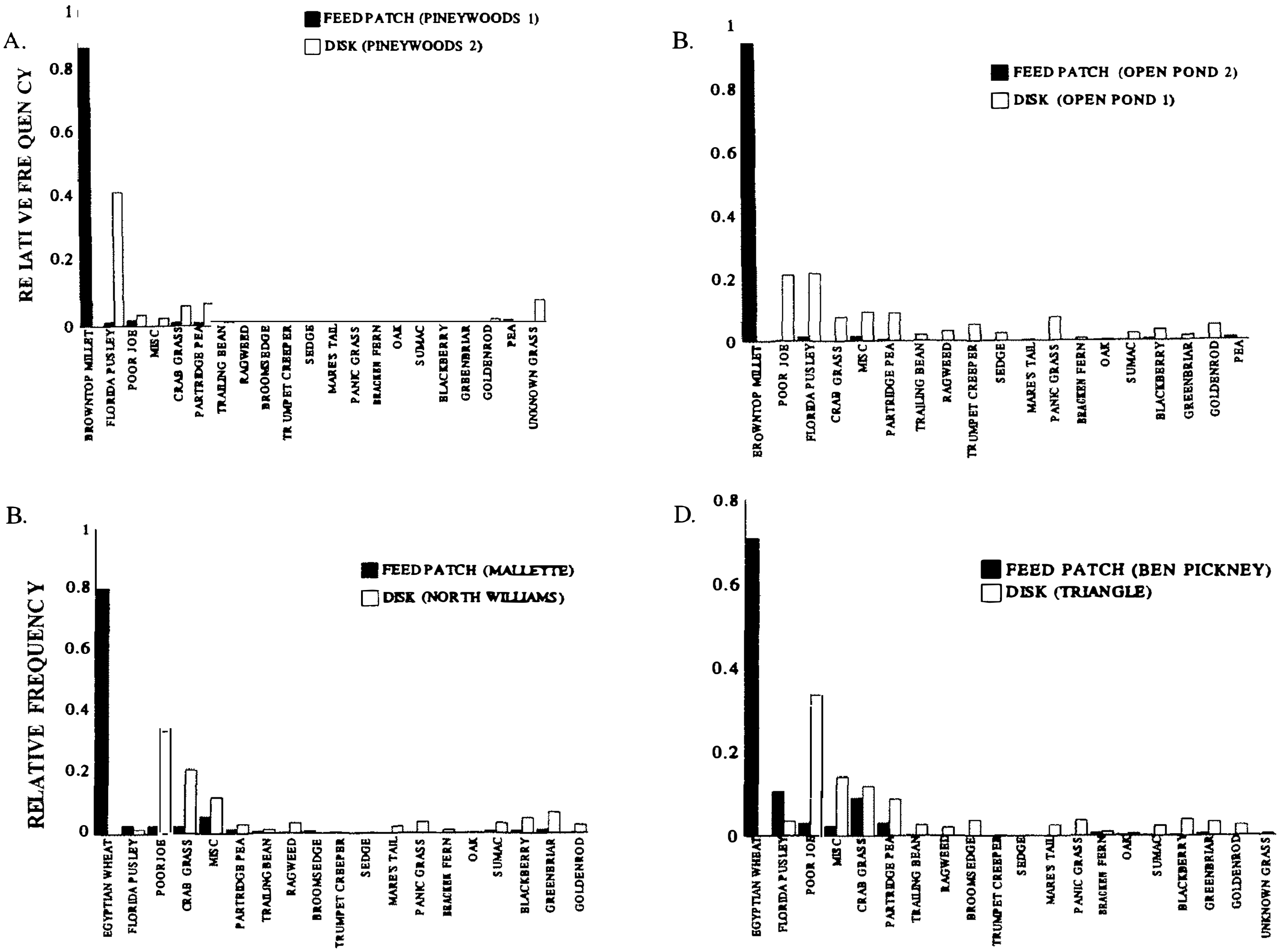

Fig. 1. Frequency of occurrence of plants on feed patch and disked only habitat plots at two plantations in the Tallahassee, FL–Thomasville, GA region. A and B represent one plantation, C and D represent the second property. Data were collected during June, July and August 1995.

demonstrate to managers that there is no net difference between use of disking versus use of feed patch management, then significant cost savings can be realized.

Our objective in this study was to design a preliminary examination to evaluate the short-term effects of disking versus feed patch management on: (1) elements of brood habitat (i.e., vegetation composition and arthropod biomass); and (2) hunting success during the subsequent fall and winter seasons after the management treatments were applied.

METHODS

Sampling Unit

We used 8 shooting courses (4 sets of paired plots with 2 pairs on each of 2 plantations). Shooting courses averaged 150–300 ha each, and were treated as management and hunting units on these properties where each plantation averaged about 1,500 ha. Major activities in the annual cycle of management events on these properties are described in Brennan (1994). Each shooting course had a previously established array of feed patches that ranged in size from 0.5 to approximately 2 acres. Management treatments (disk only versus planting) were assigned at random. Areas assigned to receive the feed patch treatment were planted with Egyptian wheat (at one property) and browntop millet (at the other property). Areas assigned to receive the disk only treatment were disked during April and May, at the same time that the feed patch areas were prepared for planting.

Vegetation and Arthropod Sampling

We estimated the relative frequency of occurrence of plant species present on disked and feed patch areas using a meter square grid placed at 5 meter intervals along 25 meter transects. Thirty 25 meter transects were sampled in feed patch or disked only areas in each shooting course during June, July, and August of 1994 and 1995. Arthropods were sampled using a D-vac suction device along 30 25-meter transects in feed patch and disked only areas in each shooting course, also during June, July, and August of 1994 and 1995. During each sampling period, arthropods were sam-

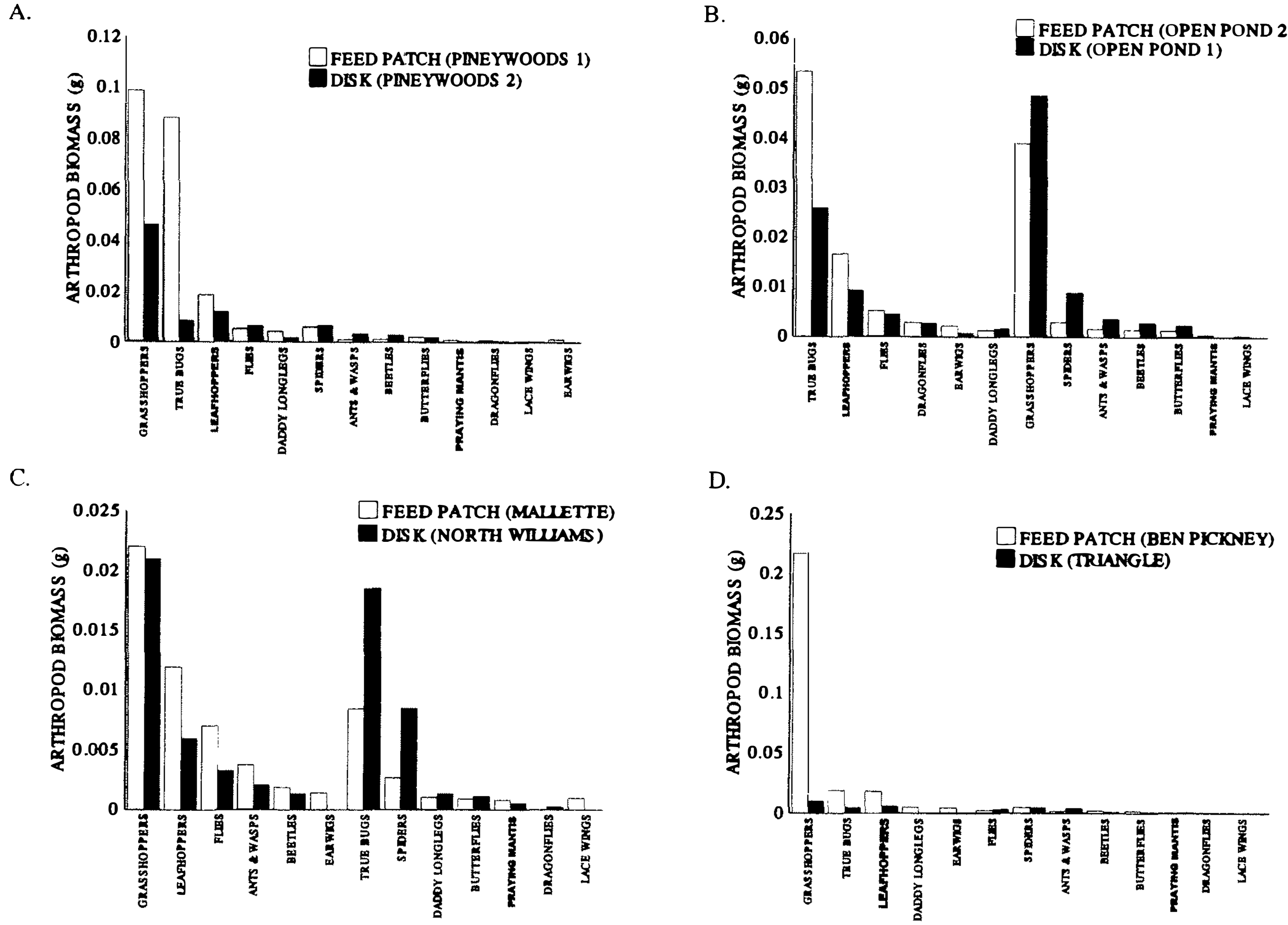

Fig. 2. Arthropod biomass on feed patch and disked only habitat plots at at two plantations in the Tallahassee, FL–Thomasville, GA region. A and B represent one plantation, C and D represent the second property. Data were collected during June, July and August 1995.

pled first. Vegetation data were subsequently collected within 1–24 hours after collecting arthropods.

In the laboratory, arthropods were sorted to Order, dried for >12 hours at 70 degrees Celsius, and weighed to 0.001 grams.

Hunting Success

Bobwhites were hunted with pointing dogs on 2–3 week intervals during the hunting season (December–February). Tallies on number of bobwhite coveys flushed per half-day (4 hours) of hunting were recorded by the plantation owners, managers, or dog handlers. Hunting success data were collected during the 1994, 1995, and 1996 hunting seasons.

RESULTS

Vegetation

Overall, plant species richness was greater on the disked plots than on the feed patch plots at both properties (Figs. 1 and 2). As expected, feed patch plots were dominated by the planted crop plants (i.e., browntop millet at one site, and Egyptian wheat at the other; Fig. 1).

Otherwise, there were only minor differences in the relative abundance of native vegetation between the feed patch plots and the disked plots.

Arthropods

At one plantation, arthropod biomass tended to be greater in the feed patches (Figs. 2a and 2b), except for grasshoppers (Orthoptera). This general pattern was also observed at the second property except that spiders and true bugs (Hemiptera) were more abundant on the disked plots than on the feed patch plots (Figs. 2b and 2c).

In general, the feed patch plots provided relatively rich patches of arthropod foods, compared to the disked only areas.

Hunting

Overall, there was no clear difference in hunting success between either the feed patch or the disked only hunting courses at either property (Fig. 3). When data were averaged across 3 years of the study, the

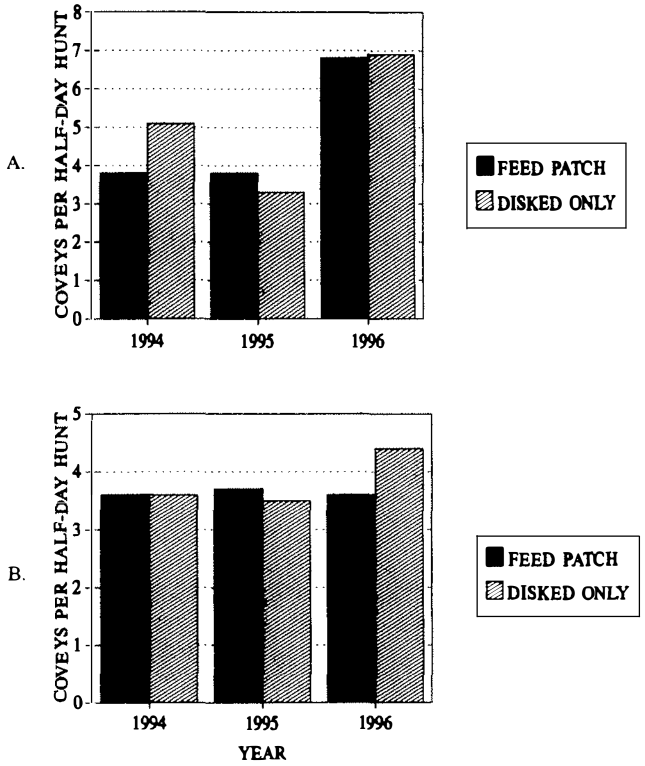

Fig. 3. Northern bobwhite hunting success on the shooting courses used for this study during the 1994, 1995, and 1996 hunting seasons (December through February). One half-day hunt equals approximately 4 hours of hunting effort.

feed patch courses averaged 3.6 coveys per half-day hunt and disked only courses averaged 3.8 coveys per half-day hunt (Fig. 3a). At the second property, feed patch courses averaged 4.8 coveys per half-day hunt and disked only courses averaged 3.8 (Fig. 3b).

DISCUSSION

Stoddard's (1931) assertion that simple disking and harrowing would be more appropriate and economical for northern bobwhite management seems to be supported by the data collected for this study, at least over a short-term (1 to 3 year) period. The increased availability of arthropod biomass on the feed patch plots apparently did not translate into increased northern bobwhite abundance and hence an increase in hunting success.

Evidently, the scale at which the feed patch and disked plots were applied (about 1–3% of the total area of usable habitat on each shooting course) was insufficient with respect to making an overall difference in bobwhite abundance, at least as indicated by hunting success.

Costs of the disked treatments averaged about \$60.00 per ha per year, whereas planting feed patches (either millet or Egyptian wheat) cost about \$180.00 per ha per year. Thus, >66% management cost savings can be realized by utilizing mechanical soil disturbance without planting seed and using fertilizer. However, further work will be required to determine the long-term effects of substituting disk only management treatments for feed patch planting. Additionally, companion experiments to assess impacts of varying the overall extent of soil disturbance (i.e., 5%, 10%, 20%, etc.) would be useful for examining the impacts of disking versus planting feed patches for northern bobwhite management. Our data also point to the need to consider northern bobwhite management and manipulative field experiments within the context of overall useable habitat space (Guthery 1997) as opposed to the minutiae of small-scale, but relatively costly, management actions.

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BIRD USE OF BOBWHITE BRUSH SHELTERS ON A CONSERVATION RESERVE PROGRAM FIELD

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ABSTRACT

Northern bobwhite (*Colinus virginianus*) are known to use constructed brush shelters. The establishment of artificial shelters is a common practice in grasslands where woody cover is lacking. We evaluated the use of brush shelters by bobwhite and other bird species in a Conservation Reserve Program (CRP) field. Twenty-seven species of birds were observed at brush shelters versus 10 species at control sites. No species occurred exclusively at control sites. Brush shelters in CRP had positive effects on avian communities by providing sites for vocalizing, prey search, loafing, and nesting.

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INTRODUCTION

Northern bobwhite are known to use constructed shelters (Guthery 1980, 1986:77; Webb and Guthery 1983; Lehmann 1984:187; Boyer et al. 1989). Establishment of artificial shelters is a common management practice in grasslands where woody cover is lacking (Lehmann 1984:281, Guthery 1986:77, Boyer 1989:3). In 1985, the Food Security Act created the Conservation Reserve Program (CRP), which allowed landowners to establish native or introduced grasses on agricultural lands to reduce soil erosion and provide wildlife habitat. Depending upon the conservation practice implemented and the amount of land enrolled, woody cover could be a limiting factor for some wildlife species in CRP fields. Woody shelter (brush) provides loafing sites, whistling perches, and escape cover for bobwhite and other bird species (Guthery 1986:76, Lehmann 1984:283).

Boyer et al. (1989) evaluated 5 brush shelter designs and found that under laboratory conditions, teepee-style (see Boyer et al. 1989:Figure 1) shelters were preferred by bobwhite. In a field evaluation, nontarget species (primarily birds) also preferred teepee-style shelters (Boyer 1989), although preference by bobwhites could not be evaluated because of insufficient sample size. In this paper, we evaluate the use of teepee-style brush shelters by bobwhites and other birds in a CRP field that was kept free of natural woody cover.

STUDY AREA AND METHODS

This study was conducted at the Texas A&M University-Kingsville Bomer Wildlife Research Area in Duval County, Texas, from September 1991–June 1993. Average annual precipitation for the area is 56 centimeters with an average maximum daily temperature range of 22–29 Celsius (NOAA 1993). One-half of the 48-hectare Bomer Research Area is under CRP contract and planted in Kleingrass (*Panicum coloratum*). The other half is primarily native thorn-scrub and is managed exclusively for northern bobwhite.

Five clusters of 6 teepee-style brush shelters (hereafter referred to as brush shelters) were erected during the CRP in June–August 1991. We followed the suggestions of Lehmann (1984:187), Johnson and Guthery (1988), and Boyer et al. (1989) and constructed brush shelters in clusters. Brush shelters were oriented in a 2-X-3 grid with approximately 8–10 meters between shelters. Each of the 5 clusters was paired with a control area of equal size (25 × 40 meters) with $\geq$ 40 meters between cluster and control areas and located $>$ 350 meters from native brush.

Each cluster and control area was visited 65 times by 5 observers (325 cluster- and 325 control-visits). At least 6 hours elapsed between consecutive visits. Each cluster and control area was monitored by circling the area in a vehicle at slow speed (6–10 kilo-

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Table 1. Birds observed at brush shelters on a Conservation Reserve Program field, Duval County, Texas, September 1991–June 1993.

Species	No. of occurrences	
	Shelter	Control
Meadowlark spp. (*Sturnella* spp.)	40	16
Northern bobwhites (*Colinus virginianus*)	15	8
Loggerhead shrikes (*Lanius ludovicanus*)	22	0
Scissor-tailed flycatcher (*Muscivora forficata*)	17	1
Savannah sparrow (*Passerculus sandwichensis*)	10	1
Grasshopper sparrow (*Ammodramus savannarum*)	1	9
Black-shouldered kite (*Elanus leucurus*)	8	0
Dickcissel (*Spiza americana*)	5	3
Vesper sparrow (*Pooecetes gramineus*)	4	3
Cooper's hawk (*Accipter cooperii*)	4	0
Black-bellied whistling duck (*Dendrocygna autumnalis*)	3	1
Ground dove (*Columbigallina passerina*)	2	2
American kestrel (*Falco sparverius*)	3	0
White-tailed hawk (*Buteo albicaudatus*)	3	0
Sparrow (unidentified)	2	1
Redwinged blackbird (*Agelaius phoeniceus*)	2	0
Northern mockingbird (*Mimus polyglottos*)	2	0
White-throated sparrow (*Zonatrichia albicollis*)	2	0
Phyrruloxia (*Phyrruloxia sinuata*)	2	0
Mourning dove (*Zenaida macroura*)	2	0
Cactus wren (*Campylorhynchus brunneicapillum*)	2	0
Lark sparrow (*Chondestes grammacus*)	1	0
Golden-fronted woodpecker (*Centurus aurifrons*)	1	0
Ash-throated flycatcher (*Myiarchus cinerascens*)	1	0
Carolina chickadee (*Parus carolinensis*)	1	0
Common nighthawk (*Chordeiles minor*)	1	0

meters per hour). Number of avian species and number of individuals per species were recorded for each visit. We assumed birds were using a cluster if they were in or on the brush shelter or within the 0.1-hectare treatment area. We assumed birds were using a control area if they were within the 0.1-hectare control area. Birds were never flushed from one treatment area to another. Species richness and Simpson's diversity index were calculated for each treatment by season (Hair 1980: 270–271). Seasons were spring (Mar-May), summer (Jun-Aug), fall (Sep-Nov), and winter (Dec-Feb).

RESULTS AND DISCUSSION

Twenty-seven species of birds were observed at brush shelters versus 10 species at control sites (Table 1). Of the 27 species of birds recorded, no species occurred exclusively at control areas and 17 occurred at brush shelters exclusively. Of the 17 species that occurred exclusively at brush shelters, loggerhead shrikes (*Lanius ludovicanus*), and raptors accounted for 39 and 32% of the observations, respectively. Raptor species included black-shouldered kites (*Elanus leucurus*), Cooper's hawks (*Accipiter cooperii*), white-tailed hawks (*Buteo albicaudatus*), and American kestrels (*Falco sparverius*) (Table 1).

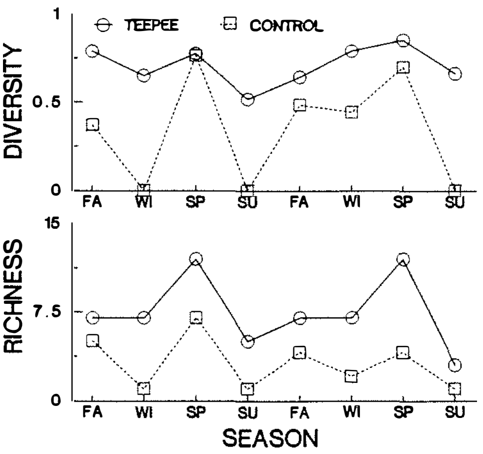

Fig. 1. Seasonal trends in species richness and Simpson's diversity index on brush shelter and control sites in a Conservation Reserve Program field, Duval County, Texas, September 1991–June 1993. Seasons are fall (FA: Sep-Nov), winter (WI: Dec-Feb), spring (SP: Mar-May), and summer (SU: Jun-Aug).

Species richness was greater on brush shelters than on controls in all season-year combinations (Figure 1) and ranged from 12 (spring 1992, 1993) to 3 (summer 1993) on brush shelters. Simpson's diversity index, from brush shelters was greater than or equal to controls in all season-year combinations (Figure 1) and ranged from 0.86 (spring 1993) to 0.52 (summer 1992) on brush-shelter areas.

Many researchers have recommended brush-shelter establishment in areas with sparse woody cover to enhance bobwhite populations. Effects of game management on nontarget species are rarely a consideration when prescribed. Webb and Guthery (1983) found that a variety of bobwhite management practices increased avian abundance and diversity. Boyer (1989) also found that bobwhite management benefitted nontarget species. Quail management practices seem to have positive or neutral effects on nongame species (Harveson 1994).

In south Texas, brush shelters in CRP fields were used by a variety of birds for different reasons. Bobwhites seasonally used brush shelters with peak observations occurring in spring and summer (n = 14), coinciding with breeding activity (Guthery et al. 1988) and male vocalization (Johnson and Guthery 1988). Brush shelters provided perch sites for raptors, flycatchers, and other insectivores. Brush shelters also provide midday loafing coverts for bobwhites (Johnson and Guthery 1988, Boyer et al. 1989) and nesting structure for songbirds.

ACKNOWLEDGMENTS

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EFFECTS OF SEASONAL FIRE APPLICATIONS ON NORTHERN BOBWHITE BROOD HABITAT AND HUNTING SUCCESS

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ABSTRACT

Since the early part of the 20th century, land managers have used prescribed fire during February and March to maintain and enhance habitat for northern bobwhites (*Colinus virginianus*) in southern pine forests. During the past 2 decades, some managers have started to shift their use of fire to mimic more "natural" lightning-season (April to August) ignitions because these fires encourage flowering of plants in intact native ground cover, and are potentially more effective at hardwood control than winter fires. Therefore, we designed a short-term pilot study to evaluate whether seasonal applications of prescribed fire had any effect on bobwhite brood habitat (as measured by vegetation composition and arthropod biomass) or bobwhite abundance (as measured by hunting success) during the subsequent fall. During the first two years of our study (1994 and 1995), results showed that arthropod biomass and bobwhite hunting success were slightly greater on the shooting course burned during lightning-season (May) than the one burned during February and March. These results indicate that applications of lightning-season fire can be used, at least on a small scale (i.e., management blocks <250 ha) in southern pine forests for hardwood control, and possibly enhancement of native ground cover without short-term negative impacts on northern bobwhites.

Citation: Brennan, L.A., J.M. Lee, E.L. Staller, S.D. Wellendorf, and R.S. Fuller. 2000. Effects of seasonal fire applications on northern bobwhite brood habitat and hunting success. Pages 66–69 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

INTRODUCTION

Since the early part of the 20th century, forest and wildlife managers have used prescribed fire during February and March to maintain and enhance habitat for northern bobwhites in southern pine forests (Stoddard 1931, Brennan et al. 1998). During the past 2 decades, some land managers have started to shift their use of prescribed fire to mimic more "natural" lightning-season ignitions during April and August (Robbins and Myers 1992; Figure 1). Lightning-season fires encourage flowering of keystone native plants such as wiregrass (*Aristida* spp.), and seem to be, under certain conditions, more effective at control of invasive hardwoods than winter fires (Robbins and Myers 1992). However, the effects of varying seasonal applications of prescribed fires on vertebrates, as well as on plants and arthropods that provide food and habitat resources, remain poorly known. Additionally, it is conventional wisdom among many quail managers that use of lightning-season fire (which coincides with the northern bobwhite nesting season) will have devastating negative effects on bobwhites and other ground-nesting birds, despite the lack of data that either support or refute this idea.

Our objective was to design a short-term, pilot study to examine the effects of seasonal applications (March versus May to June) of prescribed fire on: (1) elements of brood habitat (i.e., vegetation composition and arthropod biomass); and (2) hunting success during the subsequent fall and winter seasons.

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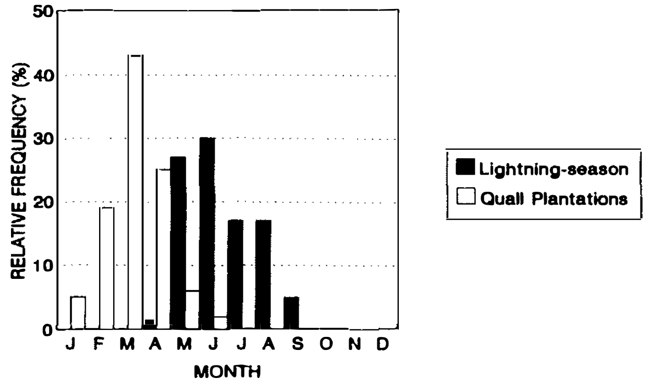

Fig. 1. Relative frequency of applications of prescribed fire on quail plantations in the Tallahassee-Thomasville region of northern Florida and southern Georgia (data from Brennan 1994), compared to occurrence of lightning strikes in the southeastern U.S. (from Komarek 1964).

METHODS

Sampling Unit

We used 2 shooting courses which were approximately 200 ha each, on a 1,500 ha hunting plantation in northern Florida. Major activities in the annual cycle of management events of hunting plantations in northern Florida and southern Georgia are described in Brennan (1994). Each shooting course had received annual applications of prescribed fire during February or March for the past 5 decades. Management treatments (winter [February to March] versus summer [May to June] applications of prescribed fire) were assigned at random.

Prescribed fires were applied during 1994 and 1996, with no burning on either course during 1995. Approximately 70–80% of the vegetation on each shooting course was burned; remnant patches (several square meters up to 0.3 ha) remained unburned and were distributed throughout the area.

Vegetation and Arthropod Sampling

We estimated the relative frequency of occurrence of plant species present on dormant and lightning season burned areas using a meter square grid placed at 5 meter intervals along 25 meter transects. Thirty 25-meter transects were sampled in areas that were burned during the summer, or during the winter, in each shooting course. Sampling was conducted during June, July, and August of 1994 and 1995. Arthropods were sampled using a D-vac suction device along 30 25-meter transects in winter and summer burned areas in each shooting course, also during June, July, and August of 1994 and 1995. During each sampling period, arthropods were sampled first. Vegetation data were subsequently collected within 1 to 24 hours after collecting arthropods.

In the laboratory, arthropods were sorted to Order, dried for >12 hours at 70 degrees Celsius, and weighed to 0.001 gram.

Hunting Success

Bobwhites were hunted with pointing dogs on 2 to 3 week intervals during the hunting season (December to February). Tallies on number of bobwhite coveys flushed per half-day (4 hours) of hunting were recorded by the plantation owners, managers, or dog handlers. Hunting success data were collected during the 1994, 1995, and 1996 hunting seasons.

RESULTS

Vegetation

The shooting course burned during summer produced more ragweed (*Ambrosia* sp.) and panic grass (*Panicum* sp.). The shooting course burned during winter produced more legumes than plots burned during summer. The presence of oak (*Quercus* sp.) sprouts was also greater on the area burned during winter (Fig. 2a). Otherwise, there was little difference in vegetation composition on the areas burned during the winter or summer.

Arthropods

During 1995, the course burned during summer produced more grasshoppers (Orthoptera), true bugs (Hemiptera), leaf hoppers (Homoptera), and spiders (Aranea), all of which are important foods for bobwhite hens and chicks (Fig. 2b). Total biomass of arthropods was greater on the shooting course burned during summer in both years of the study (Fig. 3). During 1994, the shooting course burned during summer produced a pulse of arthropods during the peak of the northern bobwhite breeding season (Fig. 4a). This pattern was not repeated during 1995 (Fig. 4b).

Hunting

During the 1994 and 1995 hunting seasons, northern bobwhite hunting success was slightly greater on the shooting course burned during summer, compared to the shooting course burned during winter (Fig. 5). There was no difference in hunting success between the summer and winter burned shooting courses during the 1996 hunting season (Fig. 5).

DISCUSSION

Contrary to popular opinion, conventional wisdom, and management tradition, our results indicate that summer (lightning-season) applications of prescribed fire can be used for northern bobwhite habitat management, especially in areas where economical control of invasive hardwoods is needed. Such applications of fire can be used without negatively impacting bobwhite populations or hunting quality. We caution, however, that use of summer fire should be limited to relatively small blocks (<250 ha) and not be used exclusively over an entire shooting plantation.

There may be significant economic advantages that can be gained from using summer fires for hard-

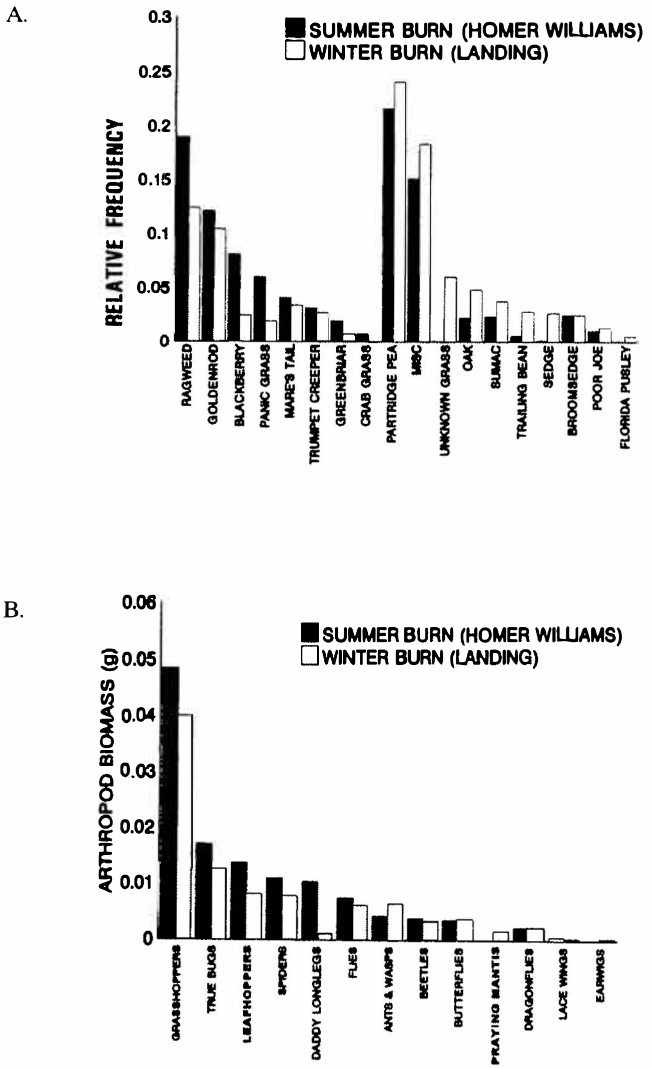

Fig. 2. (A) Frequency of occurrence of plants on shooting courses burned during summer (solid bars) and winter (open bars) measured during June, July, and August, 1994, and 1995. (B) Arthropod biomass on shooting courses burned during summer (solid bars) and winter (open bars) measured during June, July, and August, 1994, and 1995.

wood control. For example, control of small (1 to 2 centimeter diameter) hardwoods using fire costs about $5.00 per acre, whereas herbicide or mechanical methods cost between $25.00 to $40.00, or more, per acre.

Results from habitat use analyses of radio-marked northern bobwhites at Tall Timbers Research Station near Tallahassee, FL corroborate the results reported here. At Tall Timbers, bobwhite hens were documented moving broods into areas 1 to 2 weeks postfire during June and July, apparently to feed on phytophagous arthropods that respond to post-fire vegetation (Carver et al. *this volume*).

This study, along with a series of companion studies on seasonal effects of fire on other wildlife in southern pine forests, supports an emerging pattern which shows that winter versus summer fires influence wildlife populations in subtle ways. For example, results from experimental comparisons of winter versus summer fire applications had only minor effects on birds in both the Apalachicola National Forest (Engstrom et al. 1996, Engstrom unpubl.), North Carolina Sandhills (Brennan et al. 1998), and wild turkeys (*Meleagris gallopavo*) in the Red Hills region of southern Georgia and northern Florida (Sisson and Speake

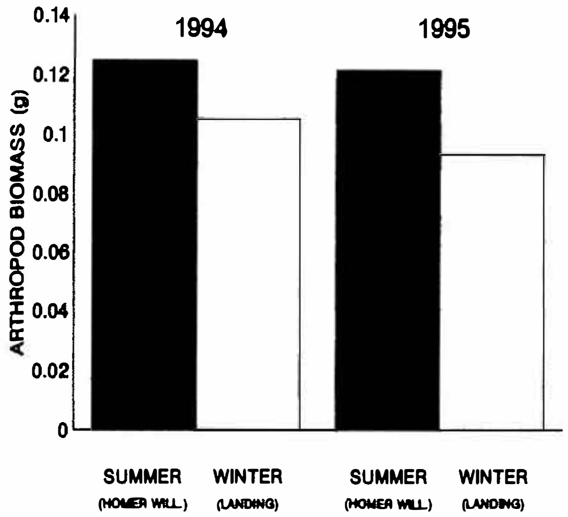

Fig. 3. Arthropod biomass (g) on shooting courses burned during summer (solid bars) and winter (open bars) measured during June, July, and August, 1994, and 1995.

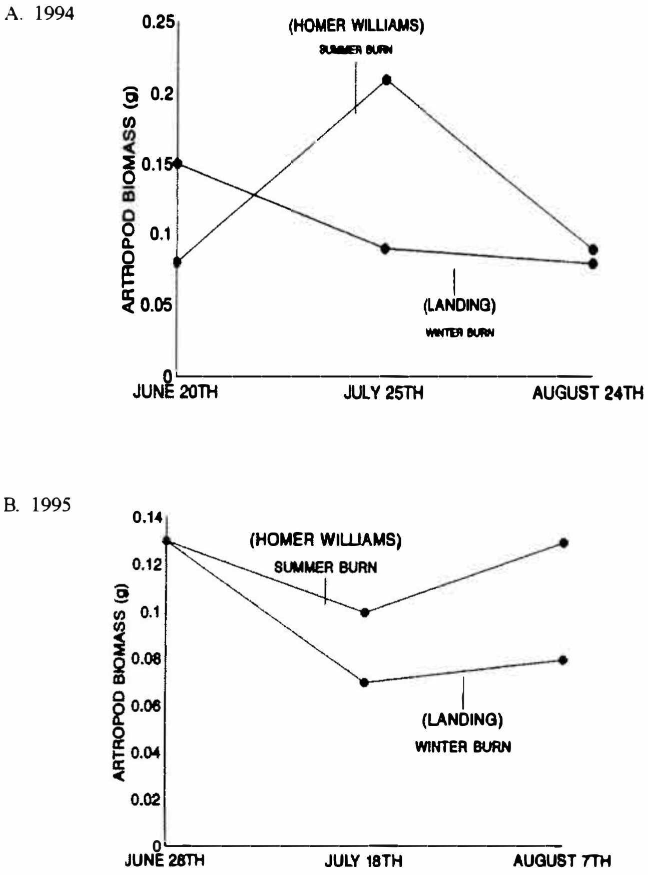

Fig. 4. Arthropod biomass (g) on shooting courses burned during summer and winter measured during June, July, and August, 1994 (A), and 1995 (B).

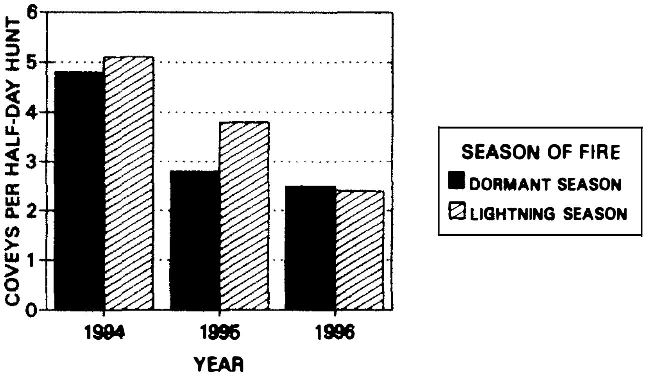

Fig. 5. Northern bobwhite hunting success during the 1994, 1995, and 1996 hunting seasons (December through February). One half-day hunt equals approximately 4 hours of hunting effort.

1994). When the results from these studies are compared with earlier classic studies on the effects of fire exclusion on birds (Engstrom et al. 1984), it is clear that the use of fire is absolutely critical to the maintenance of habitat for many species, including northern bobwhite, whereas the seasonal timing of fire application can be flexible. Nevertheless, much additional research is needed, such as long-term studies with extensive spatial replication, before we will be able to fully understand the long-term effects of applying winter versus summer prescribed fire in the context of wildlife and ecosystem management.

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BOBWHITE BROOD ECOLOGY IN RELATION TO FALLOW FIELD MANAGEMENT TECHNIQUES AND PRESCRIBED FIRE REGIME

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ABSTRACT

We used compositional analysis to rank habitats used by nesting and brood-rearing northern bobwhites (*Colinus virginianus*) in northern Florida. We used a residence index based on brood movement rates and turning angles to predict distribution of organisms among habitat types within brood ranges. We examined relationships among residence indices and vegetation and invertebrate characteristics of the habitat to draw inferences as to brood habitat quality. We related brood survival to vegetation, landscape structure and composition, and invertebrate characteristics within brood ranges. Finally, we reported effects of season of disking (fall vs spring) on vegetative (composition, canopy cover, density, ground cover) and invertebrate (richness and biomass) communities in fallow agricultural fields.

Citation: Carver, A.V., L.W. Burger, Jr., and L.A. Brennan. 2000. Bobwhite brood ecology in relation to fallow field management techniques and prescribed fire regime. Page 70 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, Jr., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

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SEED AVAILABILITY WITHIN FOOD PLOTS AND NATIVE VEGETATION AREAS ON A LONGLEAF PINE SITE IN SOUTHEASTERN LOUISIANA

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ABSTRACT

The lack of late winter foods has been hypothesized as a limiting factor for northern bobwhites in Louisiana pinelands. We determined January seed availability within food plots (rectangular and strip) and native vegetation areas on a longleaf pine site. Planted sites had considerably more seed available than native vegetation sites. However, most seeds were those of native grasses and sedges and not agricultural crops.

Citation: Olinde, M.W. 2000. Seed availability within food plots and native vegetation areas on a longleaf pine site in southeastern Louisiana. Page 70 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, Jr., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

FOOD PLOT USE BY JUVENILE NORTHERN BOBWHITES IN EAST TEXAS

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ABSTRACT

We examined use of spring-summer (i.e., warm-season) food plots by northern bobwhites (*Colinus virginianus*) with broods using radio telemetry on a 563-ha study area in Trinity County, eastern Texas, where habitat was modified to enhance it for these birds. Bobwhites from South Texas and disjunct areas of East Texas were introduced to supplement a small, resident population. All relocated and most resident bobwhites were fitted with necklace-style transmitters. Bobwhites which produced chicks were intensively radio-tracked (≥ 3 times/day) for ≥ 4 weeks or until the radio-marked parent was lost. Nine hens moved their broods to food plots within an average of 2.1 days after the eggs hatched; average distance moved was 217 m. Use of food plots by 12 broods was proportionally greater than that of native vegetation ($P < 0.001$). Food plots had lower quail-level foliage density ($P = 0.015$) and more arthropods ($P < 0.001$) than native vegetation. Our results demonstrate that warm-season food plots can potentially provide brood habitat for bobwhites in eastern Texas.

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INTRODUCTION

Although the reproductive season may be the most important phase of bobwhite life history, little is known about factors that influence chick survival during this period (Hurst 1972). Difficulty in capturing, marking, and observing young chicks in the field has precluded the gathering of quantitative data on the biology of juvenile bobwhites (Roseberry and Klimstra 1984).

Bobwhite chicks rely primarily on small arthropods during the early stages of life (Cottam 1931). Beetles (Coleoptera), true bugs (Hemiptera), and grasshoppers (Orthoptera) typically provide >90% of the foods eaten during the first 2 weeks (Hurst 1972, Eubanks and Dimmick 1974). Although aspects of brood habitat structure may vary throughout the geographic range of northern bobwhites, it appears that parents select brood foraging areas with high insect densities (DeVos 1986).

Planted food plots have long been viewed as an important management tool for increasing quail numbers (DeVos 1986). However, a search of the literature revealed a dearth of information concerning use of planted food plots by bobwhite chicks. Therefore, our objective was to evaluate the use of planted food plots by radio-marked parent bobwhites with chicks.

STUDY AREA

During 1989, Temple-Inland Forest Products Corporation conducted intensive habitat modifications on a 563-ha study area in the South Boggy Slough Hunting and Fishing Club. The modifications were implemented for a study designed to compare survival and reproduction of resident bobwhites and bobwhites relocated to the study area from other areas of East Texas and from South Texas (Liu 1995). The study area was in southeastern Trinity County, which is in the Pineywoods Ecological Region of eastern Texas (Gould 1975). The study area was in an upland forest comprised of pine and mixed pine-hardwood stands (Parsons 1994, Parsons et al. *this volume*). The dominant pines were loblolly (*Pinus taeda*) and shortleaf (*P. echinata*); dominant hardwoods included sweetgum (*Liquidambar styraciflua*), southern red oak (*Quercus falcata*), white oak (*Q. alba*), post oak (*Q. stellata*), black hickory (*Carya texana*), and bitternut hickory (*C. cordiformis*). Topography was gently rolling hills

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with elevations ranging 57–105 m above mean sea level (Parsons 1994, Liu 1995, Liu et al. 1996).

Habitat modifications, detailed in Parsons et al. (*this volume*), included basal area reduction and a burning regime whereby approximately 50% of the study area was subjected to prescribed fire each year. Escape cover, both naturally occurring and planted, was established throughout the study area. Naturally occurring thickets, primarily of blackberry (*Rubus* spp.), American beautyberry (*Callicarpa americana*), and yaupon (*Ilex vomitoria*), were protected from prescribed fires. Where such thickets were lacking, strips of Thunberg lespedeza and autumn olive were planted, usually in association with food plots. When 2 young (i.e., 5-year-old) 10-ha pine plantations were included, patches of escape cover comprised about 12% of the study area.

Supplemental food plots, both permanent and temporary, comprised approximately 20% of the study area. Permanent food plots ranged in size from 0.1–2.1 ha. These plots were located such that each was within sight of another; the maximum distance between such food plots was approximately 150 m (Liu 1995:30). Seventy-five percent of each permanent food plot was comprised of 3 approximately equal proportions of cool-season crops planted to mature during fall and winter. These portions consisted of the current-year cool-season crop, the first-year fallow cool-season crop, and the second-year fallow cool-season crop. The remaining 25% of the plot was devoted to a crop planted to mature during the current-year spring and summer (i.e., warm season). Cool-season species planted in food plots were wheat, ryegrass, crimson clover, arrowleaf clover, and hairy vetch. Warm-season species included browntop millet, Japanese millet, pearltop millet, Egyptian wheat, American jointvetch, kobe lespedeza, partridge pea, Alyce clover, iron and clay peas, and Florida beggarweed. Temporary food plots were in natural openings, abandoned log sets, roadsides, firelanes, and pipeline right of ways. They were planted during the early spring using warm-season species and again during early fall using cool-season species. Temporary food plots were generally smaller than permanent plots and did not contain fallow areas. All food plots were disked and fertilized (13N:13P:13K) before they were seeded. Firelanes were established throughout the study area to protect escape cover, food plots, and young pine plantations.

METHODS

The 3 groups of bobwhites were comprised of 2 subspecies, *C. v. texanus* from South Texas and *C. v. mexicanus* from East Texas (Johnsgard 1973), including an unknown portion of birds that were native residents of the South Boggy Management Area. South Texas bobwhites were trapped on the King Ranch in Kleberg and Kenedy Counties, in the South Texas Plains Ecological Region (Gould 1975). Most bobwhites relocated from other areas of East Texas were trapped approximately 15 km north of the study area in Trinity and Houston Counties. Resident bobwhites were trapped on the study area. Bobwhites were captured during the winters (January–March) of 1990, 1991, and 1992 in funnel traps similar to those described by Stoddard (1931). Each captured bobwhite was aged (Rosene 1969), sexed, weighed, checked for injuries, and fitted with a numbered aluminum leg band and a chest-mounted radio-transmitter (Parsons et al. *this volume*).

Resident bobwhites were released at the point of capture. For birds relocated from East Texas and South Texas, the minimum covey size was 4 birds; these birds were released at predetermined sites throughout the study area. After release, radio-marked quail were tracked with a hand-held directional Yagi antenna 3–5 days a week throughout the breeding season and during fall and winter months.

During 1990, 4 radio-marked hens moved their chicks to warm-season food plots within 3 days after the eggs hatched. Also, 6 other radio-marked bobwhites with chicks were regularly recorded in warm-season food plots and a brood with unmarked parents was flushed from such a plot.

Food plot use data were collected during spring and summer, 1991 and 1992. Use of food plots by chicks was evaluated based on the location of the radio-marked parent(s). Beginning the day after the clutch hatched, we attempted to locate the radio-marked parent ≥4 times a day at ≥1-hour intervals. Radio locations were gathered using homing techniques (White and Garrott 1990). Normally, the observer approached to within approximately 50 m of the radio-marked parent and then continuously located it as he moved around it. When the observer was confident of the bird's location, it was plotted on a detailed map of the study area. Location data were accumulated until either the parent was lost or mid-September.

Using geographical information system techniques, Liu (1995) determined that the average random-point-to-food-plot distance was 44 m. For a conservative estimate, we assumed that if the parent's location was within 15 m of a warm-season food plot, the bird and its chicks were using the plot. Usually it was not necessary to measure parent-to-food plot distances; >90% of the parent locations were either in the plot or well away from it. However, if necessary, distances were measured on the map.

Characteristics of each warm-season food plot used by a radio-marked parent and its brood were evaluated at 5 different points. These data were recorded within 2–3 days after the parent was first recorded in the plot, but at a time when the bird was away from the plot. The initial point sampled was at the estimated location of the parent the first time it was recorded in the food plot. The remaining 4 points were in randomly selected directions and were approximately 5.0 m from the first. All points were within the warm-season portion of the food plot. We did not evaluate characteristics of the cool-season portions of permanent food plots because in 1990, 8 of the 11 food plots used by parents with chicks were temporary plots.

At each vegetation sampling point, stem density,

Table 1. Vegetation density and insect biomass in native vegetation and in warm-season food plots used by northern bobwhites with broods in East Texas, spring and summer 1991 and 1992.

		Native vegetation		Food plot		
Variable	n	$\bar{x}$	SE	$\bar{x}$	SE	P-Value
Stem density (per m^2)	13	1975	73	1515	33	0.127
Foliage density						
Quail-level (0–15 cm)	13	64.00	1.57	44.55	1.26	0.015
Overhead (15–100 cm)	13	45.18	1.42	44.27	0.96	0.885
Insect biomass (g)	25	0.105	0.003	0.302	0.010	<0.001

quail-level foliage density, and overhead protection were evaluated. Stem density of both native and planted species was measured at ground level by counting the number of stems within a 144-cm^2 circular plot. Quail-level foliage density and overhead protection density were evaluated in the 0–15-cm and the 15–100-cm strata, respectively, using a 10-pin frame. The pin frame was 1.1 m long; within the frame, the pins were spaced at 10-cm intervals. As each pin was lowered from a height of 1.0 m, each pin-to-plant contact within a stratum was recorded; thus, several contacts with the same plant may have been recorded. To compare characteristics of warm-season food plots to those of native vegetation, a set of 5 points was established in a random direction 50.0 m from each food plot evaluated; 50.0 m was selected because it was slightly longer than the random-point-to-food plot distance.

During 1992, insect biomass of each warm-season food plot used by brooding parents was sampled using the sweep net method (Hurst 1972). One sample was taken at the approximate location of the parent the first time it was recorded in the food plot. A similar sample was taken in native vegetation in a randomly chosen direction 50 m from the food plot. Since the technique was somewhat destructive of the vegetation, insects were sampled after the vegetation data had been collected.

Insects in each sample were separated from debris, dried (7 hours at 83° C), and weighed. Individual insects weighing more than 0.035 grams were discarded since they were considered too large to be ingested by quail chicks (Hurst 1972).

Use of warm-season food plots by bobwhite chicks was evaluated by comparing the number of parent radio-locations associated with food plots to the number of locations not associated with food plots using Chi-square goodness-of-fit tests. Stem density, quail-level foliage density, and overhead protection were compared between warm-season food plots and native vegetation using multivariate analysis of variance (Parsons 1994). Differences in insect biomass between warm-season food plots and native vegetation were evaluated using paired t-tests. The null hypothesis for all data analyses was that there was no difference between the samples being compared. All statistical tests were performed at an alpha level of 0.05.

RESULTS

A total of 37 nests were found during the 2 nesting seasons. Eggs in 10 of these nests hatched, 2 by relocated East Texas bobwhite hens and the remainder by resident bobwhites, including 1 by a subadult male. After the eggs hatched, the 9 radio-marked hens moved their broods from the nest site to a warm-season food plot in an average of 2.1 days (range 1–8); the cock and his brood were not recorded in a food plot for 36 days. Average distance moved from the nest site to a food plot was 217 m (range 100–300 m for hens, 400 m for the cock). Additionally, 1 hen paired with a radio-marked cock and flightless chicks (*ca* 7 days old) were captured on the edge of a food plot; the hen was fitted with a transmitter and released at the food plot. Another hen for which no nest was found was first recorded with chicks in a food plot. For the 12 broods with radio-marked parents, 774 telemetry locations were recorded. Of these, 501 (65%) were $\leq$15 m from a warm-season food plot and 273 (35%) were $>$15 m away from such a plot ($P < 0.001$).

During 1991 and 1992, 13 food plots (8 temporary and 5 permanent) were used by radio-marked parents with chicks. Neither density of stems at ground level nor overhead protection differed between food plots and native vegetation (Table 1). However, quail-level foliage was less dense in food plots than in native vegetation ($P = 0.015$) (Table 1). As only 6 warm-season food plots were used by radio-marked parents with chicks in 1992, 19 additional food plots were randomly selected and insects were collected in them and in adjacent native vegetation; thus, 25 samples were taken in food plots and in native vegetation. Mean weight of insects in the warm-season food plots was 0.302 g/sample, almost 3 times that in native vegetation, which was 0.105 g/sample ($P < 0.001$) (Table 1).

DISCUSSION

DeVos (1986) reported that while the use of brood habitats varied considerably, bobwhites tend to select areas with high insect densities. In our study, radio-marked parent bobwhites used warm-season food plots which were located within a matrix of native vegetation. This use of habitat was probably a result of greater insect biomass and more accessible structure in food plots than in native vegetation. Stoddard (1931) stated that legumes attracted or produced more insects than nonlegumes and Rosene (1969) noted that certain legume crops attracted bobwhites. More specifically, Burger et al. (1995) found that red clover produced significantly more invertebrate numbers and biomass than did 6 other types of cover crops. On the South

Boggy Slough study area, warm-season food plots contained several species of legumes, including American jointvetch, kobe lespedeza, partridge pea, Alyce clover, and iron and clay peas. The relatively high biomass of insects in food plots may be attributed to the presence of these plants. Differences in quail-level foliage density suggest native vegetation was more dense than food plot vegetation. The distance traveled and rapidity with which hens moved their broods to food plots demonstrated the importance of these plots. However, only 4 of 10 parents used the food plot which was nearest its nest. In no instance was more than 1 radio-marked parent with chicks recorded in a food plot and unknown parents with chicks were never recorded in a food plot that had a radio-marked parent and chicks.

Soil types, fertilizer rates, and planting rates and times were similar for all plots. Lack of familiarity with the area, trails leading to more-distant food plots, and better escape cover in and around plots may have influenced the parent bobwhites. Also, it is possible that competition with other bobwhites and their offspring may have influenced use of food plots.

Behavior of 4 radio-marked hens with broods suggests that the food plots served as more than insect-catching grounds for the chicks. Two such hens utilized food plots for approximately 9 weeks, and 2 others were actively using food plots when radio-tracking was concluded in October, 1992. In all cases, the chicks were still associated with the food plots when they were well past the age (2–4 weeks) at which they switch from insects to seeds, berries, and other types of vegetation (Landers and Mueller 1986).

Due to relatively small sample sizes, our results must be viewed with caution. However, the 11 hens with broods definitely moved to and remained in and around warm-season food plots. Johnson (1999:764) pointed out that the outcome of a statistical hypothesis test depends on results that were not obtained. In our case, it would have required 22 parents with broods which did not use warm-season food plots to statistically balance the 11 that did; we recorded only 1 such parent, the subadult male. Additionally, although radio locations were less frequent in 1990, 11 of 12 broods were recorded in warm-season food plots during that spring and summer. We encourage other biologists to investigate the use of warm-season food plots by bobwhites with chicks.

MANAGEMENT IMPLICATIONS

Our results suggest that properly implemented warm-season food plots can potentially provide habitat for bobwhites with chicks. Our data indicate that food plots should be within 200 m of suitable nesting habitat and escape cover should be associated with the plots. Escape cover can be in the form of native vegetation, cultivated species such as autumn olive and Thunberg lespedeza, or a combination of native and cultivated species.

In eastern Texas, supplemental food plots which contain warm-season species such as browntop, pearltop, and Japanese millets, Egyptian wheat, Alyce clover, iron and clay peas, American jointvetch, and kobe lespedeza are used by northern bobwhites.

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LONG-TERM TRENDS OF NORTHERN BOBWHITE POPULATIONS AND HUNTING SUCCESS ON PRIVATE SHOOTING PLANTATIONS IN NORTHERN FLORIDA AND SOUTHERN GEORGIA

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ABSTRACT

Nearly all broad-scale assessments (U.S. Department of the Interior, Fish and Wildlife Service [USDI-FWS], Breeding Bird Surveys, Audubon Society Christmas Bird Counts, and state game agency harvest surveys) of northern bobwhite (*Colinus virginianus*) population trends during the past 30 to 50 years point to widespread declines at local, regional and national scales. Long-term records of populations that do not show long-term bobwhite declines are rare. Landowners and managers in the shooting plantation country between Tallahassee, Florida and Thomasville, Georgia have been recording quail hunting and bag records for many years. Such information can provide valuable insight into the long-term trends of bobwhite populations. We therefore analyzed bag records from 5 different properties where data had been collected for periods ranging from 14 to 80+ years. Trends from these data were completely opposite from long-term trends shown from other sources such as Breeding Bird Survey and Christmas Bird Count data. These data indicate that a long-term, continuous approach to habitat management (primarily burning with prescribed fire, and frequent soil disturbance from disking) can sustain abundant bobwhite populations and high-quality shooting. These data also call into question alternative hypotheses such as invasion of the red imported fire ant and range expansion of the coyote as being responsible for the long-term bobwhite decline. Both fire ants and coyotes are common in the Thomasville-Tallahassee area, yet, abundant bobwhite populations persist, presumably as a function of high-quality habitat management.

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INTRODUCTION

Nearly all broad-scale assessments of northern bobwhite population trends during the past 30 to 50 years indicate widespread declines ranging from 70 to >90 percent (Droege and Sauer 1990, Brennan 1991, Brennan and Jacobson 1992, Church et al. 1993, Brennan 1999). Long-term records that do not show significant northern bobwhite population declines are rare.

Several private shooting plantations in the Tallahassee, FL and Thomasville, GA region have been keeping records of annual bags and hunting efforts for many years. These data represent some of the longest continuous records of bobwhite hunting success and relative population abundance in the world. Such information may provide insight into factors that have caused the broad scale bobwhite population declines. Therefore, our objective was to compile and analyze game book data from 5 private shooting plantations, and compare the trends from these data sets to long-term northern bobwhite trends in Florida and Georgia documented from the USFWS Breeding Bird Survey (Sauer et al. 1996).

METHODS

We compiled records from plantation game books that ranged from 14 to 89 years. Data recorded were: total number of bobwhite coveys seen, and amount of time hunted. The variable "coveys seen per hour of hunting" is both a relative measure of hunting success, and relative population abundance, over time. Such data do not represent absolute abundance or population density, but they do represent relative changes over time, especially when standardized by hunting effort. Because of different hunting methods and rituals, com-

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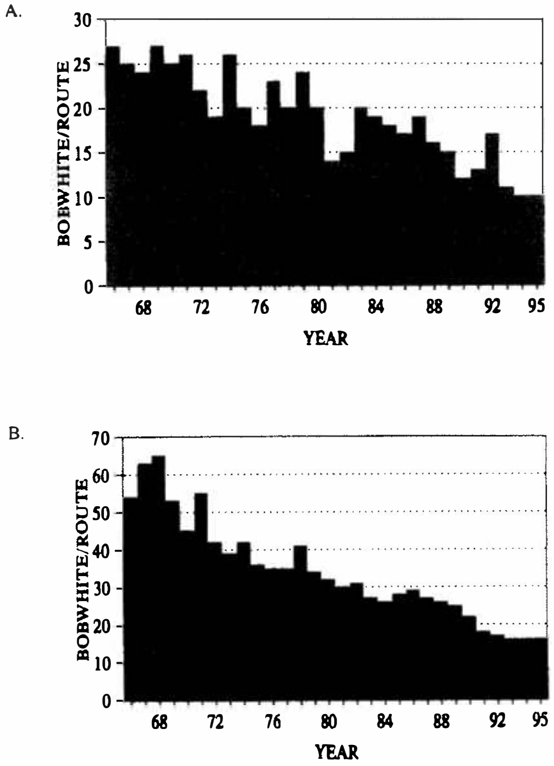

Fig. 1. (A) Northern bobwhite Breeding Bird Survey data from Florida (1966 to1995); (B) Breeding Bird Survey data from Georgia (1966 to 1995); from Sauer et al. (1996).

parisons are made only within a particular property and not among or across different properties.

RESULTS

Compared to broad-scale estimates (Figures 1a and 1b) from the USFWS Breeding Bird Survey (BBS), the bobwhite trend data from the 5 properties we studied (Figures 2a through 2e) did not show evidence of long-term declines. Regression analyses of BBS data (Figures 1a and 1b) indicated that the slope of the regression line was negative and significantly different from zero. Regression analyses of the plantation game book data (Figures 2a through 2e) indicated that the slope of all 5 regression lines was not significantly different from zero. Time series analyses of data from Figures 2d and 2e indicated an auto correlation function that showed more-or-less random fluctuation around stable mean values.

DISCUSSION

Long-term data on population trends derived from hunting efforts have provided critical insight into how land use changes have influenced game bird populations in the United Kingdom (Tapper 1992). Unfortunately, similar long-term data sets from private hunting properties in the U.S. are quite rare. It can be argued that the lack of such data has compromised our ability to definitively link the northern bobwhite decline of the past 30–50 years with loss of habitat from changing land use patterns.

Long-term northern bobwhite hunting data from the Tallahassee, FL-Thomasville, GA region show long-term trends in relative abundance that contrast with most broad-scale population estimates for this bird. These data provide support for the hypothesis that habitat loss from changing land use is responsible for the widespread bobwhite population declines observed throughout the Southeastern Coastal Plain. Ongoing northern bobwhite habitat management on the properties used in this study is conducted annually, and at a high level of intensity. Annual use of prescribed fire, disking, planting, thinning pine timber, removal of invasive hardwoods, and predator control, apparently provide relatively large amounts of useable habitat space consistently over time (Guthery 1997) for the birds.

The private shooting plantations used in this study have also experienced the widespread increase of coyotes (*Canis latrans*), fire ants (*Solenopsis* sp.) and other factors that people in the Southeast often attribute as being responsible for the bobwhite decline. Most likely, such factors are epiphenomena, as least as far as the bobwhite decline is concerned.

Variation in rainfall is responsible for about 25% of the annual variation in Coastal Plain bobwhite numbers (Brennan et al. 1997). Thus, data from this study may be useful in evaluating the potential role of other factors, such as global warming (Guthery et al. *this volume*) on bobwhite numbers.

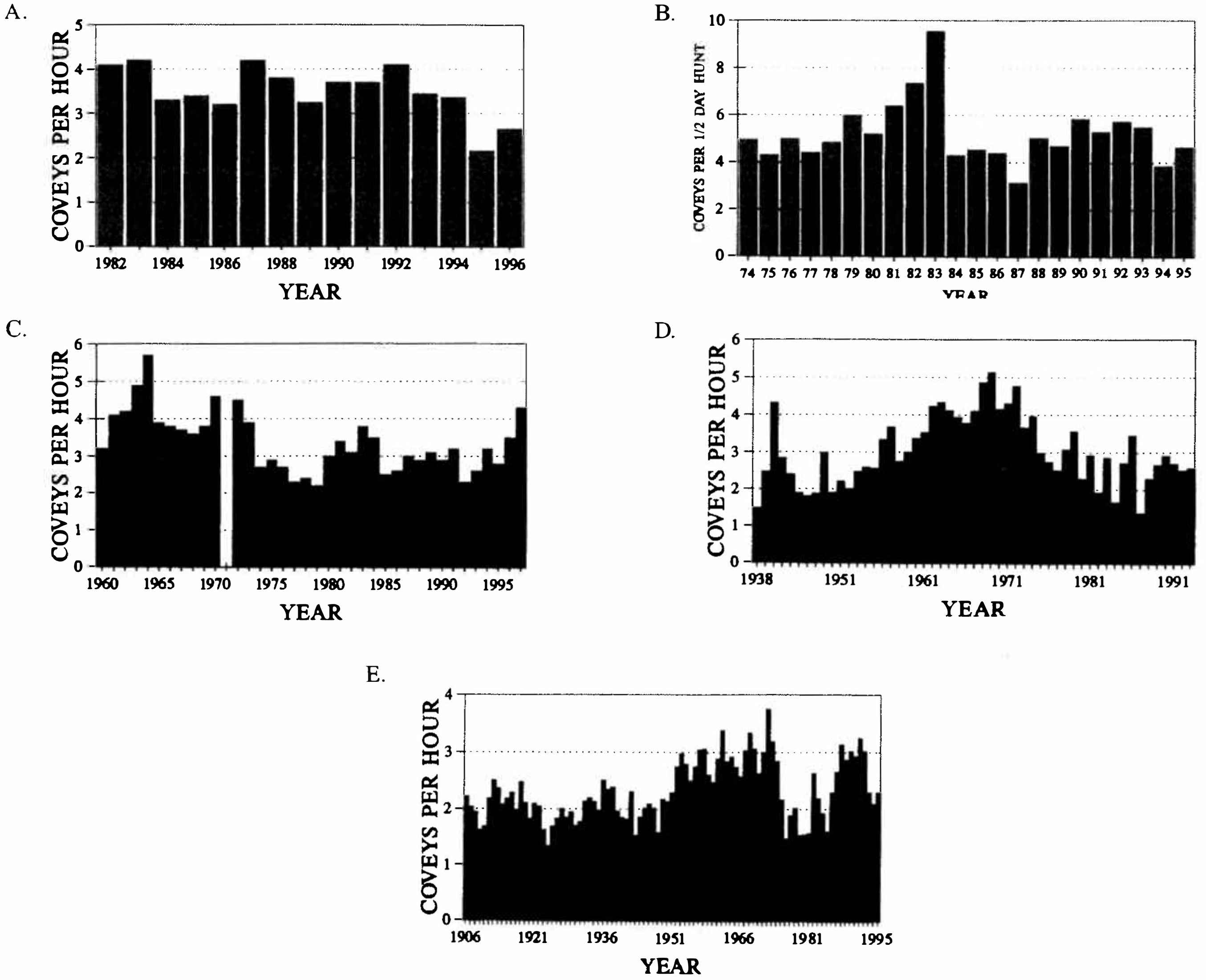

Fig. 2. Northern bobwhite hunting data, expressed as covey finds standardized in relation to hunting effort from 5 private shooting plantations (A through E) in the Tallahassee, FL and Thomasville, GA region.

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THEORY OF THE HUNTER-COVEY INTERFACE

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ABSTRACT

We established mathematical models and explored the role of a learned response (avoidance behavior) to understand and manage the hunter-covey interface. Furthermore, we examined the dynamic nature of the probability of flush, given encounter, in a population that learned to avoid hunters as time passed. Learning rate was defined as the proportion of a covey that leaves the naive population and enters the experienced population per unit of hunter-covey contact. The conditional probability of flushing and shooting at a covey, given a covey encounter, declined through the season. This is because the probability of flushing was lower for experienced than for naive coveys and the population of experienced coveys grew with exposure. Thus, quality of hunting declined at a faster rate than quail population; i.e., birds became more wary as the hunting season progresses. The birds' ability to avoid hunters provided an explanation of the sudden reappearance of bobwhites contributing to reproduction in areas where hunters were unsuccessful the previous hunting season. Management can use our models to manipulate the interface and obtain a desired population following the hunting season.

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INTRODUCTION

Wildlife biologists and hunters have long recognized avoidance behavior by northern bobwhites (*Colinus virginianus*), i.e., trap shyness and flighty behaviors. Thorndike (1911), an early animal behaviorist, formulated this concept as the Law of Effect. It states "[O]f several responses made to the same situation, those which are accompanied or closely followed by satisfaction to the animal will, other things being equal, be more firmly connected with the situation, so that, when it recurs, they will be more likely to recur." In other words, a response followed by favorable consequences becomes more probable than a response followed by unfavorable consequences. Additionally, individuals that live in groups (e.g., bobwhite coveys) may have the opportunity to learn to recognize unfamiliar dangers by observing the responses of experienced individuals in the group. This behavioral concept is termed cultural transmission (Mainardi 1980, Curio 1988, Mineka and Cook 1988). Cultural transmission of information has been reported for several avian species, in which predator-naive individuals learn to recognize predators by observing the responses of experienced birds (Klopfer 1957, Curio et al. 1978, Vieth et al. 1980).

Several assumptions in animal behavior are: (1) all behavior is caused or determined in some way; i.e., all behavior obeys certain laws; (2) explanations of behavior based on internal causes and mental states are generally useless; and (3) the environment molds behavior. Animal behaviorists explain the cause of behavior by studying only those behaviors that can be observed and measured, without reference to unobservable mental processes.

Covey dynamics for northern bobwhites in southern Texas have been reported (Lehmann 1984). The nature of the behavior process, termed the hunter-covey interface, was explored because hunter-harvest data are commonly used in bobwhite density estimates, management, and establishing future hunting regulations. We used mathematical models to predict possible outcomes of the learning process on the hunter-covey interface. We started with a simple static model of daily harvest and generalized the model to account for avoidance behavior by bobwhites and site selection by hunters. The theoretical background for understanding the hunter-covey interface provides information that can be incorporated into harvest management plans.

METHODS

We first established and developed a static model of daily harvest. Under the static model 1 hunting party hunts 1 area on 1 day. The number of birds harvested (K) on any day is the product of coveys encountered times the number of birds shot per covey encountered. This statement may be expressed as

$$K = mp(N/s) \quad (1)$$

where

m = mean number of birds shot per covey flushed,
p = probability of encountering a covey,

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N = total bobwhite population at the beginning of the day, and

s = average covey size on the day.

The probability of encountering a covey (p) is of considerable practical and theoretical interest. Conceptually, we may view a given hunt as an area covered superimposed on an area hunted. Therefore, a hunt will effectively cover an area of some size within a larger area available for hunting. Assuming (1) hunting pressure is nonredundant, i.e., new space is hunted at each instant, and (2) coveys are randomly distributed in space on the hunted area, then the probability of encountering any covey is the area covered on the hunt divided by the area available for hunting,

$$p = a/A \tag{2}$$

where

a = the area (ha) effectively hunted on a day, and

A = the area (ha) available for hunting.

The area effectively hunted increases with the speed of the hunters, the time spent hunting, and the effective width of the hunting zone. The relationship can be described as:

$$a = vhw \tag{3}$$

where

v = the velocity at which hunters travel (linear units/hr),

h = hours spent hunting, and

w = the effective width of the hunting zone (linear units).

The width (w) is homologous to effective strip width in line transect sampling of wildlife density. The time for hunting (h) is limited, and more or less fixed to morning and evening. However, the velocity may be increased by hunting from vehicles, horses, and/or by use of dogs. Rosene (1969:347) estimated a hunter on foot with dogs covers about 120 ha per day, whereas hunting parties using horses or vehicles cover 400–600 ha per day. If one assumes hunters using vehicles flush 3–5 times as many coveys as hunters on foot, then it is possible for low quail densities to be associated with high time-rates of flushing (coveys per hr) when hunters increase velocity and width.

The above arguments lead to a more general model of daily kill as:

$$K = m(vhw/A)(N/s). \tag{4}$$

This simple model holds under random distribution of coveys and nonredundant hunting pressures, which limits the model's application. More realistic models could incorporate avoidance behavior (learning) by coveys (Sisson 1996), which may be counteracted by hunters with selection of better habitat patches for hunting, baiting, or both.

Also, encountering a covey relates to how a covey responds (freeze, fly, run) when a hunting party approaches. The probability of flushing a covey also must address if it is within shooting range. The word flush, in the context of our paper, means hunters flush a covey within shooting range. However, there will be a fraction of the coveys flushed because of avoidance behavior (all coveys encountered will not flush). Then the probability a covey flushes, given encounter, is defined as p_f. Under avoidance behavior, we revise the previous equation to:

$$K = m(vhw/A)p_f(N/s). \tag{5}$$

The above equation is subject to the assumption hunters do not preferentially select portions of areas for hunting and they do not bait. However, whether hunters bait, preferentially select hunting sites, or both, is not of concern in a more general conceptual model of daily harvest. Preferential site selection is conceptually similar to baiting in model development. We can define an area of size B which is preferentially selected and/or baited within the general area of size A. We specify all hunting occurs within area B and hunters show no preferential use within area B. Then the probability of encountering a covey becomes conditional on p_h, the probability a covey occurs in area B. Note that p_h relates specifically to the bobwhite population and not to area. The model for the daily kill now becomes:

$$K = m(vhw/B)p_fp_{h.}(N/s). \tag{6}$$

This equation provides a deterministic estimate and therefore is best considered an average value under the conditions specified. Also, we realize that certain variables in the general model are dynamic. For example, scenting conditions for dogs vary with temperature and humidity (Gutzwiller 1990), which imposes variation in the effective width of the hunting zone (w). Populations decline through the hunting season as does the mean number of birds in coveys. And behaviorally, bobwhites may become more wary as time passes and exposure to hunting continues.

Next, we explored learning behavior leading to hunter-avoidance. In particular, we examined the dynamic nature of the probability of flush, given encounter, in a population that learns to avoid hunting parties over time (t). Naive coveys C_n were defined as not being exposed to hunting pressure. We assumed all coveys were naive at the start of the hunting season, and the probability of flush, given encounter, was lower for experienced coveys than for naive coveys; i.e., experienced coveys showed hunter-avoidance behavior. Individuals from naive coveys were lost through harvest, natural mortality, and emigration into the population of experienced coveys. The population of experienced coveys acquired gains from ingress of naive individuals and losses from harvest and natural mortality.

Population dynamics of the naive and experienced coveys can be modeled with similar natural mortality rates and harvest-loss rates per hunter-covey contact. The dynamic variable of interest is the mean probability of flush, given encounter, at some time t, defined as $p_{f,t}$. Since hunters are less likely to flush an experienced covey than a naive covey, this mean is a weighted average of p_{fn} and p_{fe} at time t,

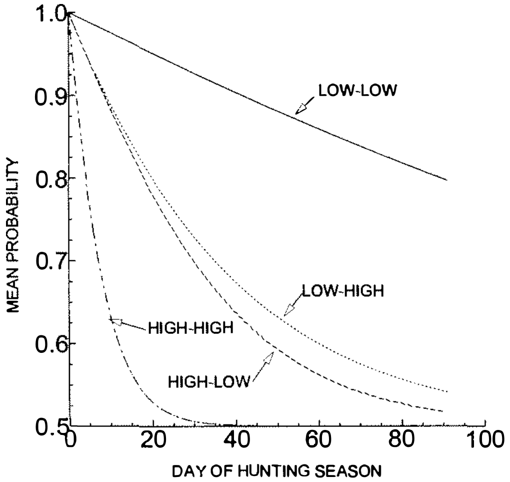

Fig. 1. Modeled trends in the mean probability of flush given an encounter for a bobwhite population consisting of naive and experienced coveys. Descriptors refer to hunting-intensity-learning rate; i.e., low-low indicates low hunting intensity and low learning rate. Experienced coveys have a lower conditional probability than naive coveys. The figure provides qualitative information on the dynamics of the mean probability.

$$(7) \qquad p_{f,t} = (p_{fn}C_{n,t} + p_{fe}C_{e,t})/(C_{n,t} + C_{e,t})$$

where

$p_{f,t}$ = average probability of flush given encounter for a population containing naive and experienced coveys on day t,

p_{fn} = probability of flush given encounter for naive coveys,

p_{fe} = probability of flush given encounter for experienced coveys,

$C_{n,t}$ = total population of naive coveys on day t, and

$C_{e,t}$ = total population of experienced coveys on day t.

The dynamics of naive and experienced covey populations may be defined in differential form as

$$(8) \quad C_{n,t+1} = C_{n,t} - jpC_{n,t}H - kpp_{fn}C_{n,t}H - lC_{n,t}$$
$$= C_{n,t}\,(l - jpH - kpp_{fn}H - l)$$

and

$$(9) \quad C_{e,t+1} = C_{e,t} + jpC_{n,t}H - kpp_{fe}C_{e,t}H - lC_{e,t}$$

where

j = the learning rate or rate at which coveys become experienced for each hunter-covey contact,

k = the loss rate to harvest for each hunter-covey contact,

l = the daily loss rate to nonhunting mortality, and

H = the number of hunting parties.

The coefficients may be considered as some fraction of a covey per unit of hunter-covey contact (j, k) or per covey (l).

RESULTS

The mean probability of flush, given encounter, initially declined as experienced coveys increased as a proportion of the total population (Figure 1). It was possible for the mean to stabilize at some value under high hunting pressure and a high learning rate. This stabilization occurred when the population was saturated with experienced coveys; i.e., coveys that encountered hunters during the hunting season.

The dynamic model revealed several qualitative outcomes of the hunter-covey interface under avoidance behavior (Figure 2). The population of naive coveys may only decline, whereas that of experienced coveys may grow throughout the hunting season. Naive coveys declined more rapidly as hunting pressure and learning rate increased; conversely, experienced coveys increased more rapidly to peak populations during the season as hunting pressure and learning increased. Under high hunting pressures and learning rates, it was possible for a population to consist entirely of experienced coveys for a large portion of the season (see HIGH-HIGH graph, Figure 2).

Temporal trends in the daily harvest would be similar to those for the mean probability of flush given encounter (Figure 1). Under these models, the total population declined continuously because of natural mortality. Likewise, the daily kill would decline continuously (holding hunting pressure constant) because the kill represents some fraction of the total population. Trends in daily kill will appear flat with low harvest rates, learning rates, and natural mortality. Trends will appear more spiked as these variables increase.

DISCUSSION

Empirically observed values for m range between 1.5 and 2.0 birds downed per covey flushed. Bennitt (1951) reported an average of 1.86 (SD = 0.076) for hunters in Missouri. Harvest data from a southern Texas corporate hunting lease, which included 2 hunters per covey flush, indicate m = 1.68 (SD = 0.572) (unpublished data).

The static model provides intuitive methodology for increasing or decreasing daily harvest or time available for hunting. This model predicts daily harvest declines as take per flush, velocity of travel, time spent hunting, width of the hunting zone, and the probability of flush, given encounter, decline (holding the population of coveys constant). Hunting time required to obtain a specified harvest on a given day varies inversely with the product of the 4 variables under management control, m, v, w, and p_f; i.e., the time required to meet the specific harvest goals increases in a hyperbolic fashion as the product of these variables decreases linearly.

The model resulting in qualitative analysis of the dynamic interface between hunter and covey warns against general statements concerning the effects of avoidance behavior. According to the model, effects are contingent on the learning rate and hunting pressure (Figure 1). Trends in the probability of flush, given encounter, under LOW-LOW and HIGH-LOW regimes illustrate the potential effects of hunting pressure under identical learning rates. Moreover, the prob-

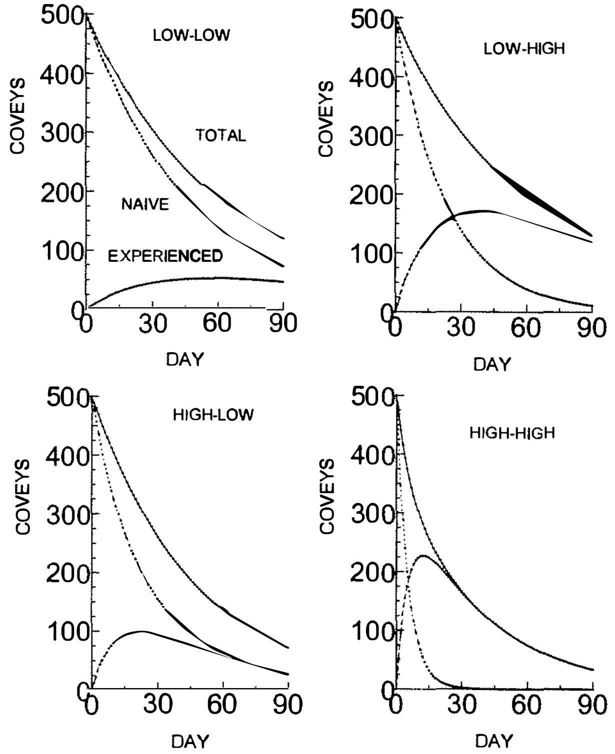

Fig. 2. Modeled trends in populations of naive, experienced, and total coveys under different hunting intensities and quail learning rates during a 90-day season. Descriptors refer to hunting intensity-learning rate. The figure provides qualitative information on covey dynamics because values of variables in the model are unknown.

ability of flush, given encounter, varies in a nonlinear manner over time. Under these models, the probability of flush, given encounter, was constant for experienced and naive coveys. Only the mean probability may vary with time, because of changes in the proportions of naive and experienced coveys. Therefore, there may exist periods within seasons where the mean probability of flush, given encounter, is unaffected by hunting intensity and learning rate (all coveys are experienced). This occurred at about day 45 in the hypothetical HIGH-HIGH regime (Figure 1). The mean probability changed imperceptibly after day 45.

MANAGEMENT IMPLICATIONS

If the assumption is that harvest makes no difference in population dynamics of quail, then there is no applied value in our models. However, if this is not the case, then the daily kill models illustrate several variables amenable to management action; velocity, time, width, baiting, and kill/flush. For example, the latter variable may be influenced by restricting hunters to smaller gauge shotguns. Also, the models may be used to maximize recreation. That is, solving to maximize *h* could be attained by manipulating the remaining variables in the daily harvest model. Finally, knowledge of the dynamics of hunter-avoidance could be applied in managing harvest. One could start with naive hunters, say youth, to propagate wariness and then allow the more experienced hunters access. In theory, this would maximize recreation with some constraints on the total harvest.

ACKNOWLEDGMENTS

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SURVIVAL RATES OF NORTHERN BOBWHITE CHICKS IN SOUTH-CENTRAL IOWA

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ABSTRACT

We estimated survival rates for radio-tagged northern bobwhite quail chicks (*Colinus virginianus*) in south-central Iowa from 1986 to 1988. Survival rates and survival functions were calculated for chicks from broods raised by females, broods raised by males and from broods that did not have an adult associated with them. Survival functions differed between broods with hens and those without adults. Predators accounted for almost all of the observed mortality.

Citation: Suchy, W. J., and R. J. Munkel. 2000. Survival rates of northern bobwhite chicks in south-central Iowa. Pages 82–84 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, Jr., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

INTRODUCTION

The advent of sub-miniature radio-telemetry makes it possible to collect demographic information unattainable by earlier methods. In a companion study we monitored 190 northern bobwhites through the nesting season from 1984–1988 and found that 11% of the clutches were produced by hens that laid and incubated a second clutch (Suchy and Munkel 1993). In most instances where this happened, the hen had left her first brood 19 to 25 days after hatching, became associated with a male, and then laid and incubated a second clutch of eggs. Suchy and Munkel (1993) also found that males incubated and raised 16% of all clutches produced. An obvious question that needed to be answered was: How well do chicks survive after the hen abandons her brood?

The objective of this study was to estimate chick survival rates from the period beginning 21 days after hatch, the time period when hens typically abandoned their broods to renest. We also tested if chick survival rates are lower when the hen abandons the brood to renest or when the chicks are brooded by a male.

METHODS

We captured bobwhite chicks using a 3 meter × 3 meter hoop net by locating radio-marked adults with broods at night. We then attached radio-transmitters and numbered leg bands on from 2 to 6 chicks from each brood and released the birds. Necklace style transmitters (<1 gram, Holohill, Ltd., London Ontario) were attached by spreading the loop over a hollow tube, inserting the bird's head into the tube and carefully rolling the loop off onto the bird's neck. Birds were located daily using truck-mounted and hand-held Yagi antennas. Radio-marked chicks were followed daily until their transmitters failed (usually after approximately 4 to 5 weeks). Chicks that did not successfully re-associate with their brood were excluded from analysis. An attempt was made to determine the proximate cause of death (Dumke and Pils 1973) when a mortality occurred.

Survival Rates

We calculated survival rates using the staggered entry technique (Pollock et al. 1989a,b) to produce Kaplan-Meier survival estimates (Kaplan and Meier 1958). Cause-specific mortality rates (Heisey and Fuller 1985) were calculated for all chicks combined. This assumes that daily survival rates are constant within the sampling period. Other assumptions required for this analysis are that radio-marked birds are selected randomly from the population, survival rates are independent, left-censored birds had similar rates, censoring was random, and trapping and tagging did not affect survival. Chicks were entered into the analysis based upon their age at capture.

Birds were right-censored if their fate was unknown due to radio failure. Log-rank tests were used to compare survival distributions between chicks from broods raised by females, males, and from broods that were abandoned. Z-tests were used to determine if survival estimates differed among these groups.

RESULTS

We captured 81 chicks from 1986–1988. Nine chicks were excluded because they slipped off their transmitter or failed to return to their brood. Analysis was performed on data from 41 chicks (from 9 broods) where the hen remained with the brood for the whole period, 11 chicks (from 3 broods) where the hen aban-

Table 1. Survival estimates for radio-marked northern bobwhite chicks from 21 to 59 days of age in south-central Iowa, 1986–88.

Type of brood	Number of broods	Number of individuals	Survival	SE
Female	9	41	0.817	0.083
Abandoned	3	11	0.729	0.165
Male	7	20	0.804	0.134
Combined	19	72	0.806	0.063

doned the brood and laid a second nest, and 20 chicks (from 6 broods that were cared for solely by males). The chicks captured from the broods where the hen abandoned the brood were captured 1–5 days before the hen abandoned them and were 17–20 days of age when captured. This made them 21 to 24 days old when they were abandoned. The chicks captured from broods headed by males were 18 to 25 days of age when captured and those from broods with hens were 18–28 days of age.

We estimated chick survival from 21 days to 56 days of age (Table 1) for the 3 groups of chicks. Survival estimates did not differ between chicks from broods headed by hens and those from broods that were abandoned (Z = 0.477, P = 0.636) but the survival functions (Figure 1) were different (χ^2 = 6.30, P = 0.012). Survival estimates for chicks from broods headed by males were similar to those from broods led by females (Z = 0.080, P = 0.937) and the survival functions were similar (χ^2 = 2.29, P = 0.131). Survival estimates (Z = 0.350, P = 0.729) and survival functions (χ^2 = 0.47, P = 0.495) were similar for chicks from broods led by males and chicks from broods that were abandoned.

Pooling all chicks produced a survival function in which mortality occurred at a fairly constant rate. The cause-specific mortality rates for the period were 0.140 for mammalian predation (n = 5, SE = 0.058), 0.056 for avian predation (n = 2, SE = 0.039) and 0.028 for unknown causes (n = 1, SE = 0.028).

DISCUSSION

Our estimate was 81% (95% confidence interval of ±12%) survival from age 21 days to 56 days for chicks. Survival rates for chicks from broods that were abandoned were lower during the first week after abandonment than for chicks from broods led by adults. However, the estimated survival rate by the end of the period was similar to chicks from the other broods. Chicks from broods led by males experienced the same level of mortality as chicks from broods led by females.

Because of the small size of the chicks, we did not attempt to monitor them for survival at ages younger than 17 days. We did not notice any large difference in the number of chicks in broods we captured compared to the number of eggs that were hatched by the adult; however, we did not try to make complete counts when we captured the broods. If survival is constant during this period we could extrapolate our findings to estimate survival from hatching to age 3 months. For all chicks combined this would produce a survival estimate of 52%.

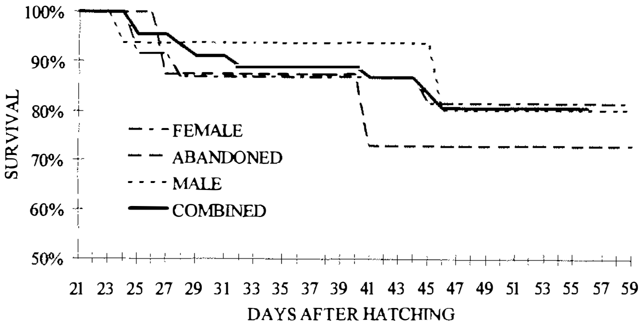

Fig. 1. Survival curves for northern bobwhite chicks in south-central Iowa from broods headed by females, males, no adult and for all chicks combined, 1986–88.

All of our estimates assume that the transmitters did not adversely affect survival. Although carrying a transmitter potentially lowered survival rates, we observed anecdotal evidence that overall survival of these birds was similar to other radio-marked adults in the concurrent study. We recaptured 3 birds during trapping activities that were captured as chicks and became right censured during the study. We also recovered 2 birds that were captured as chicks and were killed during the hunting season. Apparently none of these birds exhibited any ill effects from the radios. One of these birds was recovered a year and 3 months after it had been captured.

MANAGEMENT IMPLICATIONS

It appears that chicks are able to survive on their own after they reach approximately 3 weeks of age under the conditions tested in this study. This allows hens to renest and raise a second brood within a single nesting season. Given the low survival of adults (Burger et al. 1995, Suchy and Munkel, *this volume*) this contribution to the reproductive effort may be an important part of the ability of bobwhites to recover from low population levels.

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IS QUAIL HUNTING SELF-REGULATORY? NORTHERN BOBWHITE AND SCALED QUAIL ABUNDANCE AND QUAIL HUNTING IN TEXAS

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ABSTRACT

Wildlife managers often maintain that quail hunting is self-regulatory because they assume hunters spend fewer days hunting, and bag fewer quail per day, when hunting is "poor," while hunting more frequently, and bagging more quail per day, when hunting is "good." For this reason, managers conclude that minor changes in hunting season length and bag limit are inconsequential. We used August quail abundance (1978–1996) and harvest (1981–1983, 1986–1996) data collected by Texas Parks and Wildlife Department biologists to test the "self-regulatory" hypothesis for both northern bobwhites (*Colinus virginianus*) and scaled quail (*Callipepla squamata*). First, we tested the hypothesis that quail abundance in August was sufficient to account for the total number of quail bagged by hunters during the subsequent hunting season. We then tested the hypotheses that quail abundance could predict: (1) the number of days people hunted quail; (2) the number of quail bagged per hunter per day; and (3) the number of quail hunters during the subsequent hunting season. Quail abundance in August was correlated with the number of northern bobwhite and scaled quail bagged during the following hunting season ($r^2 = 0.769$ and 0.874, $P < 0.0005$, respectively). Texas hunters typically hunted quail about 2.5 to 3 days annually regardless of quail abundance. Quail abundance in August, however, was correlated with the number of quail bagged per hunter per day and the number of quail hunters during the subsequent hunting season (northern bobwhite: $r^2 = 0.895$ and 0.868, $P < 0.0005$, respectively; scaled quail: $r^2 = 0.833$ and 0.740, $P < 0.0005$, respectively). These results are consistent with the hypothesis that both northern bobwhite and scaled quail abundance can regulate quail hunting effort and success within the framework of the hunting regulations that have been in effect in Texas since the early 1980's.

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INTRODUCTION

It has long been recognized that northern bobwhite (*Colinus virginianus*) abundance typically fluctuates considerably among years over much of this species' range (Stoddard 1931:339–347, Rosene 1969:194–197, Schwartz 1974, Snyder 1978). Roseberry and Klimstra (1984:151–91) argued that fluctuations observed in northern bobwhite density on their research area in southern Illinois were cyclic. Similar fluctuations also have been noted for scaled quail (*Callipepla squamata*) in New Mexico (Campbell et al. 1973). In Texas, both northern bobwhite and scaled quail abundance fluctuates substantially among years (Figure 1). Additionally, there is apparent synchrony in quail abundance among the 6 Texas ecoregions (Gould 1975) where data were consistently collected since 1978 (Figure 2). This suggests that certain environmental factors act at a sufficiently broad spatial scale to influence quail abundance over much of Texas at roughly the same time.

In the past, many states, including Texas, attempted to use hunting regulations to decrease the number of quail harvested during periods of low abundance and increase harvest when quail were plentiful. The basic assumption underlying these efforts was that winter cover was inadequate to protect fall populations, so the number of quail above some threshold quantity was either lost to predation or dispersed (Errington 1934). Thus, the number of quail above this threshold were "surplus" and could be harvested by humans with no detriment to the spring breeding density or population viability. Consequently, some states reduced bag limits and/or season lengths when surveys indicated low quail abundance, and attempted to predict when high densities might occur, then subsequently increased bag limits and season lengths accordingly. This was a difficult task. For example, if fluctuations in Texas quail abundance among years (Figures 1–2) are primarily controlled by precipitation patterns, as suggested by Campbell et al. (1973:34–36), Kiel (1976), and Giuliano and Lutz (1993), then Texas Parks and Wildlife Department staff would find it difficult to accurately predict precipitation far enough in advance to use this information when setting hunting regulations (regulations typically are set 6 months be-

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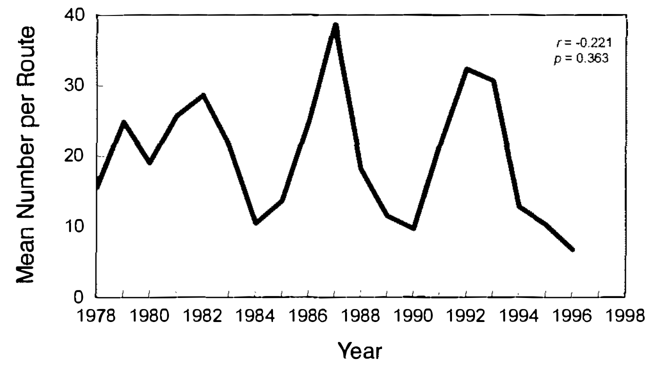
(A) Northern Bobwhite



(B) Scaled Quail

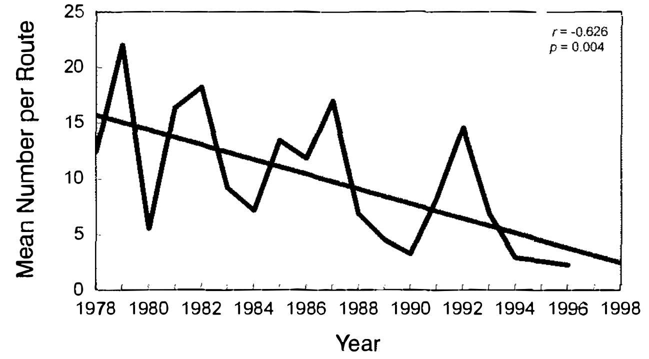
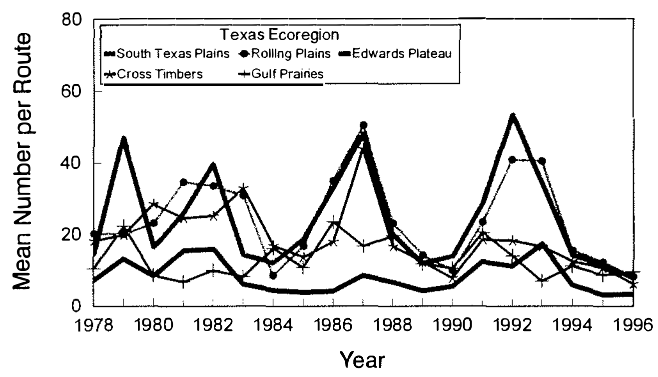


Fig. 1. Mean number of (A) northern bobwhites and (B) scaled quail counted annually per 20-mile (32.2 km) roadside survey route in Texas, 1978–1996 (Perez 1996; data from the Gulf Prairies, Cross Timbers, South Texas Plains, Edwards Plateau, Rolling Plains, and Trans-Pecos ecological areas [Gould 1975]).

(A) Northern Bobwhite



(B) Scaled Quail

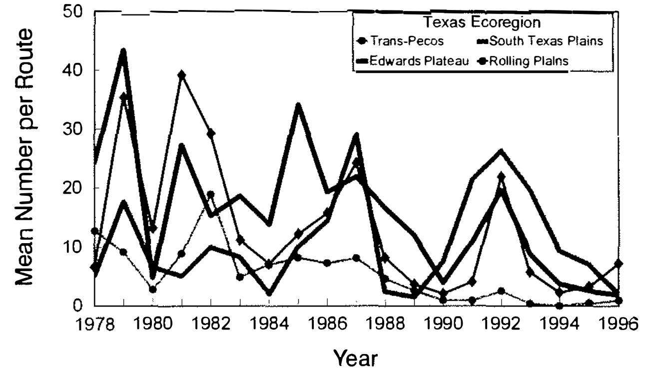


Fig. 2. Mean number of (A) northern bobwhites and (B) scaled quail counted annually per 20-mile (32.2 km) roadside survey route among each of 6 Texas ecological areas, 1978–1996 (Perez 1996).

fore the hunting season opens). Further, Roseberry (1979) predicted that, even if accurate estimates of quail production could be made sufficiently far in advance to vary hunting season length with quail abundance, only meager gains toward optimizing sustained yield harvest would be made.

In many states, including Texas, managers no longer attempt to compensate for fluctuations in quail abundance by altering statewide annual hunting season length or bag limits. This change in policy occurred for 3 reasons: First, managers typically assume that quail hunting intensity and success are largely self-regulatory, making micromanagement of the quail hunting season length and bag limit, at the statewide scale at least, unnecessary (Roseberry and Klimstra 1984:149). They assume that hunters spend fewer days hunting, and bag fewer quail per day, when hunting is "poor," while hunting more frequently, and bagging more quail per day, when hunting is "good." For example, Guthery (1986:153) argued that when quail densities are low and hunting success poor, hunters soon quit hunting—effectively closing the hunting season. Second, managers have realized that fine-grained management of quail harvest can only be accomplished by people who manage tracts of land where quail are hunted (Lehmann 1984:303, Roseberry and Klimstra 1984:149, Brennan and Jacobson 1992, Peterson 1996). Third, recent studies have demonstrated that northern bobwhite harvest is not completely compensatory (Curtis et al. 1989, Pollock et al. 1989, Robinette and Doerr 1993) and may become increasingly additive to other forms of mortality the later in the season harvest occurs (Roseberry and Klimstra 1984: 139–150). These observations call into question Errington's (1934) model of harvest theory. Strategies based on sustained yield are gaining more widespread acceptance (Roseberry 1982, Robertson and Rosenberg 1988, Brennan and Jacobson 1992, Caughley and Sinclair 1994:279–290). Moreover, Guthery (1996) argued that the fuzzy logic implicit in the additive versus compensatory harvest construct is detrimental to sound management of quail harvest and has confused the public and biologists alike. Therefore, because the relationship between hunting and the number of quail available to breed the next season is unclear, many managers maintain that data are insufficient as a basis for micromanagement of statewide hunting regulations.

Although researchers have addressed, to some degree, whether hunting-induced mortality is additive to other sources of quail mortality, the notion that quail hunting effort and success are self-regulatory has received little critical attention. Therefore, we used long-term quail abundance and harvest data collected by

Texas Parks and Wildlife Department biologists to test this hypothesis for both northern bobwhite and scaled quail hunting in Texas. Specifically, we tested whether quail abundance (as measured in August), can account for: (1) the total number of quail bagged; (2) the mean number of days people hunted quail; (3) the mean number of quail bagged per hunter per day; and (4) the total number of quail hunters during the subsequent hunting season.

METHODS

Data

Quail population trends in Texas have been monitored since 1978 using randomly selected, 20-mile (32.2 km) roadside survey lines (see Perez [1996] for the development of this technique and details of its application). Currently, 158 survey lines (20 miles each) are located in the Gulf Prairies, Cross Timbers, South Texas Plains, Edwards Plateau, Rolling Plains, High Plains, and Trans-Pecos ecological areas (Gould 1975). These routes were sampled once each August by Texas Parks and Wildlife Department biologists, either at sunrise (E to W) or 1 hour prior to local sunset (W to E). Typically only 1 to 3 biologists have run a given route over the duration of the survey. The lines were driven at 20 miles/hour (32.2 km/hour) and all quail observed were recorded by species for each 1-mile (1.6 km) interval. The number of young per brood and approximate brood age were also recorded. Because routes were not consistently run in the High Plains ecological area, these data were not included in our analyses. Northern bobwhites do not occur in the Trans-Pecos Ecological Area, while scaled quail do not inhabit the Gulf Prairies or Cross Timbers.

Quail harvest trends in Texas were determined for 1981–1983 and 1986–1996 as part of the annual Small Game Harvest Survey conducted by the Texas Parks and Wildlife Department (TPWD 1996). This survey was mailed annually to 15,000 randomly selected individuals holding a Texas hunting license. Survey questions included the species hunted, total number bagged, number of days spent hunting, and Texas county where the person hunted each species most often. Non-respondents were mailed a second and third notice for an overall mean response of 52.2%. When first implemented, the survey was mailed to both Texas residents and nonresidents. No differences were noted between the responses of these 2 groups so the survey was mailed to residents only during recent years. For the duration of the survey, the number of respondents hunting northern bobwhites and scaled quail ranged from 833 to 2,013 ($\bar{x}$ = 1,483) and 216 to 649 ($\bar{x}$ = 468), respectively.

The number of quail harvested per hunter and the number of days each hunter spent hunting quail exhibited a negative binomial distribution. Therefore, these data were arcsin transformed prior to further analysis. Regression analysis of responses to each of the 3 mailings (original survey plus the 2 reminders) was used to estimate these values for non-respondents (Armstrong and Overton 1977), thus correcting for the non-response bias associated with the survey technique. The total number of quail harvested and quail-hunter days were estimated by expanding the mean number of quail bagged per hunter by the estimated number of quail hunters. The number of quail harvested per hunter per day was obtained by dividing the estimated quail harvest by the number of quail-hunter days. Results were separately tabulated for both northern bobwhite and scaled quail by Texas ecological area (Gould 1975) and published in the annual Small Game Harvest Survey (TPWD 1996).

During the 1981–1982 and 1982–1983 quail hunting seasons, the County Commissioner's courts in Texas had authority to reject any regulatory changes proposed by the Texas Parks and Wildlife Department if they chose to do so. Consequently, bag limits ranged from 12 to 20 birds and possession limits from 36 to 60. In all but 1 Texas county, the quail hunting season opened between 31 October and 1 December and closed between 31 January and 15 February (exception: 15 October through 15 December). Because these bag and possession limits and season dates are similar to those used in later years (statewide: 15, 45, and Saturday nearest 1 November to last Sunday in February, respectively) we included all years in our analyses.

Analysis

If quail-hunting intensity and success are regulated by quail abundance in Texas, then one would expect that the mean number of quail observed per survey line in August should be sufficient to account for the total number of quail bagged by hunters during the subsequent hunting season. If this hypothesis is supported by data, then 1 or more of the following should be true: the mean number of quail observed per route in August should predict the (1) mean number of days hunters spent hunting quail; (2) number of quail bagged per hunter per day; and/or (3) number of people hunting quail during the subsequent hunting season. The last hypothesis may be more pertinent in Texas, where paying a fee for access to quail hunting areas is well established (Adams and Thomas 1983, Adams et al. 1992) than in some other states. Because we did not want to overlook any long-term trends in quail abundance, we also determined whether there was a trend in either northern bobwhite and scaled quail abundance over time.

We tested each of these hypotheses for both northern bobwhites and scaled quail using regression analyses (Wilkinson et al. 1992). The independent variable for each analysis was the mean number of quail observed per survey route (Perez 1996) for the Gulf Prairies, Cross Timbers, South Texas Plains, Edwards Plateau, Rolling Plains, and Trans-Pecos ecological areas of Texas (Gould 1975). The total number of quail harvested annually, the mean number of days each hunter spent hunting quail, the mean number of quail bagged per hunter per day, and the total number of people hunting quail (TPWD 1996) also were limited to these

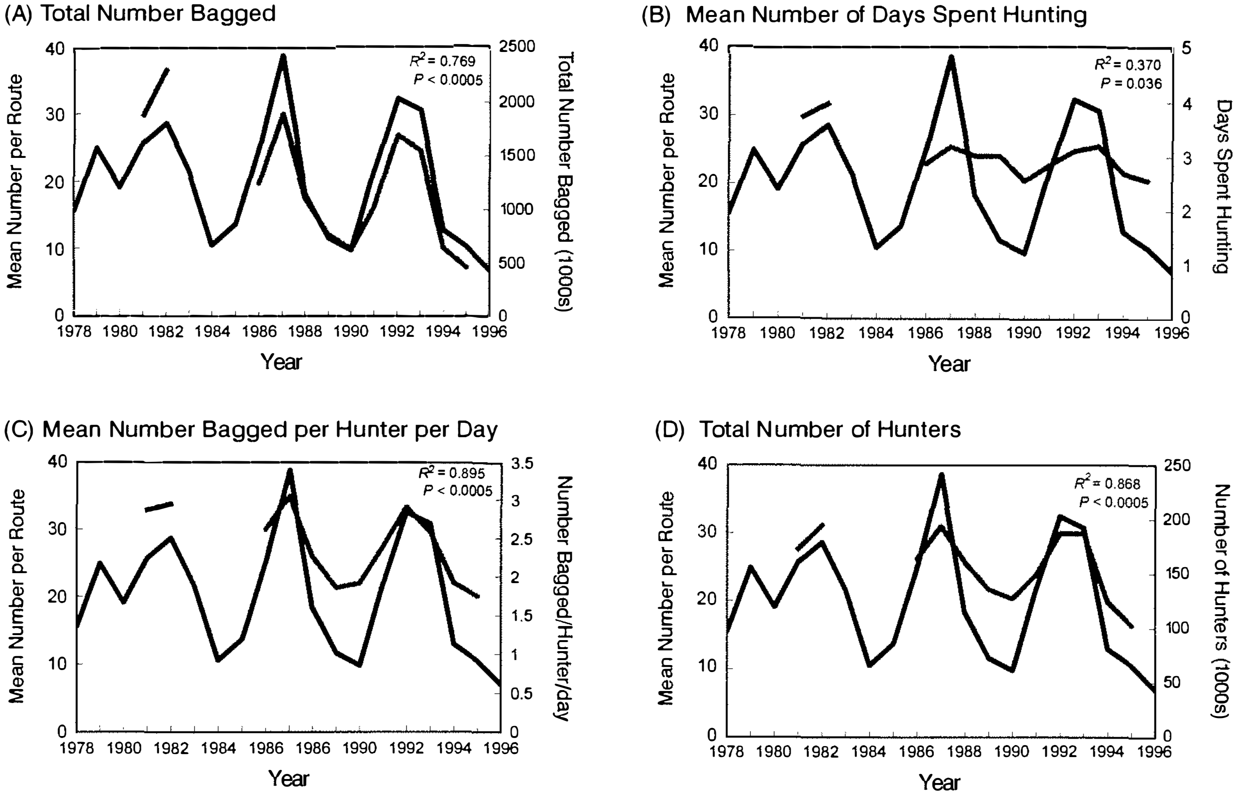


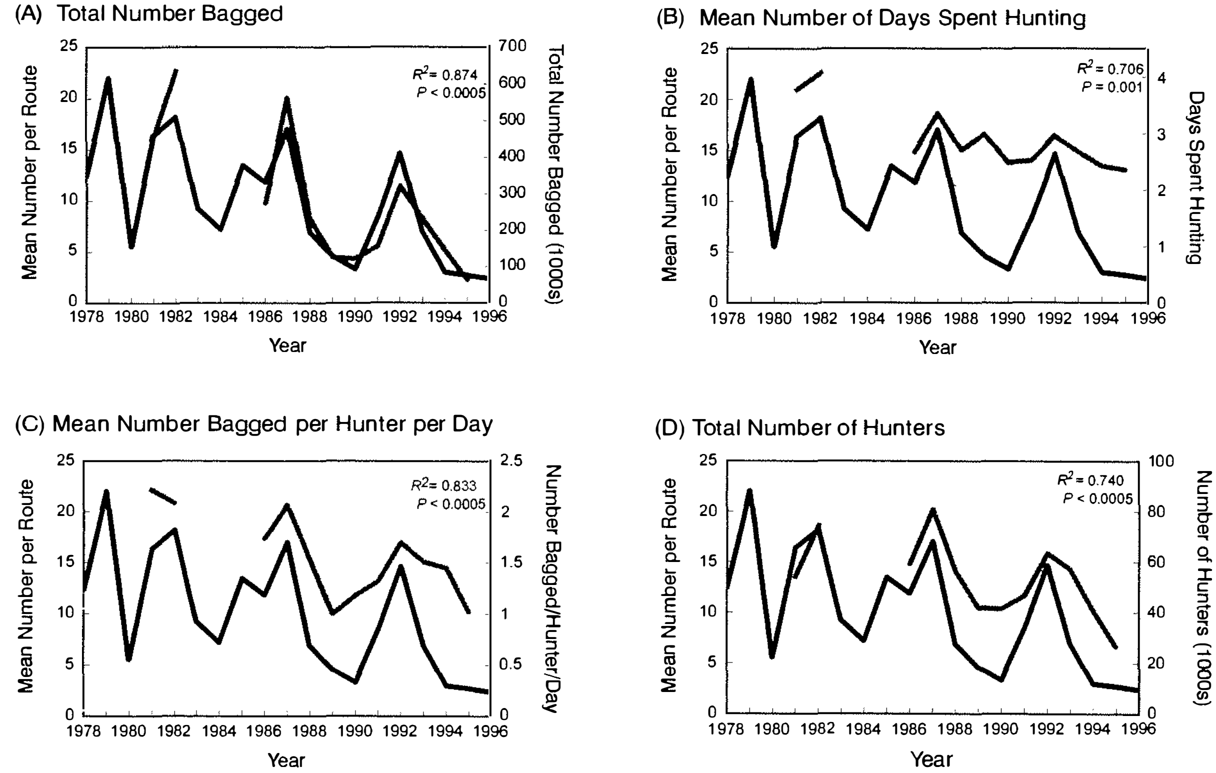
Fig. 3. Mean number of northern bobwhites counted annually per 20-mile (32.2 km) survey route in 5 Texas ecological areas shown in Figure 2A, 1978–1996 (solid line) and the estimated (A) total number of northern bobwhites bagged, (B) mean number of days each hunter spent hunting northern bobwhites, (C) mean number of northern bobwhites bagged per hunter per day, and (D) number of license holders who hunted northern bobwhites in these ecological areas (stippled lines), 1981–1983 and 1986–1996 (Perez 1996, TPWD 1996).

same ecological areas. Residual plots indicated that no further data transformations were necessary. We conducted all statistical analyses at the $P < 0.05$ level of significance.

RESULTS AND DISCUSSION

Rangewide quail abundance in Texas, as determined from August roadside counts, was sufficient to account for the total number of northern bobwhites and scaled quail harvested (Figures 3A and 4A; $R^2 = 0.769$ and 0.874, $P < 0.0005$, respectively) and the mean number of northern bobwhites and scaled quail bagged per hunter per day (Figures 3C and 4C; $R^2 = 0.895$ and 0.833, $P < 0.0005$, respectively). These results are similar to those reported by Schwartz (1974) during his 9-year study of northern bobwhite abundance (determined from August roadside counts) and harvest for Iowa. Similarly, Wells and Sexson (1982) reported that northern bobwhite abundance (number recorded by rural mail carriers per 100 miles [160.9 km]) in July or October (1962–1980) could predict both the total number of quail harvested in Kansas and the average daily bag. These data support the idea that quail abundance, as estimated by roadside surveys, can predict the number of quail harvested during the following hunting season at the statewide scale, at least in Texas, Iowa, and Kansas.

Although quail abundance in August was significantly related to the number of days people spent hunting northern bobwhites and scaled quail during the subsequent hunting season, these fluctuations were relatively small (Figures 3B and 4B; $R^2 = 0.370$, [$P = 0.036$] and 0.706 [$P = 0.001$], respectively). In essence, the average Texas quail hunter spent 2.5 to 3 days hunting quail annually regardless of quail abundance. We assumed, as did Guthery (1986:153), that Texas hunters would spend substantially fewer days hunting quail during years when quail abundance was relatively low. It appears, however, that the hypothesis that the quail hunting season in Texas is effectively closed when hunting is poor may still be tenable, but for a different reason. When quail abundance was low, substantially fewer people hunted northern bobwhites and scaled quail at all during the subsequent hunting season (Figures 3D and 4D; $R^2 = 0.868$ and 0.740, $P < 0.0005$, respectively). For example, during the quail peak seasons of 1982–1983, 1987–1988, and 1992–1994, an estimated mean of 187,189 people hunted northern bobwhites and 65,964 hunted scaled quail. Conversely, during the poor quail years of 1989–1990 and 1994–1995, only a mean of 122,157 and 37,680 people hunted northern bobwhites and scaled quail, respectively—a 34.7 and 42.9% decrease. Thus the quail season was effectively closed for a substantial proportion of quail hunters in Texas. The fee hunting system



(A) Total Number Bagged

(B) Mean Number of Days Spent Hunting

(C) Mean Number Bagged per Hunter per Day

(D) Total Number of Hunters

Fig. 4. Mean number of scaled quail counted annually per 20-mile (32.2 km) survey route in 4 Texas ecological areas shown in Figure 2B, 1978–1996 (solid line) and the estimated (A) total number of scaled quail bagged, (B) mean number of days each hunter spent hunting scaled quail, (C) mean number of scaled quail bagged per hunter per day, and (D) number of license holders who hunted scaled quail in these ecological areas (stippled lines), 1981–1983 and 1986–1996 (Perez 1996, TPWD 1996).

in Texas (Adams and Thomas 1983, Adams et al. 1992) may be part of the reason quail abundance influences fluctuations in quail-hunter numbers. It could be that, if a successful hunt appears unlikely, fewer hunters purchase access to quail hunting areas, while those who do pay for admittance hunt quail regardless of their abundance. Consequently, caution should be used in applying these results in other regions.

We observed that scaled quail abundance in Texas has declined significantly since 1978 (Figure 1B). Church et al. (1993) reported similar results for Texas and the remainder of this species' range in their evaluation of North American Breeding Bird Survey data. Conversely, our data did not show evidence of a long-term decline in northern bobwhite abundance for the composite Texas ecological areas we evaluated (Figure 1A). Brennan (1991), using Christmas Bird Count data, also observed no decline in northern bobwhite abundance in Texas. These results contrast sharply with most of the southeastern United States, where northern bobwhite abundance has declined during the last 30 years (Brennan 1991, Church et al. 1993). Texas Parks and Wildlife Department harvest data, however, suggest that northern bobwhite abundance in the Pineywoods Ecological Area, where habitat conditions are similar to the rest of the southeastern United States, has declined during this period. Because our northern bobwhite data were collected from relatively robust populations, one must be cautious in extrapolating our results to other parts of this species' range.

Although our data are consistent with the hypothesis that quail hunting is self-regulatory, we could not address how statewide changes in hunting regulations influence the number of quail harvested in Texas. As Roseberry (1979) predicted, it appears unlikely that relatively small regulatory changes would substantially alter the number of quail surviving after the hunting season (Figures 3–4). For example, because the typical person hunting northern bobwhite in Texas bags between 4 and 12 quail per season (depending on the year), and hunts quail 2.5 to 3 days, decreasing the daily bag limit by 2 birds (currently 15), and/or the season length by a week (currently 118 days), would be unlikely to influence the total number of birds bagged. Similarly, because our study was conducted at a statewide scale, we cannot address how small changes in the statewide daily bag limit and/or season length would influence the number of quail bagged, or the number of quail available to breed the following season, on a single, intensely-hunted pasture (Brennan and Jacobson 1992). However, during his 6-year study, Synder (1978) found that changes in season length and bag limit (ranging from 19 to 33 days and 6 to 8 birds) had little influence on the number of northern bobwhite harvested on his intensely hunted study area in eastern Colorado (1,623 ha of quail habitat). To address how more draconian changes in statewide quail hunting regulations might influence hunter effort and success would require experimental manipulation. Whether an experiment could be designed to yield statistically reliable results that could be extrapolated to the entire state of Texas, while remaining politically palatable, is open to question.

This study did not address the degree that hunting-induced mortality is additive to other forms of quail mortality, nor how variations in the statewide bag limit, hunting season length, and/or season timing influence this relationship. If we are to move away from the fuzzy logic implicit to the additive versus compensatory construct of quail-harvest theory to a model based on sustained yield harvest management (Roseberry 1979, 1982; Brennan and Jacobson 1992; Guthery 1996), experimental manipulations will be needed to determine the influence of hunting regulations on the number of quail available to breed during the next reproductive season. Because fine-grained management of quail harvest is best accomplished by those managing the tracts of land where quail are hunted (Lehmann 1984:303, Roseberry and Klimstra 1984: 149, Peterson 1996), we join Brennan (1991), Burger et al. (1994), and Burger et al. (1995) in calling for studies designed to determine the effect of harvest timing and intensity on the number of quail available to breed the next season at this fine-grained spatial scale.

SUMMARY AND IMPLICATIONS

Quail abundance, as determined by August roadside counts in Texas, was sufficient to account for the total number of northern bobwhite and scaled quail harvested, the mean number bagged per hunter per day, and the number of quail hunters during the subsequent hunting season. These data support the notion that Texas quail hunting, at the statewide scale, is regulated by quail abundance within the framework of the hunting regulations in effect since the early 1980's. Therefore, it is unlikely that small, statewide changes in the hunting season length or daily bag limit will significantly influence the number of quail available to breed during the next reproductive season. We have insufficient data, however, to address how substantial, statewide changes in hunting regulations influence hunter effort and success or the number of quail surviving until the following reproductive season. Similarly, additional research must be conducted to determine how hunting pressure influences reproductive numbers at the fine scale (pastures) where harvest management is best conducted.

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SURVIVAL OF NORTHERN BOBWHITES ON AREAS WITH AND WITHOUT LIBERATED BOBWHITES

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ABSTRACT

Increases in pen-raised quail releases are often implicated in the precipitous region-wide decline of wild northern bobwhites (*Colinus virginianus*). Therefore, we compared survival rates of wild radio-tagged northern bobwhites on a study area that received an influx of liberated pen-raised bobwhites from a neighboring property to those of wild bobwhites on a control area during 3 years in southwest Georgia. A total of 302 radio-tagged wild bobwhites were monitored on the wild-release (113) and wild-only areas (189) for a 22 week period from fall to spring each year during November 1993–April 1996. Fall-spring survival of wild bobwhites on the wild-only area (S = 0.43) was greater (P = 0.005) than that of wild bobwhites on the wild-release area (S = 0.18) for the 3 years combined. Losses to avian predation accounted for 38% and 58% of the fall population, respectively. Increased avian predation on the wild-release area may have been attributed to avian predators attracted to the area.

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INTRODUCTION

Liberation of pen-raised bobwhites prior to or during the hunting season is a common practice in the southeastern U.S. (Kozicky 1987, Landers et al. 1991, DeVos and Speake 1995). Much debate has occurred over whether this practice has contributed to or is in response to the decline in wild bobwhites over the past several decades. There are many concerns about possible effects that releasing pen-raised bobwhites might have on wild bobwhite populations (Landers and Mueller 1986, Landers et al. 1991, Hurst et al. 1993). Several possible negative effects have been suggested including disease transmission, genetic pollution, and increased mortality of wild birds (Brennan 1991, Landers et al. 1991, Hurst et al. 1993, Mueller et al. 1993); however, none of these topics have been thoroughly researched.

Landers et al. (1991) identified several high priority research topics which included effects of pen-raised bird releases on predator-prey relationships of wild birds. One of the suggestions in the Strategic Plan For Quail Management and Research in the United States (Hurst et al. 1993) was to "perform field research on predation rates of quail in a variety of experimental situations ranging from wild populations with no released birds to populations that have been subjected to extensive release of pen-raised quail." A recent study in Alabama (DeVos and Speake 1995) addressed this topic and concluded that slight increases in wild bird mortality could be expected; however, these differences were not statistically significant. These same authors concluded that the effects of pen-reared releases on wild bird predator-prey relations deserved further research.

As a follow up to that study, we took advantage of a "natural experiment" and examined survival of wild bobwhites on two areas, one with no liberated birds and a second that annually experienced an influx of liberated birds. Mortality rates of radio-tagged wild bobwhites were compared on an area that received an influx of pen-raised birds from a neighboring property to those on a control area where there were no pen-raised bobwhites. Our objectives were to determine if this influx of pen-raised birds had any effect on predation rates and fall-spring survival of wild birds.

STUDY AREA AND METHODS

This study was conducted on Nilo Plantation in Baker and Dougherty Counties, Georgia. Nilo is a 4,490 ha privately owned wild bobwhite hunting property located in the heart of southwest Georgia's plantation community near the city of Albany. The property has been under intensive bobwhite management for 50 years and supports an abundant population of wild bobwhites.

The habitat is maintained as a mixture of frequently burned, low basal area pine *(Pinus* spp.) woodlands, live oak *(Quercus virginiana)* savannahs, patch agricultural plantings, and open fields. Field system management consists of rotational agricultural plantings and fall disking to stimulate annual weed production and insects. A detailed description of Nilo can be found in Simpson (1976).

Two separate hunting courses were used as study areas. The area influenced by the pen-raised bird release (wild-release) was a 380 ha hunting course on the north end of the property. This area was bordered on one side by a public highway just across from a relatively small (500 ha) private property where extensive pen-raised bird releases were conducted prior to and during hunting season. The control area (wild-only) was a 316 ha hunting course on the south end of the property that was surrounded by wild quail land. The wild-only area was approximately 2 km from both the wild-release area and the property where the birds were released.

Wild bobwhites were trapped and released on both study areas during October–November of 1993–1995 using standard, baited funnel traps (Stoddard 1931). All captured birds were aged, sexed, weighed, and leg-banded. Each fall approximately 40 wild quail on each site that weighed >130g were chosen to be marked with radio-transmitters. Additional bobwhites were captured and radio-tagged as needed through the winter and early spring. We used a 6 g neck-loop mounted transmitter equipped with an activity switch (Holohil Systems Ltd., Ontario, Canada). All radio-tagged and/or banded birds were released at their capture site. Each radio-tagged bobwhite was located and checked for activity 2 to 3 times per week from capture until covey break-up in mid-April. Routine hunting was conducted on both study areas approximately once every 2 weeks. Specific causes of non-hunting mortality were determined, when possible, by evidence at the kill site and condition of the transmitter (Curtis et al. 1988).

In each of the 3 years studied, the wild-release study area was influenced by the release of a large number of pen-raised birds. These consisted of a large pre-season release (approximately 2,000 to 3,000 pen-raised bobwhites) and some subsequent smaller releases (200 to 500) during the hunting season. The exact timing and number of birds released is not known. Large numbers of these liberated birds were observed each year on the portion of Nilo adjoining this property (wild-release study site) by our staff as well as Nilo personnel. In 2 of the 3 years, the pen-raised bird release had not occurred prior to our trapping effort, and in the third year the recently released liberated birds were easily distinguishable due to their size, behavior, and vocalizations. No released birds were observed on the wild-only area.

Survival estimates for the wild radio-tagged birds on both areas for the 22-week period from capture to covey break-up were estimated using the Kaplan-Meier staggered entry design (Kaplan and Meier 1958, Pollock et al. 1989), which allowed for inclusion of additional birds during the study and censoring due to radio failure or emigration. Mortalities that occurred within 1 week of radio attachment were not used in the analysis (Robinette and Doerr 1993). Comparisons of survival curves between years and among groups were done using log-rank tests (Pollock et al. 1989). All tests were conducted at the $P < 0.05$ level.

Table 1. Kaplan-Meier survival estimates for radio-tagged bobwhites on a wild-only and pen-raised quail influenced (wild-release) study area in southwest Georgia, November–April, 1993–1996.

Year	Study area	*N*	Survival	95% CI
1993–94	Wild only	63	0.482[a]	0.376–0.588
	Wild-release	43	0.183	0.060–0.306
1994–95	Wild only	74	0.349	0.267–0.431
	Wild-release	40	0.222	0.086–0.358
1995–96	Wild only	52	0.316[a]	0.226–0.404
	Wild-release	30	0.100	0.017–0.183
1993–96	Wild only	189	0.430[a]	0.370–0.490
	Wild-release	113	0.180	0.110–0.250

[a] Indicates survival rates were greater ($P < 0.05$) than on the wild-release area.

RESULTS

We monitored 302 radio-tagged bobwhites from November to mid-April from 1993 to 1996. This included 113 bobwhites on the wild-release area and 189 on the wild-only area. Log-rank tests indicated no significant differences in survival curves between the 3 years on the wild-release area ($P = 0.51$) or the wild-only area ($P = 0.47$); therefore, data for all 3 years were combined for each study area. During the 1993–94 season, estimated fall-spring survival was greater ($P < 0.005$) on the wild-only area ($S = 0.482$) than on the wild-release area ($S = 0.183$) (Table 1). During 1994–95, fall-spring survival was again higher on the wild-only area ($S = 0.349$) than on the wild-release area ($S = 0.222$); however, this difference was not significant ($P = 0.066$). During the 1995–96 season, fall-spring survival was again significantly greater ($P = 0.043$) on the wild-only area ($S = 0.32$) than on the wild-release area ($S = 0.10$). For the 3 years combined, fall-spring survival of wild bobwhites was greater ($P < 0.005$) on the wild-only area ($S = 0.43$) than on the wild-release area ($S = 0.18$).

Predation was the leading cause of mortality on both study areas accounting for the mortality of 42% and 69% of the bobwhites on the wild-only and wild-release area, respectively. Avian predators were responsible for most (69%) of the known predation mortalities on both areas. Harvest of radio-tagged birds was not different ($P = 0.84$) on the 2 sites, averaging 12.7% on the control area and 11.2% on the wild-release area.

DISCUSSION

Wild bobwhites on our study area that adjoined a pen-raised bobwhite release area and were invaded with large numbers of liberated pen-raised quail experienced significantly higher fall-spring mortality than their counterparts on an area where no pen-raised birds were observed. An earlier study on this topic (Sexson and Norman 1972) concluded native quail were lost at a higher rate on areas where pen-raised quail were released; however, the mechanics of cause and effect were obscure. Recent research on this topic (DeVos and Speake 1995) in Alabama did not indicate any large increases in wild quail mortality due to predation; however, their data did suggest that slight increases in mortality could be expected. A similar study in South Carolina (Mueller et al., unpublished data) has similarly seen no increased mortality of wild birds due to pen-raised bird releases after 1 year of study. These discrepancies are most likely due to differences in wild quail density, as well as the size and scope of the pen-raised quail release. Our wild-release study site had an abundant native quail population and was surrounded on 3 sides by thousands of hectares of excellent quail habitat and abundant wild quail populations. The neighboring property that liberated the pen-raised birds was literally an "island" in a sea of wild quail land. This led to an unusual set of circumstances where a large number of pen-raised birds were introduced into an area already populated by a large number of wild quail. Our observations were that many species of quail predators, especially hawks and owls, were drawn to this site to prey on liberated birds and this increased predation pressure carried over to the wild birds as well. Other sets of circumstances such as lower native quail populations and/or a more widespread release of pen-raised birds at a lower density may not produce the same predator-prey interactions we observed or the increased mortality we documented.

This study was the result of taking advantage of a "natural experiment" that was beyond our control and was therefore unreplicated in nature. This limits the inferences that can be drawn; however, the data suggest that large scale pen-raised bird releases on or near a wild bobwhite area can negatively effect wild bobwhite survival. The fact that these relationships were documented for 3 consecutive years supports this case. This could prove significant as our studies of managed quail land in the area are documenting the importance of overwinter survival in maintaining high bobwhite populations (Burger et al. 1998). In addition, little is known about other possible interactions between pen-raised and wild bobwhites such as those concerning diseases and genetics.

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PREDATORS AND PRICKLY PARADIGMS: NESTING ECOLOGY OF BOBWHITES AND SCALED QUAIL IN WEST TEXAS

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ABSTRACT

Sporadic recruitment appears to be the impetus for the irruptive population patterns observed along the western edge of northern bobwhite (*Colinus virginianus*) range. We investigated hen survival, nest selection strategies, and reproductive success of sympatric northern bobwhites and scaled quail (*Callipepla squamata*) in west Texas. Radio-marked bobwhites, along with a smaller sample of sympatric scaled quail, were monitored during the spring and summer of 1994 and 1995. Predation was the major source of mortality, with mammals and raptors responsible for about 60 and 30 percent of the mortalities observed, respectively. We used TrailMaster camera systems to document the presence and behavior of various nest predators. Raccoons (*Procyon lotor*) appear to be the dominant nest predator in this area, accounting for over 80 percent of the nests destroyed. Photographic surveillance of artificial nests provides some clues for making objective assessments of predators involved in nest depredations. The amount and kinds of egg shell evidence at a nest site varied with egg size (chicken vs quail). We found egg shell evidence at 83 percent of nests using chicken eggs, but only at 3 percent of nests using quail eggs. We predict that snakes are overrated in their importance as a nest predator, when such diagnoses are based solely on the absence of physical evidence (i.e., no egg shells). Our results suggest that pricklypear (*Opuntia* spp.) was a key nesting microhabitat. Overall, 12 of 21 bobwhite and 8 of 12 scaled quail nests were located in pricklypear. Subsequent investigations revealed that nests situated in pricklypear were afforded higher survival, especially in more arid sites with less traditional nesting cover (e.g., *Schizachyrium scoparium*). Initial results with intensive, short-term mammal removal suggest that nest survival can be increased for about $0.35 per hectare.

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DEPREDATION PATTERNS OF NORTHERN BOBWHITE NEST PREDATORS IN VIRGINIA

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ABSTRACT

Little information exists that can be used to accurately identify predator species responsible for destruction of northern bobwhite (*Colinus virginianus*) nests. We used remotely-tripped cameras to photograph nest predators at 25 wild bobwhite nests that were continually filled with eggs from pen-raised quail. Data describing depredation events were collected to characterize species-specific damage patterns. Seven species of nest predators were photographed 1,797 times from June to October 1996. We describe depredation patterns for opossums (*Didelphis marsupialis*), striped skunks (*Mephitis mephitis*), raccoons (*Procyon lotor*), gray fox (*Urocyon cinereoargenteus*), and domestic dogs (*Canis familiaris*). These descriptions should help researchers identify the predator species responsible for destroyed bobwhite nests.

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INTRODUCTION

Nest depredation is the primary cause of northern bobwhite nest failure throughout their range (Stoddard 1931, Rosene 1969, Klimstra and Roseberry 1975, Simpson 1976, Lehman 1984, DeVos and Mueller 1993, Burger et al. 1995, Puckett et al. 1995, Hurst et al. 1996). Unfortunately, little information exists that provides an objective basis for accurately determining which predator species are responsible for specific depredation events. Most published reports providing diagnostic information for interpreting evidence at destroyed nests are based on studies of waterfowl (Reardon 1951) or other species (Darrow 1938, Mosby and Handley 1943, Einarsen 1956). The criteria used to describe such evidence are often ambiguous and sometimes contradictory (Baker 1978, Sargeant et al. 1998). As a result, estimates of the proportion of nests destroyed by individual predator species are frequently based on conjecture, and are therefore potentially inaccurate.

Although researchers have long recognized the need for accurately characterizing species-specific nest depredation patterns, few objective techniques have been available to address the problem. Studies attempting to distinguish patterns of predation have utilized captive-fed animals (Stoddard 1931, Darrow 1938), hair catchers (Baker 1980, Trevor et al. 1991), animal tracks (Nelson and Handley 1938, Reardon 1951), and direct field observations (Einarsen 1956). These techniques are often impractical or involve subjective assessments that make accurate diagnoses difficult, especially in complex predator communities. The recent use of remotely-tripped cameras has enabled investigators to photograph nest predators at simulated ("dummy") nests (Martin et al. 1987, Picman 1987, Leimgruber et al. 1994, Picman and Schriml 1994) and to link evidence at depredated nests to the responsible predator species (Hernandez et al. 1997). In this study, we used remotely-tripped cameras to identify nest predators and then quantify physical evidence at the depredated nest. The information presented in this paper should be useful to researchers attempting to assess which predator species are responsible for destroyed bobwhite nests.

METHODS

We conducted our study on 13 privately owned farms in Amelia County, located in south-central Virginia, from June to October 1996. Camera units triggered by passive infrared sensors (Cam Trakker®) were installed at 25 nests that had previously been incubated by wild, radio-tagged bobwhites. All nests had either hatched ($n = 4$) or been depredated ($n = 21$) prior to camera installation. Camouflaged camera units were mounted on metal stakes approximately 2 to 3 meters from the nest and 1 meter above the ground. The passive infrared beam was aligned to trigger the camera to photograph any animals approaching within 0.25 meters of the nest. Cameras contained an automatic film advance and were programmed for a 3-minute time delay between photographs. Cameras were operational 24 hours per day and equipped with an automatic flash for night photography. Each photograph was imprinted with the date and time that the event occurred.

Twelve eggs from pen-raised bobwhites were placed into each nest, closely approximating the average size clutch for wild bobwhites in Virginia (Fies, unpublished data). A bobwhite wing was placed over the clutch to conceal the eggs and simulate the presence of an incubating bird. All nests were monitored daily, usually during morning hours, and replenished with fresh eggs after each depredation event.

Physical evidence at depredated nests was quantified using procedures described by Sargeant et al. (1998). The number, extent of damage, and spatial arrangement of eggshell remains were documented on data sheets and photographed with a Polaroid® camera. Additional evidence (tracks, feces, etc.) was noted when present. All eggshell remains were collected, labeled, and stored in a freezer for verification purposes.

Slides taken by remote camera units were catalogued and examined for the presence of nest predators. Incidental observations of other species were also noted. At each nest, the number of different individuals of each species photographed was estimated by comparing pelage markings. Only data from depredation events involving a single species of nest predator were used to characterize damage patterns. Events involving multiple species of predators, or where the camera ran out of film during the depredation event, were excluded from analyses. Average values for depredation variables were calculated using Microsoft Access®, version 2.0.

RESULTS

Twenty-two different animal species were photographed 1,966 times at 25 nests (Table 1). Seven species (n = 1,797 photographs) were observed depredating eggs and 15 species were photographed at nests that were undisturbed or had previously been destroyed. Striped skunks and opossums were the species most frequently photographed, accounting for 41.4% and 36.5% of the nest predator photographs, respectively. Other species photographed destroying nests, in order of frequency, included the domestic dog (9.0%), gray fox (8.1%), raccoon (4.0%), groundhog (*Marmota monax*) (0.6%), and black rat snake (*Elaphe obsoleta obsoleta*) (0.4%). Species photographed, but not confirmed as nest predators, included the hispid cotton rat (*Sigmodon hispidus*), white-footed mouse (*Peromyscus leucopus*), domestic cat (*Felis catus*), and bobcat (*Lynx rufus*). Incidental photographs were taken of whitetail deer (*Odocoileus virginianus*), domestic cattle (*Bos taurus*), eastern cottontails (*Sylvilagus floridanus*), an eastern gray squirrel (*Sciurus carolinensis*), and an eastern chipmunk (*Tamius striatus*). Bird species photographed included northern bobwhite, mourning dove (*Zenaida macroura*), northern mockingbird (*Mimus polyglottos*), brown thrasher (*Toxostoma rufum*), and brown-headed cowbird (*Molothrus ater*).

Single-species depredation data were obtained for 222 events involving at least 44 individuals of 5 nest predator species. The amount of eggshell evidence, extent of eggshell damage, and arrangement of eggshells at depredated nests varied between species (Table 2).

Table 1. Minimum number of individual animals and the number of times species were photographed (% in parentheses) with remotely-tripped cameras at artificial bobwhite nests (n = 25) in Virginia, June–October 1996.

	Minimum number of individuals	Number of photographs
Actual nest predators		
skunk	15	744 (41.4)
opossum	20	655 (36.5)
dog	17	162 (9.0)
gray fox	4	146 (8.1)
raccoon	16	71 (4.0)
groundhog	3	11 (0.6)
black rat snake	4	8 (0.4)
Total	79	1,797 (100.0)
Potential nest predators/shell scavengers		
cotton rat	1	85 (66.9)
white-footed mouse	3	35 (27.6)
domestic cat	3	5 (3.9)
bobcat	2	2 (1.6)
Total	9	127 (100.0)
Other species		
northern bobwhite	2	12 (28.6)
mockingbird	2	10 (23.8)
unknown bird species	5	5 (11.9)
cow	2	3 (7.1)
brown thrasher	1	2 (4.8)
mourning dove	1	2 (4.8)
whitetail deer	2	2 (4.8)
eastern cottontail	2	2 (4.8)
eastern gray squirrel	1	2 (4.8)
eastern chipmunk	1	1 (2.3)
brown-headed cowbird	1	1 (2.3)
Total	20	42 (100.0)
All species	108	1,966

Opossum

Nest depredation data were collected for 15 opossums that destroyed 110 nests. Opossums usually ate most of the eggs in the clutch ($\bar{x}$ = 9.6), but left 1 or more whole eggs in many (50.0%) of the depredated nests. Opossums removed eggs from the nest with their mouth, but usually held them between their front paws to consume them. After biting into the shell to expose the yolk, the entire egg was placed into the mouth and chewed up. The chewed shell was swallowed entirely or spit out.

Eggshell evidence was present at 96 of 110 (87.3%) opossum depredation events. Almost all (92.1%) of the eggshells were severely damaged; sometimes all that remained was a membrane with small shell fragments attached. The presence of this membrane was diagnostic of opossum depredation and was found at 65.5% of the nests destroyed by this species. An average of 3.8 damaged shells were found at nests depredated by opossums. Most eggshells (86.9%) were found within 1 meter of the nest site, but few (2.6%) were found in the nest bowl. The nest structure was usually undisturbed; only 11 (10.0%) of the 110 nests had a small to moderate amount of the nest material displaced during the depredation event.

Striped Skunk

We collected data for 77 striped skunk depredation events involving 15 individuals. Skunks typically ate

Table 2. Mean number of eggs eaten, frequency that eggshells were present, mean number of eggshells, frequency of eggshells by damage type, and distribution of eggshells by distance for depredated artificial northern bobwhite nests in Virginia, June–October 1996, where the nest predator species was known.

Species	Minimum individuals (n)	Depredation events (n)	Eggs eaten ($\bar{x}$)	Events with shells (%)	Shells left ($\bar{x}$)	Eggshells by damage type: Small holes (%)	Large holes (%)	Severe damage[a] (%)	Eggshells by distance from nest: In nest (%)	≤20 cm (%)	>20 cm–1 m (%)	>1 m (%)
Opossum	15	110	9.6	87.3	3.8	2.6	5.3	92.1	2.6	55.3	31.6	10.5
Skunk	15	77	11.7	100.0	10.1	0.9	34.7	64.4	42.6	40.6	14.8	2.0
Raccoon	10	10	9.3	10.0	4.0	0.0	25.0	75.0	0.0	75.0	25.0	0.0
Gray Fox	2	7	9.1	14.3	4.0	0.0	75.0	25.0	0.0	0.0	75.0	25.0
Dog	2	18	12.0	0.0	0.0	—	—	—	—	—	—	—
Total	44	222										

[a] Includes fractured, trampled, and crushed eggshells. See Sargeant et al. (1998) for definitions.

all eggs in the clutch, consuming an average of 11.7 of the 12 eggs available. Whole eggs were left in only 9.1% of skunk-depredated nests. Skunks usually laid down while eating an egg, holding it against the ground with their front paws and biting into the shell to release the yolk. The hole was enlarged by pushing its nose into the shell and the contents were slowly licked out.

Eggshell evidence was present at all (100.0%) skunk depredation events; an average of 10.1 shells were found at each depredated nest. Many shells (34.7%) had a large hole with fragments pressed inward, presumably where the skunk pushed its nose into the shell. Most shells (64.4%) were damaged more severely. Skunks usually ate eggs close to the nest site; 83.2% of all eggshells were less than 20 centimeters from the nest bowl. Many eggshells (42.5%) were found in the nest and few (2.0%) were found more than 1 meter away. Skunks displaced nest material at 40.3% of depredated nests and often matted the vegetation where they laid down to eat the eggs.

Raccoon

Depredation data were collected at 10 nests destroyed by 10 different raccoons. Raccoons ate most of the eggs in the clutch ($\bar{x}$ = 9.3), although whole eggs were left uneaten at 4 (40.0%) of the depredated nests. Raccoons removed eggs from the nest with their front paws and consumed them while holding the egg in an upright position. Most eggs appeared to have been ingested completely since eggshells were found at only 1 of 10 (10.0%) depredated nests. In this instance, 4 eggshells were found within 1 meter of the nest; 3 of these (75.0%) were less than 20 centimeters away. One shell had a large hole (similar to damage described for skunks) and the other 3 shells were fractured more severely. Nest material was displaced at 4 (40.0%) of 10 depredated nests.

Gray Fox

Nest depredation data were collected for 2 gray foxes that destroyed 7 nests. Foxes removed an average of 9.1 of the 12 available eggs. Whole eggs were left in 2 (28.6%) of the 7 depredated nests. All 12 eggs were missing in most (71.4%) of the nests depredated by this species. Gray foxes typically removed eggs from the nest 1 at a time, presumably to cache or consume the egg away from the nest site. The fox then returned, repeating this behavior, until all the eggs in the nest were taken.

Eggshell evidence was present at only 1 of 7 (14.3%) nests depredated by gray foxes. In most instances (57.1%), there were no eggs, shells, or shell fragments remaining at the nest site. Of the 4 eggshells found at 1 depredated nest, 3 (75.0%) had large holes and 1 (25.0%) was severely damaged. All shells were found more than 20 centimeters from the nest. No nest material displacement was observed at nests depredated by gray foxes.

Dogs

We collected depredation data for 2 dogs that destroyed 18 nests. In all instances, there were no eggs, shells, or shell fragments remaining at the nest. Dogs appeared to eat eggs at the nest site, consuming them entirely. Nest material was displaced at 50% of the nests depredated by dogs. Other dogs often visited nests but did not eat any eggs. Sometimes they ate the bobwhite wing that was covering the clutch. Of the visits involving dogs for which the number of eggs eaten could be determined ($n = 40$), the eggs were not consumed 42.5% of the time.

Other Species

Several other species were observed eating bobwhite eggs, but damage patterns could not be characterized because multiple species were involved in the depredation events. Four black rat snakes and 1 eastern kingsnake (*Lampropeltis getula getula*) were observed eating bobwhite eggs. On 2 occasions, a snake was found eating eggs when the nest was checked by field technicians and no photographs had been taken by the remote camera unit. Three black snakes were photographed depredating nests. A groundhog was also photographed eating bobwhite eggs. Although 3 different groundhogs were photographed 11 times at nests, only 1 individual could be confirmed as a nest predator. It appeared that this groundhog ate 3 to 4 eggs on at least 1 occasion.

DISCUSSION

The amount and type of evidence left at depredated nests is influenced by numerous factors, only 1 of which is the predator species responsible for the depredation event. Age (or size) of the predator, variation in individual behavior, presence of multiple animals (i.e., family groups), and availability of alternate food sources can all affect the manner in which a nest is preyed upon (Sargeant et al. 1998). Habitat characteristics of nest sites (density and structure of vegetation) may also affect the appearance of depredated nests and the arrangement of eggshell evidence.

Egg size affects the number of eggs eaten, extent of shell damage, distribution of eggshells, and the ability of a predator to remove an egg from the nest site. Smaller eggs are opened more easily, more likely to be transported from the nest site (Montevecchi 1976), and more likely to be consumed completely. Hernandez et al. (1997) found eggshell evidence at 93% of depredated artificial nests containing chicken eggs versus 3% when bobwhite eggs were used. Researchers should exercise caution when comparing depredation patterns described for predators destroying nests containing large eggs (Reardon 1951) with evidence left at depredated bobwhite nests.

Characteristics of nest destruction previously described for several predator species differ from those observed in this study. Stoddard (1931) reported that opossums remove bobwhite eggs 1 at a time and "gulp them down with evident relish," leaving behind little evidence to identify it as the culprit. Similarly, Darrow (1938) reported that opossums consumed the major portion of grouse eggs and left only small bits of shell. In contrast, we observed eggshell evidence at 87.3% of nests depredated by opossums, frequently with crushed membranes that were diagnostic of depredation by this species. Other evidence that strongly indicates that a nest was destroyed by an opossum includes finding fewer than 5 crushed shells scattered within 1 meter of the nest (no shells in the nest bowl) and no displaced nest material.

Raccoons also depredated bobwhite nests differently in this study compared to what researchers have reported for nests of other species. Raccoons depredating waterfowl nests typically left eggshells with large holes at the nest site (Reardon 1951, Sargeant et al. 1998). Darrow (1938) observed that raccoons usually left most of the eggshell intact when depredating grouse nests. In our study, raccoons appeared to consume entire eggs, only leaving eggshell evidence at 1 (10.0%) depredated nest. Hernandez (1995) also found no eggshell evidence at nests baited with bobwhite eggs that were depredated by raccoons, but frequently found eggshells at nests containing chicken eggs. Differences in egg size may explain these observed variations in depredation patterns. Raccoons may leave less evidence at bobwhite nests since the eggs are smaller, simpler to handle, easier to crush, and more likely to be completely consumed than waterfowl or chicken eggs. A bobwhite nest with several whole eggs left, no eggshells, and some nest material displaced is likely to have been depredated by raccoons.

We observed characteristics of nests depredated by skunks that were similar to those described by other researchers. Sowls (1948) reported that skunks bite into duck eggs and use their paws or tongue to enlarge the opening, usually crushing at least half of the shell. This crushed appearance was also noted by Darrow (1938) and Reardon (1951). Sargeant et al. (1998) found that duck eggs depredated by skunks usually had large elliptical holes that caved inward. In all these studies, including our own, the shells were not chewed up and were left close to the nest. Considerable amounts of nest material were also frequently displaced. A bobwhite nest destroyed by a skunk usually had no whole eggs remaining, many eggshells in and near the nest (frequently every depredated egg can be accounted for), and nest material was often displaced or the nearby vegetation may be trampled.

Little published information is available describing characteristics of nests destroyed by gray foxes. Nelson and Handley (1938) reported that gray foxes usually left no shell fragments, sometimes removed only a portion of the clutch, and rarely disturbed the nest structure when removing bobwhite eggs from a nest. In our study, gray foxes depredated bobwhite nests similarly. Other investigators have described depredation patterns for red foxes like those that we observed for gray foxes. In these studies, red foxes usually took all eggs from the nest, did not disturb the nest material, left no eggshell evidence, and cached the eggs away from the nest (Darrow 1938, Reardon 1951, Sargeant et al. 1998). Although we did not locate any cached eggs at depredated nests, they could have been overlooked. Sargeant et al. (1998) reported that duck eggs cached by red foxes in enclosures were inconspicuous and located an average of 44 meters from the nest. They also reported that most incubating hens were killed and carried away from the nest to be eaten; usually only a few breast or tail feathers were left at the nest site. In our area, any nest where the incubating bird is killed and the eggs are missing is likely to have been depredated by foxes.

Domestic dogs are rarely mentioned as a nest predator of northern bobwhites or other game birds. Stoddard (1931) reported that "cur dogs" destroyed a minimum of 3% of the bobwhite nests he studied, usually leaving behind only a few pulverized eggshell fragments. Simpson (1976) could attribute only 1 of 1,092 depredated nests to dogs; in this case, the nest structure was completely destroyed and no shell fragments were found. In our study, dogs frequently visited nests but often left the eggs undisturbed. If the eggs were eaten, no eggshell evidence was left behind. The likelihood that a dog would depredate a nest is probably related to how well it was fed by its owner. Dogs might also be more likely to consume eggs containing well-developed embryos (all eggs used in this study were unincubated). Besides eating the eggs, free-roaming dogs may have detrimental impacts on nest success by harassing incubating birds and causing nest abandonment.

In some studies, snakes are implicated as the predator responsible for destroyed nests that have no physical evidence remaining at the nest site (Davis 1959, Henry 1969, Dillon 1993). Our data show that other nest predators often remove eggs or consume them whole, leaving behind no eggshells. By itself, the absence of eggshell evidence is inadequate justification for attributing nest depredation to snakes. Although numerous species of snakes have been observed depredating bobwhite nests (Stoddard 1931, Simpson 1976), studies that rely solely on a lack of eggshell evidence to conclude that a snake depredated a nest are likely biased (Hernandez 1997). Unfortunately, most investigators who report a moderate or high proportion of bobwhite nests depredated by snakes (Klimstra and Roseberry 1975, DeVos and Mueller 1993, Burger et al. 1995, Puckett et al. 1995) do not adequately describe the methods upon which their conclusions are based. Therefore, it is difficult to ascertain if snake depredation rates were overestimated in these studies.

Snakes were only infrequently observed depredating bobwhite nests in our study. However, the passive infrared sensor was probably less likely to be triggered by snakes than by mammals. Snakes often move slowly and have body temperatures similar to their environment. Of 463 depredation events that we observed, 33 (7.1%) were instances where eggs were missing, no eggshells were present, and no photograph was taken. Snakes may have been involved in some of these depredation events. The absence of an incubating bird and low egg temperatures probably reduced the likelihood that snakes would depredate our nests. In Nebraska, Glup and McDaniel (1988) reported that bullsnakes frequently destroyed waterfowl nests, but only rarely took cold eggs from abandoned nests.

Several species that were observed to be nest predators by other investigators were not observed to depredate nests in our study. Stoddard (1931) and Simpson (1976) reported that cotton rats sometimes depredated bobwhite eggs, but we could not attribute any nest predation to this species. Cotton rats were photographed 85 times at nests, but they appeared to be shell scavengers that consumed the remains of partially eaten eggs left by other predators. White-footed mice also scavenged eggshells. Other possible nest predators photographed included 3 house cats and 2 bobcats but the eggs were never eaten by these species. Stoddard (1931) reported that house cats usually killed the incubating bird but did not consume the eggs unless they contained well-developed embryos. Bobcats did not eat eggs at 5 depredated bobwhite nests in Georgia (Simpson 1976) but did consume eggs at 2 artificial bobwhite nests in Texas (Hernandez 1995). Other investigators have also reported that crows, blue jays, and turkeys (domestic and wild) occasionally destroy bobwhite nests (Stoddard 1931). However, we found no evidence that these species depredated nests that we studied, even though they were abundant and would have little difficulty locating our nests. Repeated site visits and deterioration of the nest structure after multiple depredation events made these nests easy to detect by avian predators.

Although this study provides useful data to characterize patterns of depredation for some nest predators, we do not attempt to use our results to infer which species have the greatest negative impacts. In our study, the frequency that various species depredated nests was biased, since the same individuals often depredated nests repeatedly. The absence of an incubating bird may have reduced predation rates by species that rely on olfactory cues (i.e., foxes). Also, the presence of the camera units may have caused more timid species to avoid the nests. For example, red foxes were present on the study area but were never photographed depredating nests. Red foxes are important nest predators of other species, particularly waterfowl (Sargeant et al. 1984). Other species photographed that did not depredate eggs (i.e., bobcat) may have been frightened by the camera flash or noises associated with the camera system.

Although characteristics of depredation sometimes varied among individuals of the same species, certain patterns were apparent. The presence or absence of certain characteristics can often be used to help determine which predator species are involved in depredation events (Table 3). However, many other factors (multiple predators, time elapsed since the depredation event, clutch size, incubation stage, etc.) also affect the type and amount of evidence left at depredated nests. Therefore, accurate identification of the predator species responsible will not always be possible. Researchers should recognize the importance of these factors and exercise caution when attributing nest destruction

Table 3. Characteristic evidence left at depredated northern bobwhite nests that can be used to identify the predator species most likely responsible for depredation events when observations are made within 24 hours of occurrence. Characteristic evidence descriptions are based upon authors' data and information reported by Sargeant et al. (1998).

Characteristic evidence	Most likely predator
Usually fewer than 5 eggshells present; whole eggs sometimes present; most shells severely damaged; usually one or more shells obviously chewed up with remnants consisting of membrane with small shell fragments attached; all shells usually within 1 m of nest but none in nest bowl.	opossum
All eggs eaten; 10 or more eggshells usually present; many shells with large holes and fragments pressed inward; almost all shells found within 20 cm of nest; some shells usually found in nest bowl.	striped skunk
All or most eggs missing; no shells or shell fragments present; nest material sometimes displaced; incubating bird not killed.	raccoon
All or most eggs missing; no shells or shell fragments present; cached eggs occasionally found; no nest material displaced; incubating bird frequently killed.	fox
All eggs missing; no shells or shell fragments present; nest material frequently displaced; incubating bird not killed.	dog
All or some eggs missing, no shells or shell fragments present; no nest material displaced; incubating bird usually not killed.	snake

to specific predators. Despite these limitations, we believe that predator species responsible for destroyed nests can often be identified by objectively evaluating evidence at depredated nests and combining this with information on local predator species presence and abundance.

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SEASONAL SURVIVAL AND CAUSE-SPECIFIC MORTALITY OF NORTHERN BOBWHITES IN MISSISSIPPI

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ABSTRACT

Knowledge of northern bobwhite (*Colinus virginianus*) survival and rates at which specific mortality agents remove individuals from the population is important for implementation of science-based harvest and habitat management regimes. To better understand population response to habitat management, we monitored 194 radio-marked northern bobwhites in managed old-field habitats in east-central Mississippi, 1993 to 1996. Bobwhite populations increased during the first 3 years following initiation of disking and burning practices. During the 2nd year of bobwhite habitat management breeding season survival (0.509) was high relative to other southeastern populations. However, breeding season survival declined from the 2nd through the 5th year of management (1993, 0.509; 1994, 0.362; 1995, 0.338; 1996, 0.167; $P < 0.001$). Declining seasonal survival was attributable to increasing mammalian mortality from 1993 to 1996 ($P < 0.01$). Avian mortality rates were stochastic and differed among years ($P = 0.04$), while unknown mortality rates were similar ($P = 0.13$). Avian mortality evidently operated in a density-dependent fashion, whereas mammalian mortality continued to increase despite declining bobwhite population. Northern bobwhite cause-specific mortality rates among years differed by sex ($P < 0.01$) and age ($P < 0.01$). Indices of breeding season relative abundance declined with declining survival. We hypothesize that manipulations (burn, disk, burn/disk) which created habitat that met the seasonal requirements of breeding bobwhites and other early successional prey species, may have resulted in a functional and numerical response of mammalian predators.

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INTRODUCTION

Northern bobwhite populations have declined over most of the species range during the last 3 decades (Droege and Sauer 1990, Brennan 1991, Church et al. 1993). In the southeastern United States, North American Breeding Bird Surveys indicate an average annual decline of 3.5% from 1966 to 1996 (Sauer et al. 1997). These declines have been attributed to loss of early successional habitats associated with changing agricultural and forestry practices (Vance 1976, Exum et al. 1982, Roseberry et al. 1979, Klimstra 1982, Roseberry and Klimstra 1984, Brennan 1991). Habitat management is the prescription most frequently offered by wildlife biologists to halt population declines or enhance local bobwhite populations (Brennan 1991).

Numerous studies have described habitats used by bobwhites; several studies have reported population trends in relation to changing land use practices (Kabat and Thompson 1963, Vance 1976, Exum et al. 1982, Roseberry et al. 1979, Roseberry and Klimstra 1984). However, few studies have monitored bobwhite population response to habitat management. Webb and Guthery (1982) reported that habitat management (disking, brush piles, grazing exclosures, and half-cutting mesquite trees) on mesquite and sand shinnery oak rangelands in Texas apparently increased bobwhite use by 1.5- to 2.2-fold. From 1957–1965, bobwhite populations on Remington Farms, Maryland increased from 5 to 38 coveys/1214 ha following habitat improvements (Burger and Linduska 1967). Ellis et al. (1969) reported that on public wildlife management areas in Illinois, habitat management based on a food-patch system did not maintain quail populations; however, management regimes based on sharecropping and prescribed fire produced densities near 0.4 birds/ha. Burger et al. (1998) reported high seasonal and annual survival of bobwhites on an intensively managed plantation in Georgia. Taylor and Burger (1997) reported reproductive success of bobwhite in relation to successional vegetation management in Mississippi. How-

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ever, no study has monitored temporal changes in bobwhite survival following initiation of a habitat management regime.

Survival, reproduction, and movements into and out of the population are important determinants of population size (Johnson 1994). Precise and unbiased estimates of these parameters are necessary for science-based harvest and habitat management (Curtis et al. 1988, Pollock et al. 1989*a,* Murphy and Noon 1991, Burger et al. 1994, 1995). To quantify bobwhite population response to management, we examined temporal variation in survival and cause-specific mortality during the 2nd through 5th years following implementation of a vegetation management regime designed to create and maintain early successional plant communities in old-field habitats of northern Mississippi.

STUDY AREA

We captured, radio-marked and monitored bobwhites on the Trim Cane Wildlife Research and Demonstration Area (TCWA), 10 km north of Starkville, Oktibbeha County, Mississippi. The 320 ha-area was under rowcrop production until 1986; natural plant succession began following harvest in 1986. The developing vegetation community consisted primarily of broomsedge (*Andropogon virginicus*), Johnson grass (*Sorghum halepense*), and annual and perennial forbs (Manley 1994). A network of drainage canals left by the channelization of Trim Cane Creek dissected the area, most of which was subject to frequent inundation during winter and spring. Pioneer hardwood species such as box elder (*Acer negundo*) and green ash (*Fraxinus pennsylvanica*) dominated moist areas in fields adjacent to Trim Cane Creek, and areas of poor drainage throughout the study area.

During 1992, TCWA was divided into 50 fields, averaging 6.5 ha in size (Manley 1994) and 1 of 4 management regimes (prescribed burning, strip-disking, burn-disk combinations, control) was randomly assigned to each field. Control areas were allowed to succeed naturally; these area rapidly developed into a shrub/sapling community dominated by green ash, box elder, eastern baccharis (*Baccharis halimifolia*), or loblolly pine (*Pinus taeda*) (Manley 1994). During the period 1993 to 1996, habitat composition of TCWA and associated private lands used by radio-marked bobwhite averaged 9.1% control, 18.4% burned, 13.5% disked, 14.7% burn/disked, 11.5% pasture, 9.5% rowcrop, 22.6% woody shrubs.

METHODS

We trapped bobwhites with walk-in funnel traps baited with commercial 3-grain chicken scratch or cracked corn (Stoddard 1931). Bobwhites were aged, sexed, weighed to the nearest 1 g, banded with a #7 aluminum leg band, radio-instrumented with a 5–6 g pendant-style transmitter, and released at the capture site. Radio-transmitters operated on the 148.000 to 149.999 MHZ band and included a mortality sensor switch and a 25-cm antenna. Trapping began in late winter and continued well into the breeding season to maintain an appropriate sample size.

We located radio-marked birds ≥5 days/week using a programmable scanning receiver and handheld Yagi, or H-series antennas. Fixed-wing aircraft were used to locate individuals that dispersed great distances from the study area. Upon detecting a mortality signal, transmitters were located immediately. Evidence at the recovery site, along with transmitter condition, was used to determine the proximate cause of mortality (Dumke and Pils 1973). If signs of both avian and mammalian predators were present, or if no obvious signs were detected, the mortality factor was recorded as unknown.

We based breeding season survival rates on a 180-day interval (1 Apr-27 Sep) which began with covey breakup and initiation of reproduction (Burger et al. 1995). We used the Kaplan-Meier method (Kaplan and Meier 1958) generalized to the staggered entry case (Pollock et al. 1989*b,c*) to estimate seasonal survival. We made the following assumptions: (1) birds were randomly sampled; (2) survival times were independent among individuals; (3) censoring mechanisms (i.e., radio-failure, emigration) were random; (4) left-censored individuals (entered at staggered intervals) had survival distributions similar to previously marked birds; and (5) survival probability was not affected by trapping, handling, or radio-marking (Pollock et al. 1989*b,c*; White and Garrott 1990; Burger et al. 1995).

Birds with an unknown fate (radio-loss, radio-failure, emigration from study area, or survival past 27 September) were right-censored. Birds were allowed a 7-day period of adjustment following radio-marking, and all censored and dead observations during this period were excluded from survival analysis (Kurzejeski et al. 1987; Curtis et al. 1988; Pollock et al. 1989*b,c;* Burger et al. 1995).

We used the program STAGKAM (Kulowiec 1989) to estimate breeding season survival (Pollock et al. 1989*b*). We used the program CONTRAST (Sauer and Williams 1989) to test hypotheses of no differences in overall survival between ages, sexes, and years. We used the program MICROMORT (Heisey 1985) to calculate cause-specific mortality rates for breeding bobwhite, assuming that daily survival is constant during intervals. Cause-specific mortality rates are represented as the probability of an individual dying from a specific mortality agent during the 180-day breeding season interval, given that other competing mortality agents were present (Heisey and Fuller 1985, Burger et al. 1995). We assumed that censoring mechanisms were random, and censored observations were not considered dead or alive (Pollock et al. 1989*b*). We compared cause-specific mortality rates between years, ages, and sexes using a likelihood-ratio goodness-of-fit test (Sauer and Williams 1989).

During the second week of June, 1992 to 1996, we conducted 5-minute counts of calling males on each of 3 mornings from 11 permanent stations distributed throughout the study area. Counts were com-

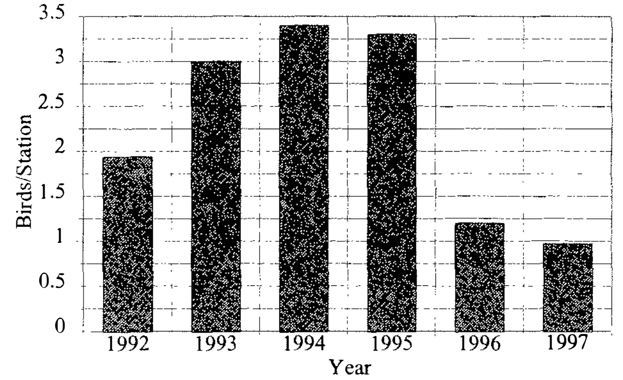

Fig. 1. Mean number of northern bobwhite males calling per station in managed old-field habitats on Trim Cane Wildlife Research and Demonstration Area, MS, 1992 to 1997.

pleted during the first 3 hours after sunrise, and mean number of whistling males/station was used as an index to breeding season density.

RESULTS

We radio-marked 194 bobwhites from 1993 to 1996 (55, 51, 57, and 31, respectively). We excluded 27 birds (13.8%) from analysis because they died or were censored within 7 days of capture (3 in 1993, 11 in 1994, 8 in 1995, and 5 in 1996). Of the remaining 167 marked individuals, 43 were alive at the end of the breeding seasons (24 in 1993, 6 in 1994, 10 in 1995, and 3 in 1996). We right-censored 40 of these 167 individuals (23.3%) due to radio-failure or emigration (27), radio-loss (5), trap-related mortality (5), or radio-related mortality (3).

Relative Abundance

Following initiation of burning and disking management practices on TCWA, mean number of whistling males/station increased from 1992 to 1994 (Figure 1). Relative abundance peaked in 1994, then declined after 1995.

Seasonal Survival

Breeding season survival of bobwhites differed among years ($S_{1993} = 0.509$, $S_{1994} = 0.362$, $S_{1995} = 0.338$, $S_{1996} = 0.167$; $X^2 = 10.54$, 3 df, $P = 0.01$; Table 1) and declined from 1993 to 1996. Survival differed between sexes ($X^2 = 23.04$, 6 df, $P < 0.001$), with females exhibiting higher breeding season survival. Breeding season survival was similar between age classes ($S_{\text{adults}} = 0.304$, $S_{\text{sub-adults}} = 0.417$; $X^2 = 11.30$, 6 df, $P = 0.08$).

Table 1. Breeding season survival of radio-tagged northern bobwhite in managed old-field habitats at Trim Cane Wildlife Research and Demonstration Area, MS, 1 April to 27 September, 1993 to 1996.

Year	N	S[a]	95% C.I.[b]
1993	52	0.509	±0.143
1994	40	0.362	±0.253
1995	49	0.338	±0.171
1996	26	0.167	±0.150

[a] Survival rate.
[b] 95% confidence interval on survival rates.

Cause-Specific Mortality

We used observed mortalities of 84 bobwhites to estimate cause-specific mortality rates during the breeding season. Cause-specific mortality rates differed among years ($X^2 = 34$, 14 df, $P < 0.01$). Avian, mammalian, and unknown predators accounted for most of the natural mortality, whereas mortality directly related to severe weather and accidents (automobile-related mortality) was low (Table 2). Mammalian mortality rate increased significantly from 1993 to 1996 ($X^2 = 13.51$, 3 df, $P < 0.01$; Table 2). Avian mortality rates were stochastic and differed among years ($X^2 = 8.3$, 3 df, $P = 0.04$), while unknown mortality rates were similar across years ($X^2 = 5.74$, 3 df, $P = 0.13$). Cause-specific mortality rates among years differed by sex ($X^2 = 50$, df = 24, $P < 0.01$) and age ($X^2 = 45$, df = 24, $P < 0.01$).

DISCUSSION

Habitat manipulations initiated in 1992 converted grass-bound broomsedge fields into a mosaic of early successional habitat patches that were used by radio-marked bobwhites for nesting, brood-rearing, foraging, loafing and roosting (Taylor and Burger, *this volume*). These management practices were conducted during each year, at the same intervals, with the same intensity. Bobwhite populations on TWCA apparently responded to these practices insofar as breeding season indices of relative abundance increased from 1992–1994. Breeding season survival (51%) during the 2nd year of management was well above that typically reported throughout the Southeast (Curtis et al. 1988, Burger et al. 1995, 1998). In the 2nd and 3rd years of

Table 2. Breeding season cause-specific mortality of radio-tagged northern bobwhite in managed old-field habitats at Trim Cane Wildlife Research and Demonstration Area, MS, 1 April to 27 September, 1993 to 1996.

Year	Cause	Radio-days	N[a]	M[b]	95% C.I.[c]
1993	Mammal	5,239	7	0.1665	±0.112
	Raptor		4	0.0951	±0.088
	Unknown		11	0.2616	±0.132
	Car		1	0.0238	±0.046
1994	Mammal	2,779	4	0.1660	±0.148
	Raptor		9	0.3735	±0.191
	Unknown		2	0.0830	±0.110
1995	Mammal	4,534	12	0.2928	±0.138
	Raptor		3	0.0731	±0.080
	Unknown		10	0.2440	±0.131
	Weather		2	0.0488	±0.066
1996	Mammal	1,359	12	0.5815	±0.208
	Raptor		2	0.0969	±0.127
	Unknown		5	0.2423	±0.184

[a] Mortalities during season due to specific agent.
[b] Cause-specific mortality rate.
[c] 95% confidence interval on survival rates.

the study breeding season survival declined. Breeding season survival on TCWA, 1994–95, (0.339) was similar to that of radio-marked bobwhite in Missouri (0.332, Burger et al. 1995), North Carolina (0.328) and Florida (0.40) (Curtis et al. 1988). Mean survival from 1993 to 1996 (0.368) was also similar to other populations reported in the literature; however, pooling over years obscures the temporally declining pattern. Breeding season relative abundance peaked in 1994, following the high breeding season survival observed in 1993. Relative abundance began to decline in 1995, and declined precipitously in 1996. Two years of high breeding season mortality and associated low reproductive success (Taylor and Burger 1997) may have contributed to reduced breeding populations in 1996.

Predation was the primary cause of mortality during the breeding season. Cooper's hawks (*Accipiter cooperi*) and great-horned owls (*Buteo virginianus*) were likely responsible for most avian depredation, whereas most mammalian depredation was attributed to feral cats. Predation may limit, regulate, or have little effect on prey populations. Predation may simply be the proximate mechanism that brings populations down to a level limited by habitat availability (Errington 1934). Predation has been defined as limiting when it prevents or slows a rise in population levels. Newton (1993) defined predation as limiting when it "measurably depresses prey breeding numbers below what the habitat could otherwise sustain." Although predation on nests and young is the primary cause of reproductive failure for many avian species and can influence recruitment and fall population size (Cote and Sutherland 1997), predation on adults is most likely to affect subsequent breeding populations (Newton 1993). Newton (1993) identified several types of predator-prey interactions that might depress breeding bird populations below levels that the habitat would support. He suggested that density-dependent predation can regulate numbers around an equilibrium level below that which habitat would support. The nature of the density-dependent relationship may be mitigated by the quantity and quality of breeding habitat. Further, density-independent predation can in some circumstances result in depression of prey breeding populations and in rare cases, local extirpation.

Predation is generally thought to act in a density-dependent fashion with predators accounting for a smaller proportion of a prey population at low prey densities than at high. Conversely, the rate of predation from a given type of predator should decline as prey populations decline. During our study, predation by avian predators seemingly behaved in a density-dependent fashion, with avian cause-specific mortality generally tracking breeding season relative abundance. This may represent a functional response of avian predators to bobwhite abundance. Keith et al. (1977) similarly reported a functional response of great-horned owls and red-tailed hawks to snowshoe hare abundance. Alternatively, because of the great mobility of avian predators, this may have represented a numerical response of hawks and owls concentrating in an area of high prey density (Newton 1993). In contrast, mammalian cause-specific mortality remained relatively constant from 1993 to 1994 as breeding abundance increased. Any mammalian density-dependent response to increasing bobwhite populations from 1992 to 1994 lagged 1 to 2 years behind. Less mobile mammalian predators might be slower to respond to density than avian predators because any numerical response is more dependent on reproduction than immigration (Newton 1993). After the bobwhite population began declining in 1995, predation by mammalian predators was insensitive to bobwhite abundance, doubling each year from 1994 to 1996, despite declining bobwhite abundance. Mammalian cause-specific mortality seemed to drive declining breeding season survival and subsequent year breeding populations, instead of being responsive to bobwhite abundance in a density-dependent fashion.

MANAGEMENT IMPLICATIONS

During our study, we witnessed changes in breeding season survival and rates of cause-specific mortality over a 4-year period on a non-hunted bobwhite population. While our estimates of low survival and high mortality may reflect short-term fluctuations in an isolated portion of east-central Mississippi, bobwhite populations at landscape and regional levels are exhibiting long-term declines. Furthermore, these rates of decline have increased within the past decade, suggesting that current landscape patterns may not allow bobwhite populations to sustain themselves under current habitat conditions, depredation regimes, and hunter harvest rates (Curtis et al. 1988, Burger 1994, 1995). Relationships among bobwhite abundance, landscape composition and complexity, and predation will not be understood until viewed as a dynamic process and evaluated with carefully designed, replicated experiments (Burger et al. 1994, 1995, Leopold and Hurst 1994). Thus, design must include estimates of density and availability of all prey species (Craighead and Craighead 1956); density estimates of the predator community (Latham 1951); and replication across spatial and temporal scales (Miller and Speake 1978).

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PRELIMINARY FINDINGS ON THE FORAGING ECOLOGY OF A NORTHERN BOBWHITE PREDATOR IN NORTH FLORIDA: THE COOPER'S HAWK (*ACCIPITER COOPERII*)

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ABSTRACT

As part of a larger study of the ecology of the Cooper's hawk (*Accipter cooperii*) in the Northern Highlands and Red Hills regions of North Florida, we collected data on landscape-level habitat selection, home range size, and diet of resident adult Cooper's hawks from April 1996–April 1997 on study areas in northern Leon County (Tall Timbers Research Station) and western Suwannee County. Data on habitat selection and home range size were collected by intensively tracking 8 radio-instrumented adult Cooper's hawks (3 males and 5 females) originally captured while breeding at nest sites on the study areas. Diet information on the study areas was obtained by observing Cooper's hawk prey deliveries at nest sites from blinds, by collecting prey remains from prey handling perches around nests, and by documenting prey captures by radio-tagged hawks. In this poster we present some preliminary findings from the first year of this study that may have implications for wildlife managers wanting to minimize rates of predation on bobwhites by Cooper's hawks.

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EFFICIENCY OF POINTING DOGS IN LOCATING NORTHERN BOBWHITE COVEYS

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ABSTRACT

We studied the efficiency of pointing dogs in locating coveys of northern bobwhites (*Colinus virginianus*) using radiotelemetry from 1992–1997 on 2 private hunting plantations in southwest Georgia. During these 5 hunting seasons, 169 hunts generated data on 838 "encounters" with 254 separate radio-marked coveys. Pointing dogs located 53% of the available coveys, 25% of which were never seen by the hunters due to evasive behavior by the birds. An additional 12% of encountered coveys were seen by the hunters even though they were never located by the dogs. This resulted in the hunters seeing a total of just over half (53%) and shooting into approximately one-third (32%) of the total radio-marked coveys they encountered.

An evaluation of "false pointing" was conducted by examining cases when dogs pointed radio-marked coveys that were never seen by the hunters. Most (58%) of these unproductive points were caused by coveys running away from pointing dogs, but were also attributed to wild flushes (28%) and pointed coveys that held tight and refused to flush (14%).

The percentage of radio-marked coveys seen by hunters was highly variable from day-to-day ($\bar{x}$ = 53%, range = 0–100%), but fairly consistent between years ($\bar{x}$ = 53%, range = 40–63%). Information obtained using pointing dogs appears to be more practical for measuring population trends than it is as a census technique.

Citation: Sisson, D.C., H. L. Stribling, and D.W. Speake. 2000. Efficiency of pointing dogs in locating northern bobwhite coveys. Page 109 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, Jr., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

INFLUENCE OF HABITAT TYPE AND PRESCRIBED BURNING ON FERAL SWINE DEPREDATION OF ARTIFICIAL QUAIL NESTS

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ABSTRACT

Feral swine (*Sus scrofa*) have increased both spatially and numerically in the Rolling Plains of northwest Texas. Resource managers have little information on the interrelationships between feral swine and native species such as the northern bobwhite (*Colinus virginianus*). Nest predation by feral swine could adversely affect bobwhite reproduction. Honey mesquite (*Prosopis glandulosa*) and redberry juniper (*Juniperus pinchotii*) are the dominant woody plants in northwestern Texas and prescribed burning is used to manage both species. Two experiments were conducted to determine the extent of feral swine depredation on artificial quail nests. In 1992–93, we monitored nest loss in mesquite and juniper habitats for six weeks. Total depredation reached 85 and 98% after three and six weeks respectively, during 1992, compared to 60 and 92% in 1993. Feral swine depredation of artificial bobwhite nests was 33% across years and was evenly distributed between vegetation types. During three-week periods in June and July 1994, depredation was greater ($P<0.001$) in an unburned (90%) pasture than in unburned areas within a burned (32%) pasture. Decreased predator activity in the burned pasture was probably due to temporary prey displacement and less forage. Feral swine depredation of artificial bobwhite nests was 14% in 1994. Feral swine could potentially have negative impacts for northern bobwhites in mesquite and juniper habitats of northwest Texas.

Citation: Tolleson, D.R., W.E. Pinchak, D. Rollins, and R.J. Ansley. 2000. Influence of habitat type and prescribed burning on feral swine depredation of artificial quail nests. Page 110 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, Jr., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

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COMPARATIVE MORPHOLOGY AND PHYLOGENETIC RELATEDNESS AMONG BOBWHITES IN THE SOUTHERN U.S. AND MEXICO

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ABSTRACT

We analyzed the morphology and phylogenetic relatedness of masked bobwhites (*Colinus virginianus ridgwayi*) and Texas bobwhites (*C. v. texanus*) to determine if the numerically stable Texas bobwhite might serve as a reasonable research and management model for the endangered masked bobwhite. We compared 26 external and 24 internal morphological features. Texas and masked bobwhites had similar body mass; however, masked bobwhites had smaller head and body dimensions and longer wing and thigh bones ($P < 0.01$) than Texas bobwhites. Genomic DNA was extracted from heart or muscle tissue of captive masked bobwhites ($n = 12$) and from northern bobwhites obtained in Florida ($n = 3$), Tennessee ($n = 5$), Texas ($n = 12$), and Oklahoma ($n = 3$). Bobwhites from South Texas and masked bobwhites appear to form a relatively closely related assemblage, possibly representing a separate lineage from other bobwhite populations. Based on gross similarities between Texas and masked bobwhites in morphology and phylogenetic relatedness, as well as in habitat conditions on the semiarid rangelands they occupy, biological and management information from Texas bobwhites seems applicable to masked bobwhites.

Citation: White, S.L., K.R. Nolte, W.P. Kuvlesky, Jr., and F.S. Guthery. 2000. Comparative morphology and phylogenetic relatedness among bobwhites in the southern U.S. and Mexico. Pages 111–114 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, Jr., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

INTRODUCTION

Masked bobwhites formerly inhabited desert grasslands extending from south-central Arizona through much of Sonora, Mexico (U.S. Fish and Wildlife Service 1995). By the early 1900's, much of these subtropical grassland communities had been destroyed by severe drought and grazing by cattle. The masked bobwhite disappeared from Arizona within 50 years of its discovery and it was thought to be extirpated from Mexico. In the 1960's, remnant populations of masked bobwhites were rediscovered in Mexico and the subspecies was listed as endangered under the Endangered Species Conservation Act of 1969. Recovery efforts have been under way for >20 years.

The Texas bobwhite has been used as part of the recovery program for masked bobwhites at Buenos Aires National Wildlife Refuge in Arizona (U.S. Fish and Wildlife Service 1995). Wild males from South Texas are surgically sterilized and used as foster parents for captive-reared masked bobwhite chicks.

Otherwise, experimental research and management techniques for masked bobwhites are limited because of their endangered status. It would be useful to determine the degree to which knowledge available for the well-studied Texas bobwhite is applicable to the masked bobwhite. The 2 races occur in semiarid environments with physiognomically similar habitat structures; common plant species are similar at the generic level (Fitzpatrick and Guthery 1993). However, before information on Texas bobwhites can be used in the management of masked bobwhites, it seems important to determine the degree to which Texas and masked bobwhites are morphological and genetic equivalents. Accordingly, our objective was to examine the comparative morphology and phylogenetic relatedness of Texas and masked bobwhites. We also examined phylogenetic relatedness between these races and other races of bobwhites in the continental United States.

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METHODS

Morphology

Data were collected from 50 (24 F, 26 M) captive-bred masked bobwhites and were compared to like samples of mixed-strain domestic and wild Texas bobwhites. We measured 26 external, 11 skeletal, and 13 organ measurements from each specimen. First-year, non-breeding masked bobwhites aged >150 days were obtained from the Patuxent Environmental Science Center (PESC) and were euthanized with chloroform. Mixed-strain (Texas and northern stock) domestic bobwhites were obtained from Schuenemann Enterprises, a commercial breeder in Nueces County, Texas. Wild Texas bobwhites were obtained from hunters at the Chaparral Wildlife Management Area in Dimmit and LaSalle counties, Texas.

External measurements were taken according to Baldwin et al. (1931) to the nearest 1 mm using a flat ruler or to the nearest 0.1 mm using vernier calipers prior to skinning and dissection. Measurements included body mass (g), total length, wing chord length, culmen length, beak height, beak width, head length, head width, head height, body length, body width, body diameter, tail length, tail width, wing breadth, tarsus length, tarsus diameter, and length and width of each toe.

To obtain skeletal measurements, each specimen was partially skinned to expose the breast, back, and legs. All measurements were taken to the nearest 0.1 mm using vernier calipers with tissue intact according to Robbins and Schnell (1971) and McLelland (1991). Measurements included length of the humerus, radius, ulna, sternum, keel, synsacrum, femur, and tibiotarsus; width and minimum width of the synsacrum; and depth of the keel.

Each specimen was dissected by cutting through the abdominal membrane at the vent and along the contour of the breast muscle through the rib cage until the sternum was removed to expose the body cavity. Mass of internal organs was measured with an analytical balance accurate to 0.0001 g. Linear measurements were taken to the nearest 1 mm using a flat ruler or to the nearest 0.1 mm using vernier calipers. Data were obtained on mass of liver, heart, kidney, adrenal glands, ovaries or testes, proventriculus, gizzard, and spleen. Linear measurements included heart width and height and length of small intestine, large intestine, and caeca.

Molecular Genetics

Of the 50 masked bobwhites obtained from the PESC, 12 (6 M, 6 F) which were not brood mates were chosen for genetic analysis. Wild bobwhites were obtained from Leon County, Florida ($n = 3$); Fayette County, Tennessee ($n = 5$); Houston County, Texas ($n = 6$); Ellis County, Oklahoma ($n = 3$); Stonewall County, Texas ($n = 3$); and Brooks County, Texas ($n = 3$). One pen-reared bobwhite was obtained from a private breeder. Two northern bobwhites from each sample location were chosen for genetics analysis plus the 1 domestic bird, resulting in a total of 25 samples.

Genomic DNA was extracted from heart or muscle tissue using standard proteinase K digestion of the tissue followed by organic extraction of protein using phenol and methylene chloride and isopropanol precipitation of DNA (Maniatis et al. 1982). A segment of the mitochondrial D-loop was amplified using the polymerase chain reaction (PCR; Saikai et al. 1988). PCR amplification solutions and conditions were those described by Bickham et al. (1996) using primers LGL 951 and LGL 1115.

PCR fragments were directly sequenced using the ABI Taq Dye Deoxy^{tm} Terminator Cycle Sequence Kit. Twenty-five samples were sequenced using the 1115 primer. Six samples were also sequenced using the 951 primer to give confirmed double-stranded sequence. Phylogenetic interpretation of data was obtained using the exhaustive procedures of PAUP (Swofford 1993).

Statistical Analyses

Analysis of variance is a robust test so assumptions of normality and homogeneity of variance can be violated if each sample has >20 observations and approximately the same number of observations (Kleinbaum and Kupper 1978:248). Because our data met these conditions, each morphological variable was compared in a 3 × 2 factorial analysis to determine if differences existed between 3 strains and 2 sexes. General linear models (PROC GLM, SAS Institute 1988) were used for the analysis because cell sizes were unequal but cell frequency patterns were proportional. Each analysis tested the null hypotheses that the means were not different for the 3 strains and for the 2 sexes and that no interaction effects were present ($P < 0.01$). We used Tukey's HSD post hoc test to compare means at $P < 0.01$ to increase the power of tests and to control for Type I errors.

RESULTS

Morphology

Forty-five factorial analyses yielded significant results ($P < 0.01$) for all variables except tail width, indicating strain, sex, or interaction effects were present. Interaction effects were present for mid-toe length ($P = 0.0063$) and gizzard mass ($P = 0.0035$). Domestic males (21.1 ± 0.98 mm) (x ± SE) had a longer mid-toe length than domestic females (20.5 ± 1.29 mm); Texas males (19.7 ± 0.72) and females (19.7 ± 0.72) had similar mid-toe length; and masked bobwhite males (18.2 ± 1.11 mm) had a shorter mid-toe length than masked bobwhite females (18.8 ± 0.68 mm). Domestic females (4.1 ± 0.12 g) had the largest gizzard mass. Domestic males (3.4 ± 0.54 g), Texas males (3.3 ± 0.42 g), and Texas females (3.3 ± 0.45 g) had similar gizzard masses, as did masked bobwhite males (2.5 ± 0.25 g) and females (2.4 ± 0.21 g). Because the 2 sexes exhibited different patterns within or between groups, main effects for mid-toe length and gizzard mass could not be determined.

Males had longer mean head length ($P = 0.0003$), tail length ($P = 0.0022$), wing chord length ($P = 0.0079$), and tibiotarsus length ($P = 0.0083$) than females. No other effects due to sex were discovered.

Differences for strains were evident ($P \leq 0.001$) for 42 body components. The most common pattern observed was no statistical difference for masked bobwhites and Texas bobwhites with measurements from these races being smaller than those for the domestic strain (masked = Texas < domestic). This pattern held in 18 of 42 tests (42.9%). Variables included body mass, total length, sternum length, and keel depth. Organ measurements that fit this pattern included heart height and mass of kidneys, adrenal glands, proventriculus, and spleen.

The second most common pattern (13 of 42 tests, 31%) was a gradation in dimensions (masked < Texas < domestic). This pattern held for head width and height, body width and diameter, tarsus length, and length and width of certain toes. Synsacrum length and width and length of the small and large intestines fit this pattern.

A second gradation (Texas < masked < domestic) occurred in 6 of 42 tests (14.3%). Length of the long bones (radius, femur) fit this gradation.

Molecular Genetics

Amplification of the 25 samples representing 7 localities and 1 pen-raised bird gave a fragment of about 650 base pairs. Sequences of these birds using the 1115 primer gave a minimum of 500 base pairs of sequence information. The 6 samples sequenced with the 951 primer confirmed a double-stranded sequence for a minimum of 466 of the 500 or more bases that were called using the 1115 primer. An additional 43–64 bases were determined as single-stranded sequences for the 951 primer for those 6 samples.

Using the region confirmed by double-strand sequence (466 bases) and excluding nucleotide 258, which gave ambiguous sequence results, the exhaustive search algorithm gave 8 trees which collapsed to a phylogenetic network (Figure 1). All branches shown are found in all 8 trees. There are no alternate branching patterns supported using the 50% majority rule consensus trees. Each tick mark on the tree in Figure 1 represents a nucleotide substitution. Although the network cannot be rooted, as no sister taxon was analyzed, the obvious phenetic break is between the masked and south Texas bobwhites, inclusive, and the remainder of the population examined.

The molecular data showed high levels of subdivision among the bobwhite populations analyzed. Only the 2 birds from Ellis County, Oklahoma, 1 bird from northern Texas, and the pen-raised bird shared complete identity for the region sequenced. Birds from other localities had locally unique variants.

High levels of heterogeneity existed within localities. Three variants at reasonably high frequencies were found among the masked bobwhite samples. Three of the 7 localities showed 2 haplotypes, even though only 2 birds were sampled from each locality. These data are concordant with probabilities suggesting that most localities possess ≥2 haplotypes.

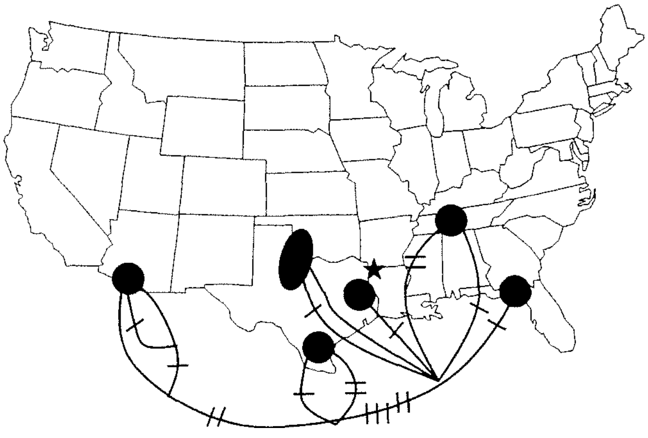

Fig. 1. Unrooted phylogeographic network detailing relatedness among populations of northern bobwhites. Tack marks represent nucleotide substitutions observed among 466 nucleotides of ND 6, glu-tRNA, and D-loop. The starred locality represents the BOG 1 variant which is defined by a nucleotide change observed only using primer 951 (see text).

Sequencing for masked bobwhites revealed ≥3 haplotypes present at reasonably equal frequencies. Therefore, the data suggest that diversity of mtDNA lineages within the captive population of masked bobwhites is not substantially different from the diversity in wild populations of northern bobwhites.

DISCUSSION

Our purpose was to assay the comparative morphology and phylogenetic relatedness of masked bobwhites and Texas bobwhites. Our analyses of comparative morphology is problematic, because of certain confounding effects. For example, masked bobwhites and domestic bobwhites were propagated under different regimes. Also, the masked bobwhites examined in this study arose from a founder population of 57 birds wild-trapped in Mexico in 1968–70 (U.S. Fish and Wildlife Service 1995). The descendants of these founders may not typify historical or extant populations of masked bobwhites in the wild.

In the context given above, we generally found morphological differences that would be expected based on strain (domestic bobwhites larger than Texas or masked bobwhites) or pen-rearing (larger organ masses in pen-reared than in wild birds). The masked bobwhites we examined were structurally smaller and more elongate than wild Texas bobwhites. Whereas these were statistically significant effects, absolute differences were small. White (1995) provides the full set of morphological data collected for this study.

The phylogenetic affinities of bobwhites from south Texas appear to lie with the masked bobwhite population. Only 2 common changes separated the masked bobwhite population from the south Texas population. Five changes separated the masked bobwhite and south Texas bobwhite from all other populations. As the phylogenetic network (Figure 1) is unrooted because there was no sister taxon included in our analysis, we cannot at this time suggest that south Texas birds and masked bobwhites represent a separate lineage from other bobwhite populations. Phenetically, however, this is the proper interpretation.

MANAGEMENT IMPLICATIONS

Based on general morphological similarity and phylogenetic relatedness between Texas and masked bobwhites, we found no reason to suspect that the Texas bobwhite would not be a good research and management model for the masked bobwhite. In other words, biological and management knowledge available for Texas bobwhites would seem applicable to masked bobwhites. The implications of our results should be applied cautiously until comparative studies on the habitat ecology of these races have been conducted.

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RESTOCKING NORTHERN BOBWHITES IN EAST TEXAS: A GENETIC ASSESSMENT

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ABSTRACT

Habitat on a 610-ha study area in the Pineywoods Ecological Region of eastern Texas was enhanced for northern bobwhites (*Colinus virginianus*). In February and March 1990, 1991, and 1992, bobwhites from south Texas (*C. v. texanus*) and disjunct areas of east Texas (*C. v. mexicanus*) were captured, radio tagged, and relocated to the study area which had a small (<25 birds) resident population. Blood samples were collected from the birds relocated in 1991. Samples were also collected from birds in the resident population during 1991 and 1992; these birds were assumed to be offspring of the previous years' resident and relocated bobwhites. Restriction site variation of mitochondrial DNA (mtDNA) revealed geographic subdivision between the subspecies but not between resident and east Texas relocated birds. The observed frequency differences of mtDNA haplotypes were used to assess the relative reproductive success of the 2 subspecies. Among the birds examined for mtDNA variation, offspring produced on the study area during 1990 and 1991 were genetically more similar to the east Texas subspecies than to the south Texas subspecies. These results suggest that efforts to restock northern bobwhite should involve either local birds or birds from the same subspecies. Management implications of these findings are discussed.

Citation: Nedbal, M.A., S.G. Evans, R.L. Honeycutt, R.M. Whiting, Jr., and D.R. Dietz. 2000. Restocking northern bobwhites in East Texas: a genetic assessment. Page 115 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, Jr., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

TEMPERATURE AND HUMIDITY RELATIONSHIPS OF SCALED QUAIL NESTS IN SOUTHERN NEW MEXICO

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ABSTRACT

We observed unmarked and radio-marked (20 females/1994; 9 females and 11 males/1995) scaled quail (*Callipepla squamata*) during the nesting season in the Chihuahuan Desert of southern New Mexico. In 1994, pairing was completed by early April. Clutch size averaged 13.8 ± 1.7 (n = 7). Nests were located an average 216 ± 13.8 m from permanent water. All 97 chicks disappeared from radio-marked pairs by 16 July. In 1995, all radio-marked females and 6 of the radio-marked males were paired by mid-April. Clutch size averaged 10.3 ± 1.3 in nests (n = 8) that averaged 545 ± 1.7 m from permanent water. Almost half of the hatched chicks (49.6%) fledged in 1995. Nest temperature never exceeded 34°C, while ambient temperatures reached ≥43°C. Nest humidity averaged 23%, while ambient humidity averaged 12%.

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INTRODUCTION

Scaled quail are native to the Chihuahuan Desert and surrounding grasslands of the southwestern United States and northern Mexico where they inhabit arid to semi-arid habitats that average 20.3–38.1 cm of annual precipitation (Agricultural Research Service 1994). Scaled quail populations have been declining at an average rate of 3.8% per year throughout their range since 1966, with the decline increasing to 8.2% annually since 1982 (Church et al. 1993). Because of their importance as a game bird, research has focused on improving habitat to increase numbers in the states where they occur (Campbell 1960). One such habitat improvement has been installation of rain catchments called guzzlers. Studies by Campbell (1960), however, have shown water developments to be of little value for scaled quail. Little is known about the reproductive biology of scaled quail and how it may influence population numbers. Therefore, we studied temperature and humidity relationships of scaled quail nests to derive a better understanding of their reproductive ecology.

STUDY AREA

Observations of scaled quail were conducted on the USDA Jornada Experimental Range (JER), a working cattle ranch that is closed to sport hunting, located 37 km north of Las Cruces, New Mexico. JER was established in 1912 for range research and currently is part of the Long-Term Ecological Research Program (LTER). Precipitation on JER, which averages 24.7 cm annually, reflects its location near the northern edge of the Chihuahuan Desert (Agriculture Research Service 1994). Over half of the annual rainfall occurs between 1 July and 30 September. Annual precipitation was 16.1 cm during 1994 and 22.7 cm in 1995 on JER. Average spring and summer rainfall on JER is 1.1 cm in May, 1.5 cm in June, 4.5 cm in July and 5.0 cm in August. No rainfall occurred during May 1994, 1.8 cm fell in June, 4.5 cm fell in July and 2.1 cm fell in August. In 1995, 1.9 cm of rain fell in May, 1.6 cm fell in June, 3.7 cm fell in July and 2.9 cm fell in August. Mean maximum ambient temperature is highest in June when it averages 36°C, and lowest in January when it averages 13°C. During 1994, beginning on 30 May the temperature was over 36°C on 47 days, and it exceeded 40°C for 13 days beginning on 24 June. In 1995, the temperature exceeded 36°C for 27 days between 30 May and 31 July. Temperatures were above 40°C for 4 days beginning 25 July in 1995. Humidity averaged 8% from May until the beginning of the "monsoon season" in July. From the beginning of the summer rains through August, humidity averaged 19%. Temperatures often ranged as much as 25°C between day and night.

METHODS

After locating coveys on JER using Weimaraner bird dogs, we placed funnel traps baited with whole milo at covey locations. We weighed, aged and sexed

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Table 1. Ambient temperature and humidity in relation to scaled quail nest temperature and humidity at the Jornada Experimental Range, New Mexico (1995).

Nest site and no.	Date	Time of recording	Ambient °C temp.	Nest temp °C	Difference	Ambient humidity	Nest humidity	Difference
Guzzler 1	June 2	7:30 a.m.	29	32.0	+3.0	5%	9%	−4
Guzzler 1	June 6	10:00 a.m.	27	32.3	+5.3	1%	15%	−14
Guzzler 1	June 10	7:30 a.m.	18	19.4	+1.4	15%	22%	−7
Smith tank	June 8	11:00 a.m.	27	32.0	+5.0	8%	19%	−11
Smith tank	June 29	3:00 p.m.	30	32.0	+2.0	10%	20%	−10
Smith tank	June 30	7:30 p.m.	29	34.0	+5.0	19%	35%	−16
Smith tank	July 18	6:00 p.m.	30	31.7	+1.7	20%	35%	−15
Smith tank	July 25	12:00 p.m.	37	33.2	−3.8	12%	34%	−22
Smith tank	July 31	2:00 p.m.	40	33.7	−6.3	18%	26%	−8
Guzzler 2	July 28	3:30 p.m.	43	33.3	−9.7	12%	15%	−3

captured quail. We radio-marked a sample of the captured birds each year with 6.5–7.0-g transmitters. These birds were subsequently located every two days. Once hens began laying eggs, nest locations were recorded. After incubation was initiated, temperature and humidity sensors were placed inside nests (*n* = 1, 1994; *n* = 3, 1995). Temperature/humidity sensors, the size of a dime, were obtained from HyCal Engineering, El Monte, California. Sensors were connected by a 60-m PVC-encased cable to a hand-held voltage meter which provided on-site nest microenvironmental readings. Separate ambient temperature and humidity readings were taken simultaneously at 60 meters adjacent to the nest site. Wire mesh access and escape ramps were attached to metal cattle water troughs. Means are accompanied by SE for standard error in text.

RESULTS

We captured 68 scaled quail in 1994 (29 females, 39 males) and 20 (9 females, 11 males) in 1995. The average breeding mass of adult males in 1994 was 197.5 ± 3.3 g (*n* = 15), immature males' mass averaged 195.7 ± 2.6 g (*n* = 24), adult females' mass averaged 192.4 ± 4.2 g (*n* = 11), and immature females' mass averaged 182.6 ± 2.1 g (*n* = 18). In 1995 adult males averaged 188.3 ± 4.6 g (*n* = 11), adult females' average mass was 202.2 ± 4.6 g (*n* = 9). No immature quail were trapped in 1995 suggesting poor survival of 1994 hatchlings.

We radio-marked 20 female scaled quail in 1994 and 9 female and 11 male quail in 1995. By 1 April 1994, 11 radio-marked females were paired. Pairs moved up to 1 km from permanent water. Pairs nested an average of 216 ± 13 m (*n* = 3) from permanent water in 1994. Clutch size (*n* = 7) the first nesting season averaged 13.8 ± 1.7. The first monitored clutch hatched on 23 June and the last on 30 June 1994. By 16 July, all 97 chicks of radio-marked hens had disappeared. Three 12 day-old chicks drowned in water troughs without escape ramps. No renesting attempts were observed. Scaled quail began reforming coveys by 1 August in 1994.

In 1995, we monitored 16 radio-marked quail from June to October. All radio-marked females were paired by April 10, and the 6 males that found mates were paired by 16 April. Nests averaged 545 ± 17 m (*n* = 4) from permanent water and clutch size averaged 10.3 ± 1.3. The first nest hatched 14 June 1995 and the last, a renest, on 19 August 1995. Almost half (49.6%) of chicks that hatched (*n* = 15) fledged. One cock incubated eggs through hatching after his mate was killed by a great-horned owl (*Bubo virginianus*). Once hatched, adult quail brought their chicks to water sites with ramp access in 1995. One pair led their 1-day old brood 3 km to a water trough where ramps had been constructed to provide quail access to drinking water.

Ninety percent of nests (*n* = 15) over both years were located in large honey mesquite (*Prosopis glandulosa*) plants in areas of coppice dunes, while the remaining 10% of nests were in soaptree yucca (*Yucca elata*). Of those nests found in mesquite, half were in wood rat (*Neotoma* spp.) middens. Five transmitters that had been apparently lost were carried by wood rats into their subterranean dens, one to a depth of 1 m.

Ambient temperature at nests averaged 31°C, while temperatures in nests averaged 31.4°C (Table 1). The highest ambient temperature recorded at nest sites was 43°C; highest temperature recorded in any nest was 34°C (Table 1). From June through July, ambient humidity at nests averaged 12%, while humidity in the nests averaged 23% unless a rain event occurred. After a thunderstorm on 30 June 1995, ambient humidity was 19% and nest humidity was 35%, and on 18 July 1995, ambient humidity was 20% and nest humidity was 35%. These were the highest readings for ambient and nest humidity during the nesting period for both 1994 and 1995.

DISCUSSION

JER experienced a drought during 1994 and 1995. Average rainfall for JER during May–August was 6.3 cm and 1.4 cm below average for that time period in 1994 and 1995 respectively. Henderson (1971) stated that scaled quail are well adapted where ambient temperatures rarely exceed 40°C. During 1994, temperatures were above 40°C for 16 days during summer months. However, temperatures exceeded 40°C for only 4 days in 1995, and that occurred between 23–31 July when chicks were 33–40 days old. Within 4 weeks of hatching, all chicks had disappeared in 1994. Further, we captured no immature scaled quail during spring 1995. Nearly half of monitored pairs' chicks fledged on JER in 1995. We hypothesize that the long period of high temperature exacerbated by drought conditions was primarily responsible for reproductive failure on JER in 1994.

After chicks were lost in 1994, radio-marked scaled quail did not renest. By 1 August, they were observed forming coveys, which is 1 month earlier than reported in west Texas by Wallmo (1957). In 1995, 2 pairs renested after their nests were destroyed by coyotes (*Canis latrans*) and successfully hatched 10 eggs each.

Nest temperatures were generally greater than ambient temperatures, and nest humidity was consistently greater than ambient humidity in nests during daylight hours. Humidity of the nest averaged 23% throughout the nesting period despite the ambient humidity averaging 12%. The birds maintained the nest temperature below 34°C despite ambient temperatures in excess of 38°C.

Clutch size in 1994 averaged 13.8 ± 1.7 ($n = 7$) and in 1995 averaged 10.3 ± 1.3 ($n = 15$). Zammuto (1986) stated clutch size for scaled quail averaged 13.4 ($n = 86$).

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SURVIVAL AND CAUSES OF MORTALITY OF RELOCATED AND RESIDENT NORTHERN BOBWHITES IN EAST TEXAS

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ABSTRACT

We estimated survival of 3 groups of northern bobwhites (*Colinus virginianus*) on a 563-ha intensively managed study area in eastern Texas. During the 3-year study, 155 bobwhites from South Texas and 136 bobwhites from East Texas were captured, radio-marked, and relocated to the study area; 139 bobwhites that were resident on the study area were also captured, radio-marked, and released at the point of capture. There were no differences ($P > 0.05$) in survival among the 3 groups of bobwhites. However, survival of bobwhites from South Texas were consistently lower than those of the other 2 groups during each year; both bobwhites from East Texas and resident bobwhites survived better than bobwhites relocated from South Texas. Avian predation claimed 57.6% of 243 known-fate birds, mammalian predation and apparent capture stress each caused 9.1% mortality, while 1.2% of the birds died of snake predation and 14.0% were lost to unidentifiable causes.

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INTRODUCTION

The northern bobwhite was present but probably not abundant throughout much of the eastern U.S. before Europeans arrived. Early farming practices favored the species, and populations boomed. In the southern U.S., numbers peaked about 1890 and remained relatively stable until about 1940. Thereafter, land use changes resulted in declining populations (Rosene 1969), with the declines continuing into the 1990's (Brennan 1991, Church et al. 1993).

In eastern Texas, bobwhite populations followed similar trends; population declines were evident by the late 1930's (Lay 1954). In eastern Texas and throughout the Southeast, many approaches have been used to restore bobwhite populations. These included reducing bag limits, season closures, predator control, and restocking both pen-reared and wild-trapped birds (Lay 1954, Coggins 1986). Most wild-trapped bobwhites relocated to the Southeast came from southern Texas and Mexico where they were relatively abundant and easy to capture; normally, local birds were not available for trapping and relocation.

None of these approaches were successful (Lay 1954), and research demonstrated that the best way to restore bobwhite populations is to recreate suitable habitat (Klimstra 1972). However, a literature search revealed no studies that investigated the combined effects of both habitat rehabilitation and restocking. Likewise, only a single study (DeVos and Mueller 1989) investigated restocking using local bobwhites. The study suggested that relocation of local birds into nearby areas apparently devoid of quail can be successful.

In 1989, Temple-Inland Forest Products Corporation initiated a project to convert a second-growth forest into an area intensively managed for northern bobwhites. The general goal was to restore the bobwhite population by improving the habitat and relocating bobwhites into the newly created habitat. One objective of an associated research project was to evaluate and compare survival rates among 3 groups of bobwhites, those relocated to the study area from South

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Texas (*C. v. texanus*), those relocated from disjunct areas of East Texas, and those assumed to have been raised on or around the study area (i.e., residents). Bobwhites in the latter 2 groups were of the *C. v. mexicanus* subspecies (Johnsgard 1973).

METHODS

The 563-ha study area was in southeastern Trinity County, which is in the Pineywood Ecological Region of eastern Texas. Climate in this region is hot and humid with annual precipitation ranging from 90 to 150 cm (Gould 1975). Forest cover was mainly 50 to 60 year-old pine and mixed pine-hardwood stands with some mixed hardwood-pine stands along drainages. Forests on and around the study area have been described in detail by Rayburn (1983), Parsons (1994), Liu (1995), and Liu et al. (1996).

The first step in habitat modifications involved thinnings which reduced basal area throughout the study area to 9 to 14 m^2 per ha (Parsons et al. *this volume*). Timber on a 101-ha tornado-damaged area was salvaged and the area site-prepared and planted to pine seedlings. A variety of native and agricultural species were planted in warm-season and cool-season food plots which comprised approximately 20% of the study area. Naturally occurring and planted cover blocks comprised approximately 30% of the study area. Food plots and escape cover are described in detail in Parsons et al. (*this volume*). The study area was initially burned with a prescribed fire in 1989 and approximately half of it was burned again each year thereafter. Food plots, cover blocks, and young pine plantations were excluded from fire.

Although a drive count in February 1989 indicated that there were no bobwhites on the study area, 2 small coveys of about 10 birds each were known to be on or adjacent to it when relocation of South Texas and East Texas bobwhites was initiated. Trapping and relocation of these birds took place during January to March of 1990, 1991, and 1992. Bobwhites residing on the study area were captured during the same periods. The South Texas birds were captured in Kleberg and Kenedy Counties in the South Texas Plains Ecological Region (Gould 1975). Most East Texas bobwhites were captured in and around young pine plantations on Temple-Inland lands in Houston County, approximately 15 km north of the study area. Each bird was aged, sexed, checked for injuries, fitted with a leg band and a frequency-specific transmitter (Parsons et al. *this volume*), and released at a previously selected site on the study area in a covey of no less than 4 birds.

Radio-marked birds were tracked at least 5 days a week except during the deer hunting season when tracking was reduced to 2 to 3 days weekly. During 1990 and 1991, birds that were deemed to have not moved for a week were flushed to determine their survival status. In 1992, the transmitters had a mortality detection circuit, so it was not necessary to flush the birds to determine survival status. Throughout the study period, radio-marked birds were recaptured and transmitters replaced as necessary.

When a bird was found dead, the cause of death was determined using a key developed at Tall Timbers Research Station, Tallahassee, Florida (B.S. Mueller, personal communication). Causes of mortality were categorized as avian, mammalian, snake, capture-related, or unknown.

When a bird was lost (i.e., could not be radio-located), efforts were made to find it and determine its fate for 3 weeks. Thereafter, the bird was considered permanently lost for purposes of survival analyses. If a bobwhite was recovered alive later, it was put back into the population as a new bird. If the bird was found dead after the 3-week period, we assumed that it died the day after the last day it was radio-located.

The Kaplan-Meier procedure as modified by Pollock et al. (1989*a*, 1989*b*) was used to estimate survival of the 3 groups of bobwhite. In the analyses, the time unit of survival was a week (i.e., only when a bird survived an entire week was it considered to be alive for that time period). For each week of the nesting season, survival distribution values were compared among subpopulations using normal tests (Pollock et al. 1989*b*). Since the capture, handling, and radio-marking might have caused subtle injuries to the birds which could have influenced survival, the survival data during the first week after release were excluded from the analyses.

Survival distributions were compared using log-rank tests, as modified by Pollock et al. (1989*b*), with the null hypothesis that there were no differences among distributions. Comparisons were made among groups within each year as well as within each group among different years. The alpha level for all tests was set *a priori* at 0.05.

RESULTS

During 1990, 1991, and 1992, 50, 50, and 55 South Texas bobwhites, respectively, and 31, 50, and 55 East Texas bobwhites, respectively, were released on the study area. In 1990, 13 resident bobwhites were captured, aged, sexed, banded, radio-marked, and released at the point of capture. In 1991 and 1992, 69 and 57 resident birds were likewise captured, processed, and released.

Survival and Mortality

Among-group Survival

In 1990, the Kaplan-Meier procedure was applied to data collected during the first 18 weeks after the release of the birds (i.e., from 27 February to 2 July). Thereafter, low sample size precluded meaningful statistical analysis. During that period, East Texas relocated birds had higher survival than resident birds ($P \le 0.05$) (Figure 1). However, there were no differences in survival distributions between South Texas relocated birds and either resident ($P > 0.05$) or East Texas relocated ($P > 0.05$) birds. In 1991, trapping was

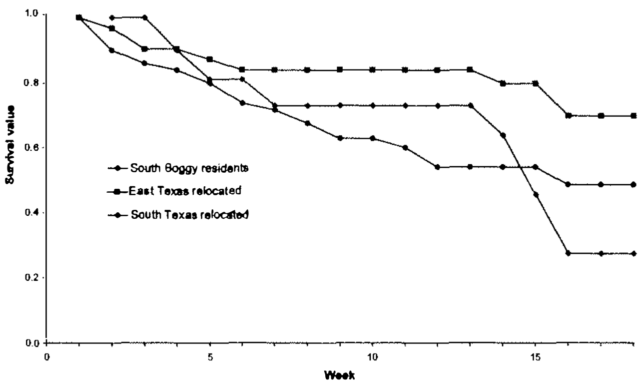

Fig. 1. Survival of northern bobwhites on the Temple-Inland study area, Trinity County, Texas, 1990; the first day of week 1 was 27 February and the last day of week 18 was 2 July.

discontinued in the last week of February; thus, survival analyses were initiated on 4 March. During the 36-week period between that date and 10 November 1991, survival distributions did not differ among the 3 groups of bobwhites (Figure 2). During 1992, bobwhites in both East Texas and South Texas were easy to capture. As a result, survival analyses were initiated on 17 February and carried until 25 October (36 weeks), when the project ended. Although survival distributions of East Texas and resident bobwhites were strikingly similar and different from that exhibited by South Texas relocated birds (Figure 3), the log-rank tests were not significant ($P>0.05$).

Within-group Survival

Log-rank tests showed no significant among-year differences within each group. However, South Texas relocated birds showed high consistency in their survival distributions among the 3 years, whereas residents and East Texas relocated bobwhites exhibited among-year variation (Figures 4, 5, and 6).

Breeding-season Survival

On the study area, the breeding season started in early April each year, when the birds began to whistle; covey break-up began in early to mid-April. By early May, some females had started nesting. Although bobwhites were recorded on nests or with flightless chicks from May to late September, the majority of the nesting activities were concentrated between May and mid-July (Parsons 1994). Each year during that period, survival distributions showed the steepest decrease (Figures 1, 2, and 3).

Bobwhites relocated from East Texas had higher survival values than South Texas relocated birds during each of the 31 weeks included in the pooled nesting seasons (Table 1). Likewise, South Boggy bobwhites had higher survival values than South Texas birds for 26 weeks. Finally, East Texas bobwhites showed better survival than South Boggy birds in 1990 and 1991, but the relationship was generally reversed in 1992 (Table 1). During the 3-year study period, 68.4% of the known-fate South Texas birds that were alive at the beginning of May died of predation by the middle of July. During that same period, 37.7% of East Texas relocated birds were lost to predators as were 39.7% of resident bobwhites.

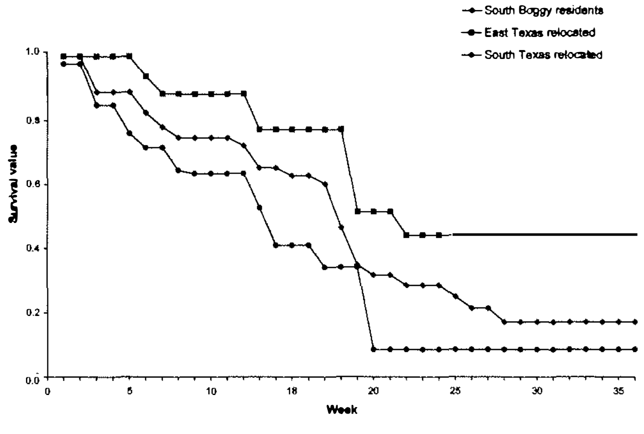

Fig. 2. Survival of northern bobwhites on the Temple-Inland study area, Trinity County, Texas, 1991; the first day of week 1 was 4 March and the last day of week 36 was 11 November.

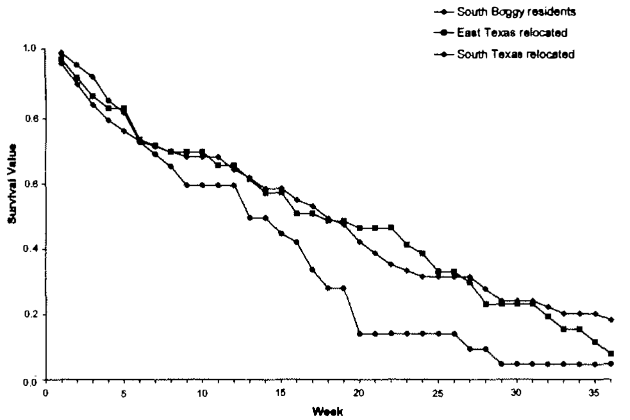

Fig. 3. Survival of northern bobwhites on the Temple-Inland study area, Trinity County, Texas, 1992; the first day of week 1 was 17 February and the last day of week 36 was 25 October.

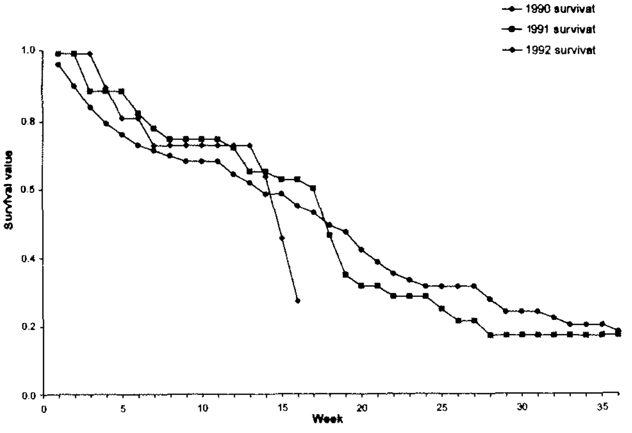

Fig. 4. Survival of resident northern bobwhites on the Temple-Inland study area, Trinity County, Texas; the first day of week 1 was 27 February, 4 March, and 17 February in 1990, 1991, and 1992, respectively.

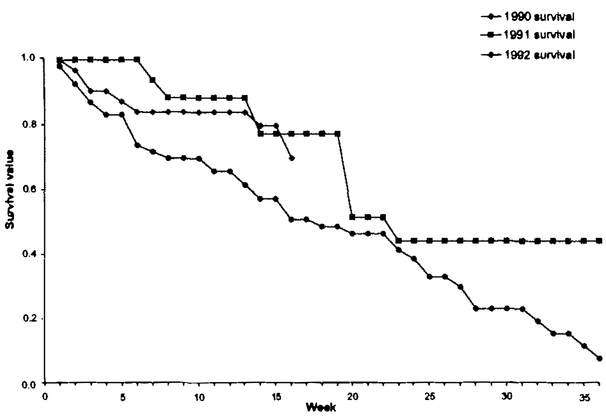

Fig. 5. Survival of East Texas relocated northern bobwhites on the Temple-Inland study area, Trinity County, Texas; the first day of week 1 was 27 February, 4 March, and 17 February in 1990, 1991, and 1992, respectively.

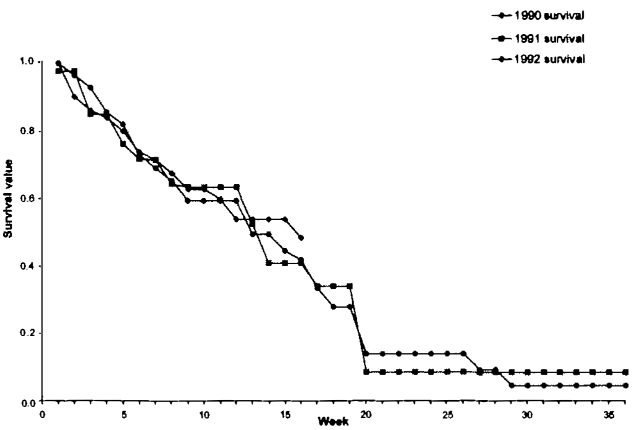

Fig. 6. Survival of South Texas relocated northern bobwhites on the Temple-Inland study area, Trinity County, Texas; the first day of week 1 was 27 February, 4 March, and 17 February in 1990, 1991, and 1992, respectively.

Table 1. Weekly Kaplan-Meier survival distribution values during the nesting season, and results of simple *Z*-tests comparing these values between South Boggy resident and East Texas and South Texas relocated northern bobwhites on the South Boggy Slough study area, Trinity County, Texas.

	Kaplan-Meier survival distribution values			*Z*-values		
Week ending	S. Boggy residents	E. Texas relocated	S. Texas relocated	S. Boggy versus E. Texas	S. Boggy versus S. Texas	E. Texas versus S. Texas
1990[a]	(*n* = 13)	(*n* = 31)	(*n* = 50)			
7 May	0.7290	0.8387	0.6284	−1.2421	1.0785	1.9783*[b]
14 May	0.7290	0.8387	0.5999	−1.2041	1.3176	2.2077*
21 May	0.7290	0.8387	0.5399	−1.1899	1.8910	2.7391*
28 May	0.7290	0.8387	0.5399	−1.9690*	0.8562	2.5163*
4 June	0.6379	0.7968	0.5399	−2.9258*	−0.6181	1.8444
11 June	0.4556	0.7968	0.5399	−4.0262*	−1.8659	1.7770
18 June	0.2734	0.6972	0.4859	−3.0271*	−1.4629	1.4024
25 June	0.2734	0.6972	0.4859	−2.6966*	−1.3204	1.3155
2 July	0.2734	0.6972	0.4859	−2.4227*	−1.1824	1.2473
1991	(*n* = 71)	(*n* = 52)	(*n* = 54)			
5 May	0.7471	0.8824	0.6348	−1.3267	0.7061	1.6160
12 May	0.7471	0.8824	0.6348	−1.2785	0.7111	1.5767
19 May	0.7471	0.8824	0.6348	−1.2617	0.7061	1.5767
26 May	0.7222	0.8824	0.6348	−1.5344	0.5385	1.5907
2 June	0.6523	0.8824	0.5267	−2.2040*	0.9719	2.6512*
9 June	0.6523	0.7721	0.4097	−1.0198	1.9002	2.5952*
16 June	0.6281	0.7721	0.4097	−1.1719	1.4758	2.2389*
23 June	0.6281	0.7721	0.4097	−1.1245	1.4592	2.2055*
30 June	0.6019	0.7721	0.3414	−1.9920*	1.8999	3.6271*
7 July	0.4651	0.7721	0.3414	−2.2331*	0.8598	2.5292*
14 July	0.3489	0.7721	0.3414	−3.1031*	0.0525	2.5292*
1992	(*n* = 62)	(*n* = 60)	(*n* = 58)			
3 May	0.6825	0.6568	0.5949	0.2948	0.9794	0.6599
10 May	0.6349	0.6568	0.5949	−0.2464	0.4417	0.6419
17 May	0.6190	0.6144	0.4958	0.0505	1.4040	1.2643
24 May	0.5856	0.5720	0.4958	0.1467	0.9118	0.7367
31 May	0.5856	0.5720	0.4462	0.1403	1.4145	1.2162
7 June	0.5501	0.5085	0.4200	0.4435	1.2945	0.8556
14 June	0.5318	0.5085	0.3360	0.2342	2.0195*	1.6834
21 June	0.4938	0.4864	0.2800	0.0751	2.2412*	2.0640*
28 June	0.4748	0.4864	0.2800	−0.1154	1.7286	1.7699
5 July	0.4220	0.4643	0.1400	−0.4459	3.4712*	3.6258*
12 July	0.3869	0.4643	0.1400	−0.7779	2.5466*	2.9982*

[a] Sample size at the beginning of the ratio-locating year (i.e., 27 Feb., 4 March, and 17 Feb. in 1990, 1991, and 1992, respectively); for 1991 and 1992, sample size includes carryovers from the previous year.

[b] An * indicates a significant difference at the 0.05 level.

Table 2. Causes of mortality of 243 known-fate northern bobwhites on the Temple-Inland study area, Trinity County, Texas, 1990–1992.

		Cause of death					
Year	Bird group	Avian	Mammal	Snake	Capture-related	Unknown	Total
1990	Residents	5	1	0	0	3	9
	East Texas relocated	9	3	0	1	0	13
	South Texas relocated	19	4	0	1	1	25
	Subtotal	33	8	0	2	4	47
1991	Residents	15	3	0	10	3	31
	East Texas relocated	4	0	0	3	1	8
	South Texas relocated	9	0	0	3	8	20
	Subtotal	28	3	0	16	12	59
1992	Residents	24	6	1	3	10	44
	East Texas relocated	27	2	1	1	4	35
	South Texas relocated	28	3	1	0	4	36
	Subtotal	79	11	3	4	18	115
	Total	140	22	3	22	34	221
	Percent	57.6	9.1	1.2	9.1	14.0	90.9

Causes of Mortality

In this study, avian predation was the most important cause of mortality (Table 2). It claimed 140 birds or 57.6% of the known-fate bobwhites. Mammalian predators and capture processes each caused 9.1% mortality, and slightly over 1.2% of the birds died of snake predation. It should be noted that all snake mortality was recorded in 1992, when a different model transmitter was used. Thirty-four deaths resulted from unidentifiable causes, which accounted for 14.0% of all fate-known birds; the remaining 9.1% were alive at the end of the year.

DISCUSSION

Due to the extremely small initial population size (13 individuals), survivorship estimates of 1990 resident bobwhites were highly susceptible to stochastic events such as predation. Between weeks 13 and 16 only 3 birds were lost, but weekly survival values dropped from 0.729 to 0.2734 (Table 1). Due to extensive transmitter failure in 1991, 76% of the East Texas birds were classified as missing and removed from the analysis. Likewise, large proportions of the other 2 groups were classified as missing. No doubt many of these birds died but were misclassified due to transmitter failure. As a result, the 1991 survival estimates and predation rates were confounded by transmitter failure. On the other hand, the transmitters used in 1992 were very reliable. There were also more radio-marked birds in each group in 1992 than in 1990 or 1991. These facts make clear that 1992 survival distributions and predation rates were probably more representative of the 3 groups than were those of 1990 or 1991. Although there were no significant differences among the 3 groups, the survival distributions for South Texas relocated birds were the lowest each year, indicating that both resident and East Texas relocated bobwhites survived better than South Texas relocated birds.

The relatively high variation in annual survival estimates for both East Texas and resident bobwhites is an indication that annual changes in environmental factors had more influence on the survival of these 2 eastern Texas groups than on that of South Texas birds. The consistent annual survival patterns of the latter group (Figure 6) suggest that inherent characteristics of South Texas bobwhites had a more profound negative impact on their survival than did annual environmental changes.

Three major factors might have caused the among-year difference in survival. First, the response of predators to biological changes on the study area might have had an important impact. Habitat manipulations, i.e., thinning of the forest, establishment of food plots, and annual prescribed burning, returned much of the study area to early successional vegetation stages. These changes caused a drastic increase in early successional animal species, especially cotton rats (*Sigmodon hispidus*). Drive-counts and Lincoln Index estimates suggested that the bobwhite population on the study area increased from zero birds in February 1989 to approximately 225 birds in early January 1992.

The second factor, which was particularly important in this study, is it was necessary to prebait trap sites each year in order to capture the resident bobwhites. Prebaiting generally lasted from mid-December to mid-January, except in 1992 when the prebaiting started in late November. The prebaiting attracted a wide variety of small mammals and birds, which in turn attracted predators, especially hawks. Radio-marked resident bobwhites were released at the point of capture (i.e., trap sites); thus, this group was probably subjected to greater predation pressure than the 2 relocated groups during the early weeks of each study period. This was probably the most important factor that caused the residents to have lower survival than East Texas birds.

Survival of bobwhites during the breeding season directly affects the following year's population size. Therefore, in terms of bobwhite relocation, survival of relocated birds during the breeding season is apparently more important than survival throughout the year.

High mortality of the South Texas relocated birds during the breeding season was probably caused by their lack of adaptation to the East Texas habitats and predators. Because these birds were from a totally different ecological region, they were apparently less adapted to the environment of the study area than the other 2 groups. Although all 3 groups selected relatively open macro-habitat (Liu 1995, Liu et al. 1996), there could have been subtle differences in behavior and micro-habitat selection between South Texas birds and the 2 eastern Texas groups that exposed South Texas bobwhites to relatively high risks of predation. In contrast, the East Texas relocated and resident birds were apparently more adapted to the forested environment; thus, behavior that exposed them to high predation pressure would be less likely.

Burger et al. (1995) found that bobwhite losses to mammalian and avian predators were about equal, 25.7 and 28.7%, respectively. In our study, avian predators caused 6 times more mortality than mammalian predators (Table 1). Differences between the 2 study areas in species composition and relative abundance of predators are not known. However, it is likely that differences in habitat characteristics and predator communities resulted in the distinctively different causes of mortality in these 2 studies.

Some bobwhites relocated from South Texas survived the reproductive season into the fall each year and there was reproduction by these birds (Parsons 1994). However, from a survivorship point of view, it is a much better alternative to relocate bobwhites from other East Texas areas. In fact, with appropriate baiting techniques, bobwhites relocated from East Texas proved easy to capture. In 1991 and 1992, 76 and 68 bobwhites were captured in 4 and 7 days, respectively, and all were captured in forested, not agricultural, ecosystems.

MANAGEMENT IMPLICATIONS

Caution should be taken when relocating bobwhites. First, the origin of birds to be relocated should be carefully chosen. As shown in this study, birds from different habitat types may not survive as well as those from similar areas. Depending on the extent of differences between the habitat types, reproduction may also be impacted. If relocated birds are not adapted to the new system, low survival may occur.

Second, habitat improvement before relocating bobwhites will be necessary in areas with low bobwhite densities. Habitat of the study area used for this research was extensively modified for bobwhites. Timber density was reduced, food plots and cover blocks were established, and burning was prescribed every year to improve macro- and micro-habitat conditions. These necessary habitat improvements are costly and may negatively affect other management goals. Therefore, cost effectiveness and compatibility with other land management goals need to be considered when attempting to relocate bobwhites.

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REPRODUCTIVE EFFORT OF FEMALE MOUNTAIN QUAIL INDUCED BY DIETARY XANTHOPHYLL

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ABSTRACT

Reproductive effort of quail in the arid American West is closely associated with spring precipitation and soil moisture levels. Profound fecundity during moist springs and weak reproductive effort during dry springs has been demonstrated for several species including the bobwhite (*Colinus virginianus*) and California quail (*Callipepla californica*). I tested the effect of dietary xanthophyll on reproductive effort of mountain quail (*Oreortyx pictus*), a native quail of the American West with a distribution that includes parts of the Mojave and Sonoran deserts. Precipitation data combined with trapping results from a wild Mojave population indicate that mountain quail respond to spring precipitation with strong reproductive effort. Xanthophyll is a naturally occurring yellow plant pigment that functions to prevent solarization in plants experiencing high light conditions. Xanthophyll is widely present in plants during green-up. Using captive mountain quail housed outdoors year-round, I experimentally altered dietary xanthophyll levels. Females supplemented with xanthophyll laid eggs at a significantly greater rate than did control females, and also laid more eggs overall. Juvenile females entering their first breeding season rapidly enlarged their reproductive tracts when exposed to dietary xanthophyll early in the breeding season. Juvenile females fed a xanthophyll supplement for two weeks had significantly larger individual ova, oviducts, and total reproductive tracts than did control females. Male mountain quail exhibited enlarged testes and performed reproductive behaviors regardless of diet. Finally, during the breeding season, females sought out and ate significantly more green vegetation than did males. If other quail exhibit a similar response, then these phenomena have great potential for explaining the onset, magnitude, and duration of reproductive effort in undisturbed quail populations, and populations experiencing land use changes that alter the availability of dietary xanthophyll.

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THE EFFECTS OF ENDOPHYTE-INFECTED KY 31 TALL FESCUE SEED ON NORTHERN BOBWHITE REPRODUCTION

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ABSTRACT

We assessed the impact of feeding an endophyte-free, endophyte-infected (*Acremonium coenophialum*), KY 31 tall fescue (*Festuca arundinacea* Schreb.) and a control diet on northern bobwhite (*Colinus virginianus*) reproduction. The birds consumed significantly more of the tall fescue diets compared to the control diet. There was no difference in female body weights at the end of the experiment. Male birds lost significantly more weight on the tall fescue diets than the control diet. The birds were in positive nutritional balances on all diets. There were no treatment effects on egg production, fertility, embryo mortality, hatch ability, or number of chicks per hen. Significantly more birds died eating endophyte-infected tall fescue seed compared to endophyte-free and control diets. These results indicate that tall fescue does not affect quail reproduction as indicated by previous authors. However, the endophyte does affect the weight gain of male birds and caused high mortality in these birds. We propose the alkaloids created by the endophyte caused a swelling of the cloaca which elicited a behavioral response in the birds causing them to become cannibalistic. These data support the idea that tall fescue does not provide quality nutritional habitat for northern bobwhite.

Citation: Barnes, T.G., J.S. Lane, A. Pescatore, and A. Cantor. 2000. The effects of endophyte-infected KY 31 tall fescue seed on northern bobwhite reproduction. Page 126 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, Jr., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

EFFECTS OF FEED RESTRICTION ON LIPID DYNAMICS AND REPRODUCTION IN NORTHERN BOBWHITES

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ABSTRACT

High annual and prenesting mortality rates (0.46–0.95) in northern bobwhites (*Colinus virginianus*) compel these birds to devote extraordinary effort and resources to reproduction. Bobwhites exhibit reproductive behavior characteristic of rapid multi-clutch and ambisexual polygamous mating systems. To better understand the physiological basis of the bobwhite's high reproductive capacity, we studied effects of restricted food intake on lean mass, lipids, and egg laying. We fed 48 bobwhites 3 levels of food intake including ad libitum (100%), and 60% and 80% of ad libitum. After 15 weeks of this protocol, we switched treatments for 50% of the birds in each treatment.

Lipid levels were similar for 60% and 80% groups, but significantly greater for the 100% group. Egg laying was markedly depressed and delayed in food-restricted groups. Comparing quail in the 60% and 80% groups, the latter appeared to catabolize body lipids in order to lay eggs. Egg production rates (eggs bird^{-1} day^{-1}) were 0.7 for 100% quail, 0.18 for 80% quail, and 0.03 for 60% quail. After switching treatments, subgroups allotted ad libitum food quickly recovered. The 60% and 80% subgroups reached constant egg production (0.6–0.7 eggs bird^{-1} day^{-1}), and with lean mass and lipid levels (9.8%-13.9% of wet body mass) within 10 days of ad libitum feeding. We discuss partitioning of endogenous reserves for reproduction and importance of exogenous energy in quail ecology.

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EFFECTS OF SUPPLEMENTAL FEEDING ON HOME RANGE SIZE AND SURVIVAL OF NORTHERN BOBWHITES IN SOUTH GEORGIA

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ABSTRACT

We studied the effects of supplemental feeding on fall-spring covey home range size and survival of radio-marked northern bobwhites (*Colinus virginianus*) for 3 years in southwest Georgia. A total of 372 radio-marked bobwhites were monitored on 2 separate study areas for 25 weeks from fall-spring each year from November 1993 through May 1996. The traditional supplemental feeding program of bi-weekly broadcast spreading of whole grains from November through May was discontinued on one of the study areas during 1993–1994 and 1994–1995. Supplemental feed was distributed on both areas during fall-spring 1995–1996.

During the 2 years of no feeding, fall-spring covey home ranges were larger ($P = 0.04$) on the unfed study area. During the first of these 2 years (1993–1994), fall-spring survival of birds without supplemental feed ($S = 0.127$) was lower ($P = 0.005$) than that of fed birds ($S = 0.432$). During the 1994–1995 season while covey home ranges of birds without supplemental feed were still slightly larger ($P = 0.04$), there was no difference ($P = 0.76$) in survival between bobwhites on the sites with and without supplemental feed. Coveys seen per hour hunted was significantly lower ($P = 0.007$) on the treatment (unfed) area during 2 years.

During the year supplemental feed was distributed on both sites, there was no difference in home range size ($P = 0.87$), survival ($P = 0.90$), or hunting success ($P = 0.82$) between the 2 study sites. Supplemental feeding may reduce bobwhite movements and home range size thereby enhancing survival because of less exposure to predation. However, such an effect will probably vary among years in relation to prevailing weather and native vegetation conditions. The specific mechanisms through which supplemental feeding may effect bobwhite population performance remain unknown and require additional study.

Citation: Sisson, D.C., H.L. Stribling, and D.W. Speake. 2000. Effects of supplemental feeding on home range size and survival of northern bobwhites in south Georgia. Pages 128–131 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, Jr., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

INTRODUCTION

Supplemental feeding of game animals is controversial and generally looked upon unfavorably by most wildlife professionals (Frye 1954). The issue of supplemental feeding of northern bobwhites is complicated by varying opinions among biologists (Guthery 1986), and conflicting results of meager research on the topic. Frye (1954) documented a substantial increase in bobwhites as a result of supplemental feeding on native habitats in south Florida. Robel et al. (1969) determined that nutritional stress due to the lack of a supplemental food source in winter resulted in weight loss, reduced fat, and increased mortality of bobwhites in Kansas. However, Peoples (1992) found no evidence that supplemental feeding programs benefitted quail in Oklahoma. Guthery (1986) concluded that supplemental feeding, if applied properly, could potentially increase survival in winter and productivity in summer of bobwhites in Texas, but also pointed out that the food limitation hypothesis has not been supported by research results (Guthery 1997).

Despite these conflicting research results and predominately negative attitude of many wildlife professionals toward supplemental feeding, it is a common practice on intensively managed properties throughout the geographic range of the northern bobwhite (Frye 1954, Guthery 1986, Peoples 1992, Simpson 1976, Brennan et al. 1994). Many biologists consider that supplemental feeding only concentrates birds for harvest with no positive, and potentially negative, impacts on the population. Most often cited as a potential detrimental impact is the belief that concentrating birds in a small area or stimulating their repeated activity at a certain point will cause predators to focus their attention there and result in higher mortality rates (Landers and Mueller 1986, Curtis et al. 1988, Jackson 1989); however, this point has not been researched thoroughly.

In the fall of 1993, we initiated a large-scale study on supplemental feeding of bobwhites. This study was designed to examine the effects of supplemental feeding on northern bobwhite survival, reproductive success, and vulnerability to harvest and/or predation on study sites with and without supplemental feed. This paper deals with only a part of that larger study. Here, we examine the effects of supplemental feeding on home range size and survival of bobwhites on an intensively managed quail plantation in southwest Georgia.

STUDY AREA AND METHODS

This study was conducted on a 4,490-ha privately owned wild quail hunting property located in the heart of southwest Georgia's plantation community near the city of Albany. The property has been under intensive bobwhite management for 50 years and supports an abundant wild bobwhite population. The habitat is maintained as a mixture of frequently burned, low basal area pine (*Pinus* spp.) woodlands, live oak (*Quercus virginiana*) savannahs, patch agricultural plantings, and open fields. Field system management consists of rotational agricultural plantings and fall disking to stimulate annual weed production and insects.

Two separate hunting courses were included in this study. The control site was a 316-ha hunting course on the south end of the property and the treatment site was a 194-ha hunting course on the north end of the property. The 2 sites were separated by 3.2 kilometers. Both hunting courses had historically been under similar management, including a supplemental feeding program. Whole corn and milo were broadcast on the ground in a continuous line throughout the whole course bi-weekly from November through May at a rate of approximately 1 bushel per 4 ha/feeding. Hunting success on these 2 courses had been approximately equal for the previous 10-year period based on unpublished plantation hunting records.

Wild bobwhites were trapped and released on both study sites in October–November of 1993–1995 using standard, baited funnel traps (Stoddard 1931). All captured birds were aged, sexed, weighed, and leg-banded. Each fall, a sample of approximately 40 quail from each study site weighing >130g were chosen to be outfitted with a 6-g neck-loop mounted radio-transmitter equipped with an activity switch (Holohil Systems Ltd., Ontario, Canada). Additional birds were captured, radio-marked, and added to the sample as needed throughout the winter and early spring. All radio-marked and/or banded birds were released at their capture site. Each radio-marked quail was located and checked for activity 2 to 3 times weekly from the date of capture through May. Routine hunting was conducted on both study sites approximately once every 2 weeks. Specific causes of non-hunting mortality were determined whenever possible by evidence at the kill site and condition of the transmitter (Curtis et al. 1988).

Beginning in the fall of 1993, supplemental feeding was discontinued on the treatment course while being continued on the rest of the property. Originally designed as a crossover experiment, this study was discontinued at the landowners request in the fall of 1995 at which time the plantation's standard feeding program was reinstated. Due to the unreplicated nature of the study, we realize that treatment effects may be confounded with site effects. Therefore, observed differences in range size and survival may not be solely attributable to supplemental feeding.

Each covey location was plotted on aerial photographs 2 to 3 times per week from November until covey break-up in April. From these, minimum convex polygon home range size was calculated for each radio-marked covey where at least one individual was tracked through the period. Student's t-tests were used to detect differences in mean home range size among treatments and between years.

Survival estimates for the radio-marked bobwhites on both sites for the 25-week feeding period were estimated using the Kaplan-Meier staggered entry design (Kaplan and Meier 1958, Pollock et al. 1989), which allowed for inclusion of additional birds during the study and the censoring of others due to radio failure or emigration. Mortalities that occurred within 1 week of radio attachment were not used in the analysis (Robinette and Doerr 1993). Survival curves were compared between years and among treatments using log-rank tests (Pollock et al. 1989). Population indexes were estimated from records of coveys observed per hour of hunting on the 2 courses for 4 hunting seasons which included the hunting season prior to (1992–1993) and 1 after (1995–1996) the period of no feeding on the treatment area. Hunting success among years and between treatments was compared using analysis of variance in the general linear model (GLM) procedure (SAS Inst., Inc. 1989). Individual hunts were used as the experimental unit with a year by treatment interaction term included in the model. All tests were conducted at the $P < 0.05$ significance level.

RESULTS

Home Range

We monitored 372 radio-marked bobwhites from November to May 1993–1996. This included 189 bobwhites on the control (fed) site and 183 on the treatment (unfed) site. Home range size differed among years ($P = 0.04$) ; therefore, each of the 3 years were analyzed separately. During 1993–1994 and 1994–1995 home ranges of coveys on the areas without supplemental feed (treatment) area were larger ($P = 0.05$ and $P = 0.04$, respectively) than those of coveys on the fed (control) site (Table 1). During 1995–1996, when supplemental feed was distributed on both sites, mean home range size did not differ between courses ($P = 0.90$) (Table 1).

Survival

Log-rank tests indicated there was a significant difference in survival curves between years ($P < 0.05$); therefore, these data were analyzed separately.

Table 1. Home range size (ha) and Kaplan-Meier survival estimates for radio-marked bobwhites on supplemental fed (control) and unfed (treatment) study sites in southwest Georgia, November–May, 1993–1996.

Year	Study site	N	Home range	SD	Survival	95% CI
1993–94	Control	63	3.5	2.1	0.432[c]	0.329–0.536
	Treatment	70	8.3[b]	4.0	0.127	0.080–0.174
1994–95	Control	74	3.3	1.9	0.313	0.229–0.397
	Treatment	60	4.8[b]	1.5	0.271	0.187–0.355
1995–96	Control	52	3.9	0.8	0.305	0.211–0.399
	Treatment[a]	53	3.8	2.4	0.333	0.231–0.435

[a] Supplemental feeding was reinstated on the treatment course at the beginning of this hunting season.
[b] Indicates a home range size significantly ($P < 0.05$) larger than fed study site.
[c] Indicates survival significantly ($P < 0.05$) greater than unfed study site.

During the 1993–94 season, fall-spring survival of radio-marked bobwhites on the site with supplemental feed was higher ($P = 0.005$) than on the unfed site (Table 1). During 1994–1995, there was no difference ($P = 0.76$) in fall-spring survival between the fed and unfed sites (Table 1). During the year supplemental feed was distributed on both sites (1995–96) there was no difference ($P = 0.90$) in fall-spring survival between the 2 sites (Table 1).

Hunting Success

The GLM procedure detected differences ($F = 5.78$, df = 3, 41, $P = 0.002$) in coveys observed per hour of hunting both between years and among treatments. Therefore, these data were also analyzed separately. No difference ($F = 0.05$, df = 1, 12, $P = 0.82$) existed in coveys observed per hour hunted between the 2 courses for the season prior to (1992–1993) or after (1995–1996) the no feeding treatment (Figure 1). During the 2 years of no feeding on the treatment course (1993–1994 and 1994–1995) coveys seen per hour hunted were higher ($F = 8.48$, df = 1, 29, $P = 0.007$) on the course where supplemental feed was distributed (Figure 1).

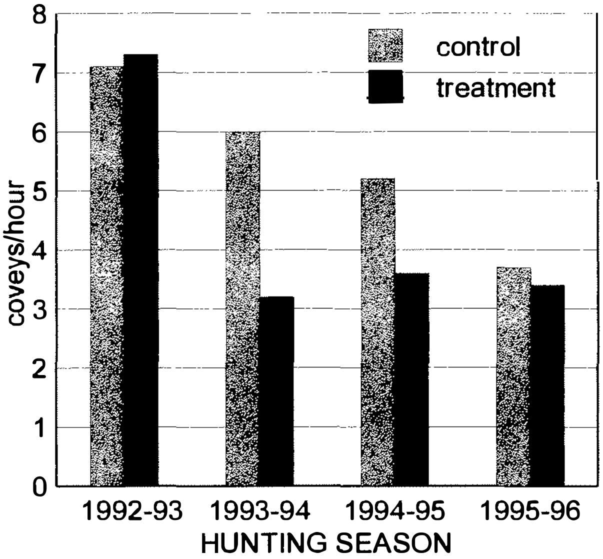

Fig. 1. Bobwhite coveys seen per hour hunted on a supplemental fed (control) and unfed (treatment) study site in southwest Georgia, 1992–1996. Both study sites were fed during 1992–1993 and 1995–1996. The treatment site was not fed during 1993–1994 or 1994–1995.

DISCUSSION

Our results support the observations of others (Frye 1954, Landers and Mueller 1986) that supplemental feeding can concentrate and localize bobwhite coveys during winter. We observed no evidence to support the idea that such concentration has any negative impact on bobwhite populations by increasing predation rates. In fact, during 1 of the 2 years when feeding was discontinued, we observed lower mortality on the site where supplemental feed was distributed. On the area where supplemental feed was distributed, home ranges were smaller and movements were more localized. This may have been attributable to the reduction of foraging time and distances of movements required to meet daily nutritional needs. This was especially true during 1993–1994 when native foods were limited and cover was light due to a drought. The increased movement and activity associated with coveys on places where supplemental feed was not distributed may have made them more vulnerable to predation, most of which (72%) was avian. This is further supported by the fact that once supplemental feeding was resumed on the previously unfed course, home range size was reduced and there were no differences in either home range size or survival between the 2 sites.

Curtis et al. (1988) documented a similar situation in which radio-marked coveys in poor quality habitat had larger ranges and subsequently higher winter mortality due to predation than bobwhites in high quality habitat. In our study, during the year when food and cover conditions were very good (1994–1995) home ranges of unfed birds were still slightly larger; however, their daily activity was much reduced and no difference in mortality rates occurred. Therefore, it appears that localization and reduced movements of bobwhite coveys in winter can, in some cases, have a survival advantage, or at worst, cannot be considered a wholesale negative. This relationship is almost certainly influenced as well by yearly interactions between weather and prevailing cover conditions. Our results combined with those of Curtis et al. (1989) seem to indicate that habitats which provide high quality food and cover result in smaller home ranges, shorter movements, and therefore lower rates of loss to predation. This can be provided by increased cover conditions and abundant food resources whether they are native, planted, or supplemented.

A recent study in Texas (Giuliano et al. 1996) concluded that high protein food sources were needed to overcome drought conditions and that supplemental feeding or habitat management to increase invertebrate abundance were management options. On-going field studies in Albany and elsewhere are investigating this hypothesis and suggest a positive effect on reproductive output under some circumstances as well. Further research is needed into the role supplemental feeding might play from a population level standpoint. Specific data are needed on effects on reproductive output, as well as on varying types of feed and methods of distribution.

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REPRODUCTION OF RELOCATED AND RESIDENT NORTHERN BOBWHITES IN EAST TEXAS

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ABSTRACT

We examined reproduction by relocated and resident northern bobwhites (*Colinus virginianus)* on an intensively managed 563-ha study area in Trinity County, eastern Texas. During the late winters of 1990–1992, 155 South Texas (84 hens, 71 cocks) and 136 East Texas (64 hens, 72 cocks) bobwhites were captured, radio-tagged, and relocated to the study area; 139 resident birds (73 hens, 66 cocks) were also captured, radio-tagged, and released at the point of capture. For the 3 years combined, the 33 South Texas, 33 East Texas, and 39 resident hens alive at the beginning of the breeding season produced 6, 13, and 22 documented nests ($P = 0.004$) and 0, 3, and 4 fledged broods. Pooled, the number of nests by East Texas and resident hens was higher than that of South Texas hens ($P = 0.003$); numbers of nests of East Texas and resident hens were similar ($P = 0.150$). Our results do not support relocation of South Texas bobwhites into the East Texas Pineywoods.

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INTRODUCTION

At one time, the northern bobwhite was considered the most important game bird of the southeastern United States (Mahan 1984). Historically, quail populations increased and decreased as man altered the environment. Land use practices associated with pioneer settlements were typified by patchy farming patterns which provided ideal quail habitat, resulting in population increases until about 1900. From the early 1900's to the mid-1940's, quail densities remained relatively high. However, since the mid-1940's, quail numbers have declined over much of the South (Mahan 1984, Brennan 1991).

As early as the late 1930's, state agencies began attempting to restore bobwhite populations (Lay 1965). Predator control, reduction in bag limits, and restocking of pen-raised and wild-trapped birds were attempted, usually with little success (Lay 1965, Coggins 1986). In eastern Texas, for example, up to 20,000 bobwhites wild-trapped in Mexico were released per year for several years prior to 1940. That effort was discontinued in 1940 because resident bobwhites were at carrying capacity (Lay 1965).

Almost without exception, declining northern bobwhite populations were due to habitat degradation; research demonstrated that the best way to restore bobwhite populations was to recreate suitable habitat conditions (Klimstra 1972). Within a given habitat, quail density is largely dependent on annual productivity and low nest success rates may be a major factor limiting reproduction (Stoddard 1931).

During 1989, Temple-Inland Forest Products Corporation initiated a project to restore the northern bobwhite population on a 563-ha portion of the South Boggy Slough Hunting Club in Trinity County, which is in the Pineywoods Ecological Region of eastern Texas (Gould 1975). The project involved creation of optimum bobwhite habitat and relocation of wild-trapped birds from South Texas and East Texas to the study area, which had a small remnant population (<

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25 birds) of native, resident bobwhites. Although a pilot study in Florida suggested that local bobwhites can be successfully relocated to suitable habitat (DeVos and Mueller 1989), no known study investigated nesting success of relocated birds. The objective of this study was to evaluate and compare nesting success of relocated and resident northern bobwhites.

METHODS

The study area, approximately 17 km southwest of Lufkin, Texas, was comprised of upland pine and mixed pine-hardwood forests. When habitat modifications were initiated, overstory trees were 50–60 years old and 27–34 m tall. Diameter at breast height averaged 35–45 cm and basal area ranged 20–27 m^2/ha. Habitat modifications included reduction of basal area to 9–13 m^2/ha by harvesting suppressed, intermediate, and some codominant trees. Patches of escape cover and food plots were established throughout the study area. When the young pine plantations are included, escape cover comprised approximately 30% of the study area. Food plots, described in detail by Parsons et al. (*this volume*), comprised approximately 20% of the study area.

Four hundred and thirty bobwhites were captured, radio-tagged, and released on the study area during January–March of 1990, 1991, and 1992. One hundred and fifty-five (84 hens, 71 cocks) South Texas bobwhites (*C. v. texanus*) (Johnsgard 1973) were captured on the King Ranch in Kleberg and Kenedy Counties Texas. Most East Texas birds (64 hens, 72 cocks) to be relocated were captured in forested areas on North Boggy Slough Hunting Club, approximately 15 km north of the study area. Both East Texas relocated and South Boggy resident birds (73 hens, 66 cocks), which were captured on the study area, are classified as *C. v. mexicanus* (Johnsgard 1973). Each captured bird was aged, weighed, checked for injuries, banded, and fitted with a frequency-specific chest-mounted transmitter. The transmitters, provided by American Wildlife Enterprises, were based on the design by Shields et al. (1982). Relocated birds were released in $\geq$ 4-bird coveys at predetermined sites throughout the study area; resident bobwhites were released at the point of capture. After release, birds were radio-located approximately 5 days per week throughout the breeding season and early fall; during the fall deer hunting season, radio-tracking was reduced to 2 to 3 days per week.

During the nesting season, which for the purpose of this study extended from 1 May–24 September, if a bird was radio-located in the same place for several days, the site was searched to determine if the bird was incubating eggs. If a nest was located, it was flagged and marked on a habitat map. When radio telemetry indicated that the bird had permanently left the nest, it was checked to determine clutch size and fate of the eggs. If possible, numbers of eggs laid and hatched were determined. Fate of the nest was classified as apparently successful if $\geq$ 1 egg hatched or apparently unsuccessful if not; if unsuccessful, it was classified as abandoned or destroyed by predators. Snake depredation was assumed when eggs in the nest disappeared and the dome of the nest cup remained intact. If integrity of the cup was damaged or destroyed, mammalian predation was assumed. If an incubating bird moved away from the nest area before the eggs hatched, the nest was classified as abandoned.

Bobwhites which produced chicks were intensively radio-tracked for at least 4 weeks after the eggs hatched (Parsons 1994, Parsons et al. *this volume*). Clutch size, numbers of eggs hatched per clutch, and numbers of broods fledged (i.e., capable of sustained flight) were examined using descriptive statistics. The numbers of nests recorded were compared among the 3 groups of bobwhite using Chi-square tests of homogeneity. Numbers of hens alive at the beginning of the nesting season, numbers of nests recorded, and numbers of hens for which no nest was found were used for these tests. The Chi-square tests computed the expected values using joint marginal probabilities for each cell and calculated Chi-square values using observed and calculated expected values. The null hypothesis was that there was no difference among the 3 sources of quail being compared. All statistical tests were performed at an alpha level of 0.05.

RESULTS

For the 3 years combined, there were 105 radio-tagged female bobwhites at the beginning of the nesting season (Table 1). Eighteen radio-tagged hens were alive at the end of the nesting season; 4, 6, and 8 hens were from South Texas, East Texas, and South Boggy, respectively. Forty-eight hens were known to be dead, and the signal was lost on 39, primarily due to transmitter failure, transmitter harness failure, or hens (either alive or dead) that simply could not be radio-located. Except for 1992, all hens actively radio-tracked throughout the nesting season definitely attempted to nest. In 1992, 1 East Texas and 3 South Boggy hens that lived through the breeding season were not observed nesting. However, nesting may have been disrupted before the nest could be located.

Forty-one nests were documented for 105 radio-tagged hens alive at the beginning of the 3 combined nesting seasons. Eggs in 13 of these nests hatched and 7 of the broods are known to have fledged. Numbers of nests varied among the reintroduction sources, with East Texas relocated and South Boggy resident hens producing at least 2 and 3 times, respectively, as many nests as South Texas relocated hens (X^2 = 12.865, 2df, P = 0.004) (Table 1). When nests produced by hens from eastern Texas (*C. v. mexicanus*) were pooled and compared to those by birds from southern Texas (*C. v. texanus*) the difference was also significant (X^2 = 12.840, 1df, P = 0.003). Conversely, numbers of nests produced by the 2 sources from eastern Texas were similar (X^2 = 0.025, 1df, P = 0.150) (Table 1).

Of the 13 broods produced by radio-tagged hens, 7 were known to have fledged. Two broods were lost to predation before fledging and fate of the remaining

Table 1. Numbers of relocated (South Texas and East Texas) and resident radio-tagged hens alive at the beginning of the nesting season (May 1) and numbers of documented nests, successful nests (≥1 egg hatched), and fledged (i.e., flying) broods produced by these hens in East Texas, 1990–1992.

Reintroduction source	Year	Hens	Nests		Fledged broods
			Recorded	Successful	
South Texas					
	1990	12	2	0	0
	1991	7	2	0	0
	1992	14	2	0	0
	Pooled	33	6	0	0
East Texas[a]					
	1990	9	3	2	2
	1991	3	3	1	0
	1992	21	7	1	1
	Pooled	33	13	4	3
Resident[a]					
	1990	5	2	2	1
	1991	16	12	4	1
	1992	18	8	3	2
	Pooled	39	22	9	4

[a] An East Texas hen and a resident hen each made 2 nesting attempts.

4 is unknown because contact with the radio-tagged parent was lost before the chicks fledged. East Texas cocks were recorded incubating 5 nests for which the hens could not be definitely identified; the 2 such 1990 nests were probably produced by East Texas hens. Two of these 5 were successful; 1 brood was definitely lost to predation and the cock that incubated the other disappeared before the chicks fledged. Two other east Texas cocks assumed incubation shortly after the hens (1 South Boggy, 1 East Texas) completed the clutches; the East Texas hen definitely nested again. One nest was successful and the brood fledged; the other nest was unsuccessful. Also, a South Boggy cock and an East Texas cock assumed incubation duties after the East Texas hens with which they appeared to be paired died; both nests were successful, but both cocks lost their transmitters before the chicks fledged. No South Texas cock was observed incubating eggs. Finally, 3 flightless broods and 7 fledged broods from unknown nests were also recorded; the 3 flightless broods all fledged. Most flightless and fledged broods for which no nests were found were the result of South Boggy or East Texas radio-tagged cocks paired with unknown hens.

Estimated clutch initiation dates were determined for the 46 nests and for the 10 flightless and fledged broods recorded during the study. Forty-six, 23, 21, 8, and 2% of the clutches were initiated during May, June, July, August, and September, respectively. Estimated hatching dates were determined for 25 clutches. Eggs in the majority of the nests hatched during June (32%) and July (36%); eggs in a few nests hatched in August (12%), September (16%), and October (4%). For 36 nests with complete clutches, mean number of eggs per nest was 12.4 (S.D. = 3.2). One clutch, with 8 eggs, was known to be a second nesting attempt by an East Texas hen which had lost an unknown number of eggs in her first attempt. Two South Boggy hens made second nesting attempts after their first nests, both with unknown numbers of eggs, were lost to predation; 1 nest was destroyed, and the other abandoned, before the clutches were complete. Average clutch sizes for 17 South Boggy, 11 East Texas, 4 South Texas, and 4 unknown-hen nests were 11.7, 12.2, 15.3, and 11.5 respectively. The number of eggs that hatched was known for 14 nests; for these, the mean was 12.1 (S.D. = 3.6). For the 17 fledged broods recorded, mean number of chicks was 8.3 (S.D. = 4.4).

DISCUSSION

Although numbers of hens alive at the beginning of the nesting season were similar among groups (Table 1), South Texas bobwhites produced fewer nests and fledged broods than did hens from the other groups. As a result, bobwhites relocated from South Texas probably contributed little to the observed population recovery on the study area. An associated genetic study supports this conclusion (Nedbal et al. 1997).

Survival during the nesting season is a major reason for the lower number of nests produced by South Texas hens. In a concurrent study, Liu et al. (*this volume*) found that South Texas bobwhites had lower survival through the breeding season than did East Texas and resident birds. During that period, South Texas bobwhites suffered higher predation rates than did other groups. The authors attributed this to differences in microhabitat selection on the study area.

South Texas hens that nested had little success fledging chicks. Only 5 nests with eggs were recorded; 4 were depredated by snakes, and an avian predator took the hen associated with the fifth nest before the eggs hatched. However, 2 broods assumed to have been produced by South Texas birds were recorded. In 1 case, a South Texas hen paired with a South Texas cock was known to be nesting, but the eggs hatched before the nest was located. However, a week after the chicks fledged, behavior of the adult bobwhites suggested that they had lost the chicks (Parsons 1994). The other South Texas hen was checked in late August of 1990 and did not appear to be nesting. In early October, she was flushed with 10 flying chicks that may have been hers.

There were no obvious differences in nesting characteristics of the bobwhites in our study area and those elsewhere. Ninety percent of all nests were initiated during May, June, and July. In Illinois, Klimstra and Roseberry (1975) reported that 80% of clutches were initiated during the same 3 months. In our study, 80% of estimated hatching dates were in June, July, and August; 75% of clutches hatched during the same time period in Illinois (Klimstra and Roseberry 1975). For the 3 groups, mean clutch size in this study (12.4 eggs) was equal to that reported by Sloan (1987) in South Texas, and compares favorably to 12.9 and 13.6 observed by Parmalee (1955) in central Texas and Simpson (1972) in Georgia, respectively. The 4 known-size South Texas clutches averaged 15.3 eggs; all 4 were initiated in May, and thus were most likely first nests. Average clutch sizes for 5 East Texas and 7 resident nests produced in May were 13.6 and 12.1, respectively. In Missouri, Burger et al. (1995) reported an average clutch size of 15.2 eggs for first nests incubated by hens. Thirty-three percent of the documented nests were successful. If failed nests of the 5 South Texas birds are excluded, hatching rate increased to 37%. Both rates are similar to the 34% reported by Klimstra and Roseberry (1975), somewhat higher than the 27 and 28% reported by Sloan (1987) and Klimstra (1950), and lower than the 44 and 45% reported by Burger et al. (1995) and Lehmann (1984), respectively.

Twenty-four (52%) nests were lost to predation. Lehmann (1984) and Sloan (1987) reported losses of 46 and 53%, respectively, in South Texas. In other areas, predator-related nest losses of 37, 50, 37, and 38% were noted by Stoddard (1931), Klimstra (1950), Klimstra and Roseberry (1975), and Burger et al. (1995), respectively. Snakes depredated 22 (48%) of all known nests. Snake predation in this study was lower than the 50% reported by Sloan (1987) but much higher than the 25, 12, 12, and 17% reported by Jackson (1947), Klimstra and Roseberry (1975), Lehmann (1984), and Burger et al. (1995), respectively. At the time of our study, raccoons, coyotes, and wild hogs were hunted and trapped on the South Boggy Slough Hunting Club. The higher percentage of snake predation in this study may be the direct result of lowering these predator populations, thus reducing their depredation of bobwhite nests. In an effort to determine what species of snakes were preying on the eggs, remote cameras were placed at several nest sites. Although no pictures were taken of any nest predators, during the spring of 1992, 3 bobwhites were radio-located inside Texas rat snakes (*Elaphe obsoleta*); 2 of these birds were hens. Neither hen was known to be nesting but both had enlarged ovaries. This suggests that snakes depredated numerous nests before incubation began.

Five (11%) of the 46 nests were abandoned. This value is similar to the 11% reported by Jackson (1947) and Klimstra and Roseberry (1975), lower than the 20% recorded by Sloan (1987), and higher than the 5 and 2% observed by Lehmann (1984) and Burger et al. (1995). In our study, 2 of the 5 nests were abandoned soon after a remote camera was placed at the nest site. Also, a nest was abandoned after the hen was captured off the nest to replace the failed radio-transmitter. If the 3 nests knowingly disturbed are eliminated, nest abandonment in this study would be only 4%. Regardless, both values are relatively low when compared to most other studies. Perhaps in expanding populations, hens demonstrate stronger nest fidelity than in populations at carrying capacity.

Only 1 nest (2%) was depredated by mammals. This value was much lower than those recorded in other studies. Sloan (1987) and Burger et al. (1995) reported that 27 and 12% of all nests were depredated by mammals. Finally, although Parsons (1994) recorded an average of 1.9 fire ant (*Solenopsis invicta*) mounds within an 11-m radius of the nests, only 1 nest was apparently depredated by ants. At random points in the habitat, he recorded 2.1 mounds in the same size circle.

MANAGEMENT IMPLICATIONS

Before initiation of habitat modification, the land manager at the Boggy Slough area knew of only a small covey of bobwhites on the study area. By February 1992, there were an estimated 225 resident bobwhites on the study area (Liu et al. *this volume*). The design of our study did not allow us to compare the relative contributions of the 3 groups of bobwhites to the population increase. However, this study did demonstrate that bobwhites relocated from the South Texas Plains to the East Texas Pineywoods were inefficient in their ability to successfully nest, hatch eggs, and fledge chicks into the population. Conversely, there were no obvious differences in reproductive efficacy of resident bobwhites and those relocated to the study area from disjunct areas in the Pineywoods, especially when the contributions of East Texas cocks are included. If managers elect to modify forested areas and recreate suitable bobwhite habitat, it may be possible to enhance population recovery by stocking with wild-trapped birds from nearby areas. Conversely, although bobwhites in South Texas are often abundant and easy to capture, our data do not support using such birds to restore bobwhite populations in East Texas and the southeastern United States.

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HABITAT USE BY REINTRODUCED MOUNTAIN QUAIL

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ABSTRACT

Mountain quail (*Oreortyx pictus*) have declined in much of the Intermountain Region of the western United States. Many areas that once supported these birds now seemingly lack necessary food and cover, especially in critical riparian zones. Additionally, mountain quail appear to need periodic disturbance (fire, moderate grazing, etc.) to provide adequate forage and nesting areas. If mountain quail do not readily occupy suitable habitats, either because of restricted movements or because of habitat discontinuities, it may be necessary to stock birds in order to restore populations. In September 1995, we began a restoration program with the objective of reintroducing mountain quail into former ranges in eastern Oregon and Washington. In the winter of 1996--1997, we released 17 radio-marked birds into a drainage in Hell's Canyon as a pilot study to determine habitat use, survival estimates, and movement patterns. An additional 40 radio-marked birds were released during spring 1998 to determine habitat use, nesting success, and brood survival.

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BRAIN CHOLINESTERASE DEPRESSION AND MORTALITY OF BOBWHITE CHICKS EXPOSED TO GRANULAR CHLORPYRIFOS OR FONOFOS APPLIED TO PEANUT VINES

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ABSTRACT

Granular-formulated insecticides are applied on over 60% of the peanut acreage in North Carolina, each year, to control southern corn rootworm. This application is applied as a 0.45m band overtop peanut vines between June and August. Lorsban® 15G (chlorpyrifos) and Dyfonate® 15G (fonofos) are used 90% of the time by peanut growers. Quail chicks foraging within or on the edge of peanut fields may consume granules as grit material as the insecticide granules are not soil-incorporated. Therefore, we examined the hazard posed by these insecticides to bobwhite chicks foraging in peanut fields. Two identical experiments were conducted in which 4, 15×150m plots, were treated with Lorsban 15G or Dyfonate 15G and 2 plots were untreated. Human-imprinted bobwhite chicks (N = 7–9 chicks per plot) from two age groups, 4–7 or 11–12 days, were allowed to forage for one hour in treated and control plots. Brain cholinesterase (ChE) activity and ChE depression, relative to control ChE values, were determined for each chick. Differences in ChE activity between treatments were tested for using a two-way ANOVA with "broods" serving as the experimental unit. Relationships of age to ChE depression, within treatments, were analyzed separately using linear regression. Chicks foraging in peanut fields were observed ingesting granules directly and indirectly via granules adhered to arthropods. Chick brain ChE depression averaged 22% (SE = 3.6) and 8% (SE = 3.2) for chicks exposed to Dyfonate and Lorsban, respectively. Brain ChE was significantly lower than control values for chicks exposed to Dyfonate ($P = 0.014$). While ChE depression was not correlated to chick age ($P > 0.15$), two 4-day-old quail chicks exposed to Dyfonate died and one 7-day-old chick was unable to walk. Chicks exposed to Dyfonate were lethargic and brooded whereas chicks exposed to Lorsban and control chicks showed no overt behavioral changes. Our results indicate that this application of Lorsban 15G presents a relatively low hazard to quail chicks foraging in recently treated peanut fields. In a follow-up experiment, chicks foraging in Dyfonate-treated peanut fields, 1 day post-application, exhibited less ChE depression ($\bar{x}$ = 12%, SD = 10.2) than chicks exposed immediately following the application, suggesting the hazard from Dyfonate may be temporary.

Citation: Palmer, W.E., J.R. Anderson, Jr., and P.T. Bromley. 2000. Brain cholinesterase depression and mortality of bobwhite chicks exposed to granular chlorpyrifos or fonofos applied to peanut vines. Page 138 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, Jr., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

EXPOSURE OF CAPTIVE BOBWHITES TO AN AT-PLANTING APPLICATION OF TERBUFOS (COUNTER® 15G) TO CORN

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ABSTRACT

Terbufos is a highly toxic, organophosphate insecticide that is commonly applied to corn fields during planting. Quail use crop field edges during April, when corn is planted in North Carolina, and consequently may be exposed to at-planting insecticides. Therefore, we attempted to quantify the hazards to quail from an at-planting, banded application of Counter® 15G using penned northern bobwhite quail. Eight, 7.5 × 7.5m pens were placed in cornfields immediately after planting. Six field pens received Counter 15G at 22.7g per 100m of cornrow. Pens were placed such that a 2.5 × 7.5m section was located in standing wheat. The remainder of each pen extended past the "turnrows" into a section of regular rows in each cornfield. Two quail of each sex were placed in each pen. Behavior of quail using cornfields was observed from blinds and categorized as feeding, loafing, dusting and other. Blood serum, for determining cholinesterase (ChE) activity, was collected from a sub-sample of quail (n = 3) from each pen prior to and at 1.5, 8.5 and 15.5 days following exposure. Change in (ChE) activity from pre-exposure levels was determined and averages for birds from each pen were compared between treatments using a one-way analysis of variance. In quail exposed to terbufos, serum ChE activity declined 21% relative to pre-exposure levels at 1.5 days (P = 0.04; df = 1,4), but not at later dates sampled (P > 0.08). No mortality was observed. Observations of quail in pens revealed no unusual behaviors or changes in behavioral patterns over the course of the study. Our results suggest that Counter® 15G is unlikely to cause mortality or significant behavioral changes in wild quail inhabiting farms.

Citation: Palmer, W.E., J.R. Anderson, Jr., and P.T. Bromley. 2000. Exposure of captive bobwhites to an at-planting application of terbufos (Counter® 15G) to corn. Page 139 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, Jr., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

SURVIVAL RATES FOR NORTHERN BOBWHITES ON TWO AREAS WITH DIFFERENT LEVELS OF HARVEST

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ABSTRACT

We estimated survival rates for radio-marked northern bobwhites (*Colinus virginianus*) in south-central Iowa from 1984 to 1988. Survival rates and survival functions were calculated for 2 areas that received different and varied amounts of hunting pressure. Survival from fall-spring averaged 17.1% ± 6.9% on the Brown's Slough study area (BSSA) and 20.1% ± 5.7% on the Millerton study area (MSA). Although these estimates were not different (P = 0.898), the survival functions did differ between the 2 areas (χ^2 = 25.82, P<0.001). Mortality due to hunting averaged 27.7% ± 8.2% on the BSSA during the fall-spring period and 12.3% ± 4.9% on the MSA. Predators accounted for 52% of fall-spring mortality on the BSSA and 79% of the mortality on the MSA. The BSSA had much lower rates of predation the 2 months following the hunting season. Survival rates during both the spring-fall period and annually did not differ between the 2 areas (P = 0.395 and P = 0.979). Hunting did not appear to be a limiting factor for quail numbers on these areas during the study.

Citation: Suchy, W.J., and R.J. Munkel. 2000. Survival rates for northern bobwhites on two areas with different levels of harvest. Pages 140–146 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, Jr., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

INTRODUCTION

Many studies have examined the life history and various population dynamics of the northern bobwhite (e.g., Stoddard 1931, Roseberry and Klimstra 1984). Most of the studies in Iowa on quail have focused on censusing populations (Kozicky and Hendrickson 1952, Kozicky et al. 1956, Kozicky 1957, Stempel 1962). Many of these early studies utilized methodology that produced variable results. Since the 1960's quail populations have declined in Iowa (Suchy et al. 1991) and throughout most of their range (Church et al. 1993). The advent of radio-telemetry makes it possible to collect detailed demographic information unattainable by earlier methods. Detailed information on survival could potentially help identify causes of the decline and, more importantly, provide insight into management practices that could mitigate the factors responsible.

The primary objective of this study was to evaluate the impact that hunting has on survival rates on 2 areas that receive different levels of hunting pressure. The Brown's Slough study area (BSSA) was centered around a state wildlife management area which traditionally received heavy hunting pressure. The Millerton study area (MSA) was a similar area of privately owned land with lower hunting pressure (Suchy and Munkel 1993). Causes of hunting and natural mortality were estimated using radio-marked quail captured on both study areas. We compare the causes of non-hunting mortality as well as the overall timing of all sources of mortality to evaluate the apparent impact hunting had on quail numbers on these areas.

METHODS

Study Area

The BSSA (1,960 acres) and MSA (2,315 acres) consist of some of the best northern bobwhite habitat in Iowa. Seventeen habitat types were identified and measured on each study area. The proportion of cropland, grassland, woodland and strip cover on the BSSA averaged 24.6%, 45.2%, 10.9% and 17.8% from 1984–88 while the MSA averaged 38.9%, 35.8%, 9.3% and 15.8%. The biggest specific difference in land use was that soybeans were planted on an average of 20.5% of the MSA but only 5.3% of the BSSA. The percent of cropland on the MSA was reduced by about 25% during 1987 and 1988 due to enrollment in the Conservation Reserve Program. The amount of each cover type on the BSSA was more consistent, although some intermittent flooding occurred when nearby Rathbun Reservoir rose above normal pool levels.

During the period of the study, the mean number of quail observed on the annual August roadside survey increased from 2.4 to 14.5 birds per 30 miles in the southern Iowa region (Suchy et al. 1991). Flush counts conducted prior to the hunting season each year averaged 37 birds per square mile on the BSSA and 42 birds per square mile on the MSA.

Capture Methods

We captured birds by bait-trapping in September, October, February and March (Stoddard 1931:442) and night-lighting in May–October (Bartholomew 1967), attached radio-transmitters and numbered leg bands and released them. Birds were aged as either juvenile or adults and their sex was recorded (Rosene 1969: 44–54). Backpack style transmitters (5–6 grams, AVM Instrument Co. Ltd., Livermore, CA) were attached using wing loops to all quail weighing ≥ 150 g. Birds were located >3 times per week using truck-mounted and hand-held Yagi antennas. An attempt was made to determine the proximate cause of death (Dumke and Pils 1973) when a mortality was suspected based on inactivity of the marked bird.

Hunting Pressure

Hunter bag-checks were conducted on each study area using a stratified design to sample the number of parties on each area. The number of vehicles on each area was counted at the beginning and end of each survey period. Hunter interviews were conducted to determine whether the party was hunting quail, the number of hours each party hunted, the number of coveys flushed, the number of quail retrieved and the number hit but not retrieved for as many of the parties as possible. The hunting season was divided into 3 periods: the first 9 days (quail and pheasant open concurrently), the remainder of the pheasant season, and the remainder of the quail season. The pheasant season opened on November 3, 2, 1 and October 31 and closed on January 1, 5, 4, 3 in 1984 to 1988, respectively. The quail season opened the same day as the pheasant season and ended on January 31 each year.

Survival and Mortality Rates

We calculated survival rates for 2 periods, the fall-spring period from October 1 to March 31 (182 days), and the spring-fall period from April 1 to September 30 (183 days). The fall-spring period begins when coveys are formed and most juvenile birds are large enough to carry transmitters, includes the hunting season, and ends when coveys begin to break up in the spring. The spring-fall season coincides with the nesting season. Annual rates were calculated by combining the 2 periods. We used the staggered entry technique (Pollock et al. 1989b) to produce Kaplan-Meier survival estimates (Kaplan and Meier 1958). The assumptions required are that radio-marked birds are selected randomly from the population, survival rates are independent, left-censored birds had similar survival rates, censoring was random and trapping and tagging did not affect survival. If tagging does affect survival then our estimates will be negatively biased; however, we believe the comparisons between the 2 areas would still be valid, because potential differences in survival would be relative.

Birds were right-censored if they survived past the end of a period, or if their fate was unknown due to radio failure or loss or movement off the study area. Birds that died or were censured within 7 days of being radio-marked (Pollock et al. 1989b) were excluded from analyses to minimize the impact of capture. Birds surviving to the next period were treated as new, independent observations. Log-rank tests were used to compare survival functions between age, sex and study areas (White and Garrot 1990). Z-tests were used to determine if survival estimates differed between age, sex and study areas after any period (Pollock et al. 1989b). A generalized Chi-square hypothesis testing procedure was used to determine if survival rates differed between study areas and years (Sauer and Williams 1989). A 5% level of significance was used for all comparisons.

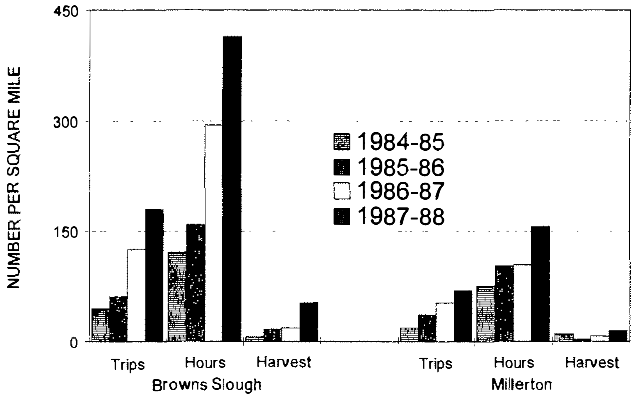

Fig. 1. The estimated number of trips, hours spent afield and harvest on the BSSA and MSA, 1984–1988 based upon hunter interviews. Trips are the number of hunters going afield on a day, hours are the number of hunters multiplied times the number of hours each hunter spent hunting and harvest is the number of birds retrieved.

Cause-specific mortality rates (Heisey and Fuller 1985) were calculated for each period on each study area. This assumes that survival rates are constant within the period. A generalized Chi-square hypothesis testing procedure was used to determine if cause-specific harvest mortality rates differed between areas and years (Sauer and Williams 1989). Cause-specific rates were calculated by month for each study area during the fall-spring period.

RESULTS

We captured 822 quail from 1984–1988. Radio transmitters were placed on 628 birds. We excluded 14 birds (2.2%) from analyses because they died or were censured within 7 days after release.

Hunting Pressure

The number of hunter trips, hunter hours and the number of quail killed varied considerably on the BSSA and MSA during the study (Figure 1). Hunting pressure, in general, increased as the study progressed. The number of hunter trips increased from 137 to 551 on the BSSA and from 68 to 252 on the MSA between the 1984–1985 and 1987–1988 hunting seasons. Hunting pressure was consistently higher on the BSSA. Hunter trips, hunter hours and harvest were, on average, twice as high on the BSSA. The reported crippling rate on the BSSA averaged 28% of the harvest and was higher than on the MSA, which averaged 17% of the harvest. Hunters reported flushing an average of

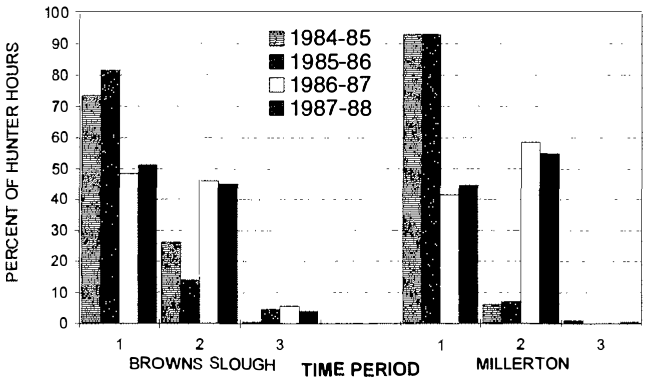

Fig. 2. The estimated number of hunter hours on the BSSA and the MSA from 1984–1988. Period 1 was the first 9 days of the season. Period 2 was from the end of Period 1 to the end of the pheasant season in early January. Period 3 was from the end of Period 2 to the end of the hunting season on January 31.

0.08 coveys per hunter hour on both areas. The number of coveys flushed per hunter hour increased from 0.05 to 0.12 on the BSSA and from 0.06 to 0.10 on the MSA during the study.

The distribution of the hunting pressure during the season also changed as the study progressed (Figure 2). During the first 2 years over 70% of the hunter trips occurred during the first 9 days of the season. During the last 2 years this fell to 40 to 50% as more hunters spent more time hunting later during the season. Less than 5% of the trips occurred during January (Period 3) when the pheasant season was closed. Although there were fewer hunters afield during this period they were, on average, more successful.

Cause-Specific Mortality

We estimated cause-specific mortality rates from observed mortalities of 392 radio-marked bobwhites. Avian and mammalian predators were the largest known source of mortality (24.1%) during the fall-spring period on the MSA, while harvest (27.7%) was the largest source of mortality on the BSSA when all years are pooled (Table 1). During the spring-fall period mammals were the largest source of mortality on both study areas. Annually, harvest (27.7%) was the largest source of mortality on the BSSA, while predation due to mammals (29.1%) was slightly greater than predation by raptors (27.7%) on the MSA.

Mortality due to harvest during the fall-spring period (Table 2) was similar between years on each study area ($P>0.079$) but differed significantly between the 2 areas ($\chi^2 = 5.46$, 1 df, $P = 0.020$).

When we compare estimates of cause-specific mortality by month on each study area (Figure 3) we see that most hunting mortality occurred during November and December and was higher on the BSSA. Mortality due to other causes were similar on both areas until February and March when mortality due to predation was much higher on the MSA.

Survival Estimates

Survival rate estimates were similar for males and females on both areas during the fall-spring period, except in 1987–1988 on the MSA, and for all periods during the spring-fall period. Estimates ranged from 9.5% to 40.1% for males and from 5.0% to 34.5% for females during the fall-spring period and from 25.3% to 60.5% for males and 16.2% to 55.6% for females during the spring-fall period. When data for the 2 study areas were pooled, survival rate estimates did not differ between the sexes during any period (P>0.137); therefore, sexes were pooled for all comparisons.

Survival rate estimates were similar for juveniles and adults on both areas during the fall-spring period, except in 1986–1987 on the BSSA and for all periods during the spring-fall period except in 1986 on the BSSA. Estimates ranged from 9.4% to 34.6% for juveniles and from 5.4% to 43.8% for adults during the fall-spring period and from 23.0% to 61.6% for juveniles and 18.7% to 87.5% for females during the spring-fall period. When data for the 2 study areas were pooled, survival rate estimates did not differ be-

Table 1. Fall–spring (1 October–31 March), spring–fall (1 April–30 September) and annual (1 October–30 September) cause-specific mortality rates (M) (Heisey and Fuller 1985) of radio-marked northern bobwhite pooled for all years, 1984–1988.

		Brown's Slough				Millerton			
Interval	Cause	Radio-days	*n*	M	SE	Radio-days	*n*	M	SE
Fall–Spring	Raptor	10,141	22	0.197	0.037	16,153	41	0.241	0.033
	Mammal		14	0.125	0.031		41	0.241	0.033
	Harvest		31	0.277	0.042		21	0.123	0.025
	Unknown Predator		10	0.089	0.027		21	0.123	0.025
	Other		12	0.107	0.029		7	0.041	0.015
Spring–Fall	Raptor	13,522	18	0.154	0.033	16,614	23	0.155	0.030
	Mammal		21	0.179	0.035		32	0.215	0.033
	Harvest								
	Unknown Predator		19	0.162	0.034		22	0.148	0.029
	Other		16	0.137	0.032		21	0.141	0.028
Annual	Raptor	23,663	40	0.228	0.037	32,767	64	0.277	0.032
	Mammal		35	0.162	0.032		73	0.291	0.032
	Harvest		31	0.277	0.042		21	0.123	0.025
	Unknown Predator		29	0.123	0.028		43	0.157	0.026
	Other		28	0.135	0.030		28	0.074	0.017

Table 2. Cause-specific mortality rates (M) (Heisey and Fuller 1985) of radio-marked northern bobwhites during the fall–spring period (1 October–31 March), 1984–1988.

		Brown's Slough				Millerton			
Year	Cause	Radio-days	*n*	M	SE	Radio-days	*n*	M	SE
1984–1985	Raptor	1,028	1	0.083	0.079	4,277	10	0.211	0.059
	Mammal		1	0.083	0.079		19	0.400	0.070
	Harvest		4	0.331	0.134		3	0.063	0.035
	Unknown Predator		2	0.166	0.116		6	0.126	0.048
	Other		2	0.166	0.116		0	0.000	0.000
1985–1986	Raptor	2,692	3	0.127	0.068	2,977	8	0.262	0.079
	Mammal		6	0.255	0.089		3	0.098	0.054
	Harvest		4	0.170	0.077		5	0.164	0.067
	Unknown Predator		1	0.042	0.041		5	0.164	0.067
	Other		1	0.042	0.041		2	0.066	0.045
1986–1987	Raptor	1,988	4	0.192	0.086	4,176	5	0.143	0.059
	Mammal		1	0.048	0.047		6	0.171	0.063
	Harvest		3	0.144	0.077		5	0.143	0.059
	Unknown Predator		2	0.096	0.064		3	0.086	0.047
	Other		6	0.288	0.098		2	0.057	0.039
1987–1988	Raptor	4,433	14	0.251	0.058	4,723	18	0.311	0.060
	Mammal		6	0.107	0.041		13	0.225	0.055
	Harvest		20	0.358	0.063		8	0.138	0.045
	Unknown Predator		5	0.089	0.038		7	0.121	0.043
	Other		3	0.054	0.030		3	0.052	0.029

tween the ages during any period (P>0.110); therefore, ages were pooled for all comparisons.

Survival rate estimates did not differ significantly between the 2 study areas during any year for any period or annually (Table 3). Survival rates did not differ between years for either study area except for the spring-fall period in 1985 on the MSA (*P* = 0.001). Survival rates for the fall-spring period ranged from 12 to 28% on the BSSA and from 15 to 40% on the MSA. Spring-fall survival rates were higher and ranged from 32 to 39% on the BSSA and 24 to 62% on the MSA. Annual survival rates ranged from 4 to 10% on the BSSA and from 5 to 13% on the MSA.

Survival estimates with ages and sexes pooled did not differ between years for either study area during the fall-spring or spring-fall period or for the whole year. Survival rates also did not differ between the study areas in any year for any time period.

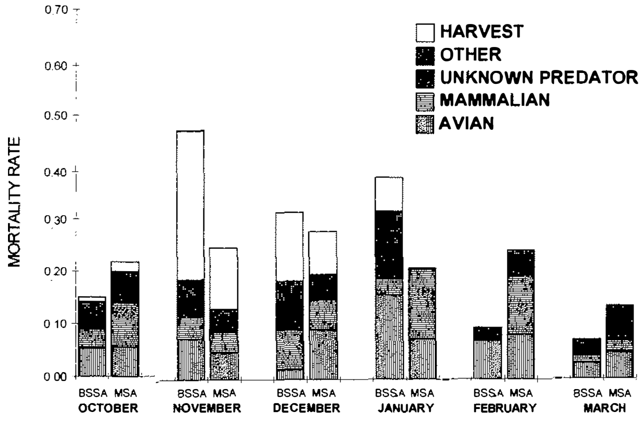

Fig. 3. Monthly estimates of cause-specific mortality (Heisey and Fuller 1985) during the fall-spring period for radio-marked bobwhites on the BSSA and MSA, 1984–1988.

Survival Functions

Although the point estimates for the above comparisons were similar for the study areas, the survival functions differed between the 2 study areas for all periods except the fall-spring period in 1987–1988, the spring-fall period in 1988 and annually for 1987–1988. The survival functions for both areas declined rapidly during the early portion of the hunting season for each year of the study (Figure 4). After these initial losses, the functions were more variable and depended upon the number of birds harvested during the hunting season. Although hunting pressure and harvest increased throughout the study (Figure 1), the proportion of radio-marked birds that died due to hunting was more variable (Table 2). Losses due to hunting were higher on the BSSA in 1984–1985 and 1987–1988 than on the 2 years in between. Mortality on the MSA was low in 1984–1985 and then remained constant. As a result, mortality due to hunting on the BSSA was 5 times higher than on the MSA in 1984–1985, about 3 times higher in 1987–1988 but very similar in the other 2 years.

Pooling birds for all years on each study area allows for a more detailed examination of the influence of harvest on the survival functions (Figure 5). Both curves are very similar until mid-November, which coincides with the end of the initial period of heavy harvest. After this, the survival curve for the BSSA falls below the MSA and stays lower throughout the rest of the hunting season. Hunting mortality on the BSSA during this period is about twice that on the MSA (Figure 3). After the end of the hunting season on January 31 the survival curve on the MSA declines while little additional mortality occurs on the BSSA during this period (Figure 3). By the end of March the difference between the 2 areas becomes statistically non-significant.

Table 3. Fall-to-spring (1 October–31 March), spring-to-fall (1 April–30 September) and annual (1 October–30 September) survival (S) Kaplan and Meier 1958) of radio-marked northern bobwhite quail in south-central Iowa, 1984–1988.

		Brown's Slough			Millerton			P-value	
		n	S	SE	*n*	S	SE	log-rank test[a]	Z-test[b]
Fall–Spring	1984–1985	17	0.219	0.113	68	0.203	0.056	0.000	0.898
	1985–1986	44	0.276	0.106	46	0.220	0.077	0.068	0.670
	1986–1987	56	0.283	0.109	62	0.397	0.084	0.013	0.403
	1987–1988	83	0.118	0.042	92	0.145	0.044	0.875	0.651
	Pooled	219	0.173	0.035	277	0.201	0.029	0.000	0.533
Spring–Fall	1985	25	0.394	0.179	41	0.624	0.095	0.001	0.257
	1986	34	0.364	0.090	42	0.267	0.073	0.185	0.400
	1987	52	0.321	0.071	66	0.240	0.058	0.070	0.375
	1988	54	0.371	0.083	51	0.334	0.077	0.447	0.741
	Pooled	165	0.367	0.044	196	0.318	0.038	0.002	0.395
Annual	1984–1985	39	0.086	0.059	81	0.126	0.040	0.000	0.573
	1985–1986	56	0.101	0.046	67	0.059	0.026	0.027	0.428
	1986–1987	82	0.091	0.040	94	0.095	0.030	0.003	0.924
	1987–1988	113	0.044	0.018	109	0.048	0.018	0.576	0.856
	Pooled	273	0.064	0.015	341	0.064	0.012	0.000	0.979

[a] comparison of survival distributions (White and Garrot 1990).

[b] comparison of survival rate estimates at end of period (Pollock et al. 1989b).

DISCUSSION

The primary objective of this study was to evaluate the impact that hunting has on quail numbers. The intent was to evaluate 2 areas of similar habitats with differing harvest rates for a period of 4 years and compare results. The study design did not anticipate that hunting pressure would change as markedly as is indicated in Figures 1 and 2. Although this variability complicates the interpretation, conclusions about the effect of hunting can still be drawn from the comparisons.

Hunting was not the major source of mortality recorded for our radio-marked birds on either study area. Predation from all sources accounted for 52% of the mortality during the fall-spring period and 55% of the annual mortality on the BSSA while hunting accounted for 35% of the mortality during the fall-spring period and 30% annually. On the MSA, predation accounted for 79% of the mortality during both the fall-spring period and annually. Hunting accounted for 16% of the mortality during the fall-spring period and 13% annually.

Despite these large differences in the sources of mortality, the survival estimates were nearly identical, 17.3% on the BSSA and 20.1% on the MSA by the

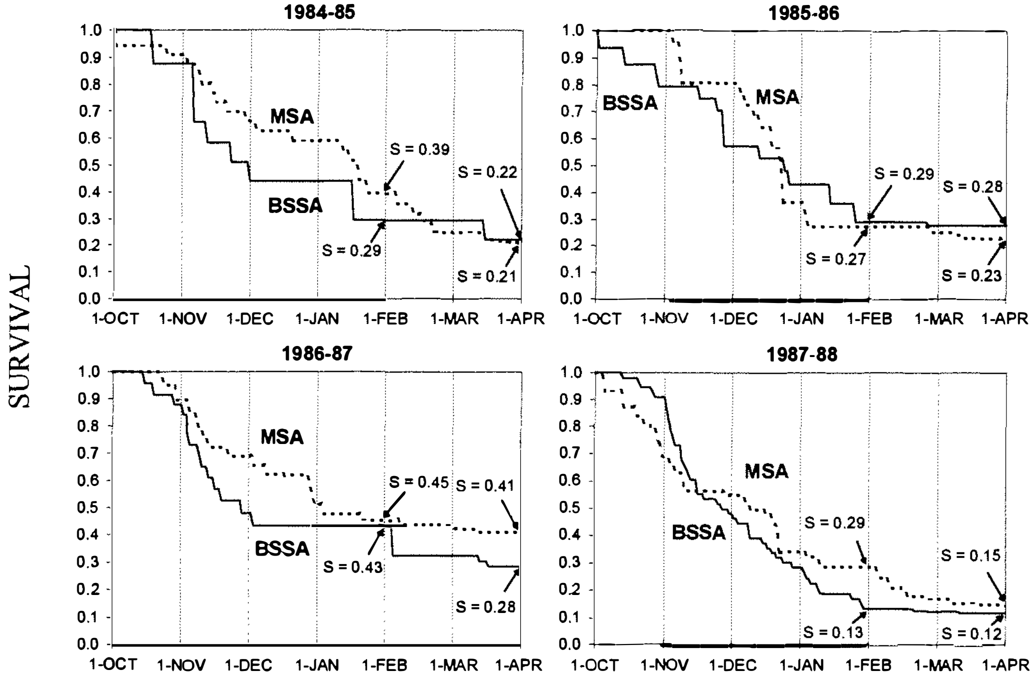

Fig. 4. Kaplan-Meier survival functions for radio-marked bobwhite on the BSSA and the MSA for the fall-spring period for each year of the study. The shaded bar represents the open hunting season and survival estimates are given for each area at the end of the hunting season and the end of the fall-spring period.

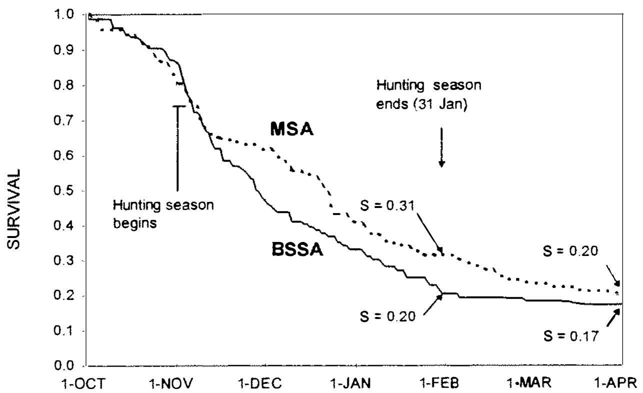

Fig. 5. Kaplan-Meier survival functions for radio-marked bobwhite on the BSSA and the MSA. Birds were pooled for each study area over all 4 years of the study. Survival estimates are given for each area at the end of the hunting season and the end of the fall-spring period.

end of the fall-spring period and were the same (6.4%) on both areas annually.

These survival rates are similar to those reported for radio-marked birds on private land in Missouri for the fall-spring (0.159) and annually (0.053) (Burger et al. 1995) and in North Carolina annually (0.061) (Curtis et al. 1988)). They are much lower than reported from studies which used flush counts or age-ratio data (0.18, Marsden and Baskett 1958; 0.154, Kabat and Thompson 1963; 0.188 and 0.182, Roseberry and Klimstra 1984) or from band recoveries (0.167, Pollock 1989a). Vance and Ellis (1972) reported similar survival estimates (0.215 and 0.233) from flush counts on public land in Illinois during the fall and winter.

Although crippling losses based upon hunter surveys was estimated to be about 28% and 17% of the reported kill on the 2 areas according to our hunter bag surveys, this mortality source was only detected in our radio-marked birds a total of 3 times or about 5% of the harvest mortality. This mortality source may be reported as predation in our study if wounded quail were killed or scavenged by predators. This would increase our estimate of hunting mortality to about 49% on the BSSA and 17% on the MSA during the fall. The survival rate estimates, however, would be unchanged.

The level of harvest on the MSA is similar to what Burger et al. (1995) found on private land in Missouri (22.9%) but lower than on private land in Illinois (42.5%) (Roseberry and Klimstra 1984). The level of harvest on the BSSA was lower than the 70% that Vance and Ellis (1972) found on public land in Illinois.

Most hunting regulations for quail are based upon the assumptions that harvest mortality simply replaces natural mortality (Errington and Hamerstrom 1935, Baumgartner 1944, Marsden and Baskett 1958). Some recent studies suggest that harvest above a threshold level, particularly in January and February, can be additive (Roseberry and Klimstra 1984, Curtis et al. 1988, Pollock et al. 1989a, Robinette and Doerr 1993). The low survival rates in our study appear to be related to predation, not harvest. This is similar to what Burger et al. (1995) found in Missouri. Results from our study indicate that little hunting pressure and even less kill (< 5%) occurred during the later part of the quail season. Even in years when hunter kill was low (1985–1986 and 1986–1987), survival rates were not significantly higher than the years when the kill was high. Hunting pressure and harvests were twice as high on the BSSA compared to the MSA, yet by 1 April the survival estimates for the 2 areas were very similar. This is vividly illustrated in Figure 4 where it appears that hunting simply removed birds that would have been lost to predators later during the fall-spring period. The survival functions for the 2 areas differ, mainly due to the additional harvest in November to January on the BSSA (Figure 5), but the net number of birds remaining in the population to begin the nesting season are similar. The apparent reason is that predation is low after the hunting season closes on the BSSA while on the MSA, predation remained higher.

Our results and their interpretation assume that the birds with radio-transmitters have the same survival rates and behavior as the rest of the population. If this assumption is not true then our conclusions may be inappropriate.

MANAGEMENT IMPLICATIONS

There is little evidence that hunting at the level measured on the MSA and BSSA impacted the number of quail on our study areas. Although the fall-spring period is a time of heavy mortality, predation appears to be the most important factor limiting quail numbers on these 2 areas. Additionally, little harvest occurred late in the season with 40% or more of the harvest occurring during the first 9 days of the season in all years. Most of the birds taken at this time probably would not have survived till spring anyway. Survival functions derived for the 2 study areas seem to indicate that even when harvest is low, the final survival rate does not change. We agree with Burger et al. (1995) that relationships among harvest, predation, productivity and abundance must be viewed dynamically. Careful evaluation of the relationships between these factors is needed if we hope to be able to manage for stable populations.

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RELEASING CAPTIVE-REARED MASKED BOBWHITES FOR POPULATION RECOVERY: A REVIEW

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ABSTRACT

Efforts to reestablish the endangered masked bobwhite (*Colinus virginianus ridgwayi*) to its former historic range have been a primary focus on the Buenos Aires National Wildlife Refuge (BANWR) since it was established in 1986. Prerelease conditioning techniques developed prior to refuge establishment continued to be utilized in an effort to improve postrelease survival of captive-reared masked bobwhite chicks. Foremost among these techniques was the use of wild Texas bobwhite (*C. v. texanus*) males as foster parents. Texas foster parents were released with broods from 1985–1996. The efficacy of this technique was evaluated in 1994 using radio telemetry. Results suggested that postrelease survival of chicks was poor. Using an adaptive approach, prerelease protocols were modified over several years in an effort to improve postrelease survival among chicks. Since 1995. released chicks were monitored via radio telemetry and results of the modified releases indicated survival had improved. Though these results are preliminary and this study is ongoing, it appears that our modifications to prerelease conditioning may improve survival rates of captive-reared masked bobwhite chicks. The results of this research project may have implications for captive-reared quail release projects elsewhere.

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INTRODUCTION

Historically, quail have been one of the most popular upland gamebirds throughout the United States (U.S.), and are of national importance to outdoor enthusiasts today. Recreational hunting opportunities have declined in recent years, largely due to a near ubiquitous decline in northern bobwhite (*Colinus virginianus*) populations nationwide (Brennan 1991). This unfortunate event has become a source of concern among both biologists and hunters. Habitat loss is the primary factor thought to be responsible for the northern bobwhite population decline (Brennan 1991). Therefore, many recent management programs have focused on improving habitat conditions. In many situations, aggressive habitat management is needed and such management actions often result in improved quail population levels, if a viable population is present before such habitat management actions are applied. Unfortunately, many areas throughout the U.S., that historically supported viable quail populations, no longer do so. Efforts to restore quail populations in areas where local extinctions have occurred often requires a reintroduction program.

Reintroducing quail into various parts of the country has been a controversial issue for decades. Stoddard (1931) discussed releasing both pen-reared birds as well as wild stock in the Southeast and believed quail reintroductions and translocations were worthwhile endeavors, especially if habitat conditions were suitable. However, Kabat and Thompson (1963) stated that releasing captive-reared birds in Wisconsin could not be justified due to chronic lack of success and the high expenses involved. In contrast, Kozicky (1993) believed reintroducing captive-reared birds to repopulate formerly occupied habitats, or to supplement wild populations at low densities, represented a major opportunity to enhance quail populations. He suggested the technique not be dismissed prematurely, and challenged scientists to develop a safe and efficient means of accomplishing successful captive-bred releases. Hurst et al. (1993) emphasized that additional research on methods of producing and releasing wild, disease-free quail must be developed before they could fully endorse the technique.

Unfortunately, the U.S. Department of the Interior, Fish and Wildlife Service (USDI, FWS) often does not have the luxury of debating the deficiencies and merits of reestablishing endangered species to historic habitats. The USDI, FWS has a legal mandate to restore an endangered species to habitats the species formerly occupied within the U.S. as part of the recovery process. In many cases, releasing captive-reared birds and

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mammals may be the only viable alternative. Such is the case with the endangered masked bobwhite, which was extirpated from the U.S. about 1900 (Brown 1900, 1904).

The masked bobwhite occupies a limited geographic range and is presently thought to be restricted to the Buenos Aires National Wildlife Refuge (BANWR) in southeastern Arizona and two privately owned ranches in northwestern Sonora, Mexico. Masked bobwhite life history is documented by Tomlinson (1972) and Brown (1989), and recovery history is documented in the Recovery Plan (U.S. Fish and Wildlife Service 1995) as well as by Kuvlesky et al. (*this volume*). The USDI, FWS launched a propagation and release research program using captive-reared masked bobwhite chicks during the 1970's. The agency attempted to reestablish a self-sustaining population in the Altar Valley of Arizona for almost 15 years (Kuvlesky et al. *this volume*). Though a self-sustaining population never materialized, several important release techniques were developed during this period (Ellis and Tomlinson 1974, Ellis et al. 1978, Ellis and Carpenter 1981) that were eventually adopted by BANWR when it was established in 1986 (Kuvlesky et al. *this volume*). In our paper, these techniques will henceforth be referred to as the "*established*" propagation and release techniques. USFWS biologists believed the continued use of established techniques would have eventually resulted in success had sufficient habitat been protected from livestock grazing. Since livestock were not permitted on BANWR, it was assumed that application of the established techniques would inevitably yield a self-sustaining masked bobwhite population on BANWR.

Established propagation and release techniques were used for 10 years and succeeded in establishing a breeding population of masked bobwhites. However, doubt remained as to whether a self-sustaining population had been established. Postrelease survival of chicks seemed poor, and this prompted questions regarding the efficacy of the established protocols. The effectiveness of using Texas bobwhites, for example, was seriously questioned because chick telemetry studies and field observations indicated broods and foster parents were not staying together following release. It was possible that foster parents were abandoning their "adopted" broods for receptive masked bobwhite hens, because releases occurred during the masked bobwhite breeding season. It was also possible that chicks did not stay with foster parents because imprinting had not occurred. Because of these concerns, the 1995 Recovery Committee recommended significant changes to the established propagation and release protocols. They believed such changes would yield improved postrelease chick survival (U.S. Fish and Wildlife Service 1996). The Recovery Committee's recommendations were implemented during summer 1995 and have continued, with modifications, to date. The purpose of our paper is to: (1) describe the prerelease conditioning techniques used from 1994 to 1998, and; (2) to compare the survival of chicks released under established protocols in 1994 with those released under the new protocols from 1995 to 1998. In addition, we briefly discuss the implications that prerelease conditioning has on masked bobwhite recovery as well as for the reestablishment of other quail populations throughout the country.

STUDY AREA AND METHODS

The evaluation of prerelease conditioning techniques on BANWR began during June 1994 and continued each year through 1998. BANWR is located in southeastern Arizona approximately 97 km south of Tucson. The Refuge consists of over 48,000 ha of semidesert grassland, which is described in detail by McLaughlin (1992) and Burgess (1995), with elevations in the grassland ranging between 975–1159 m above sea level. Soils and vegetation were similar on all sites used in this study. Annual precipitation averages 48 cm and is bimodally distributed in the form of intense late summer thunderstorms (July to September) and more uniform winter precipitation (November to February). Average annual temperatures are between 13–16 ° C (McClaran 1995) with 60–90 days of frost during winter and more than 60 days of hot weather (≥27° C) during May, June, and July.

Prerelease Conditioning Techniques: 1994

Masked bobwhite chicks utilized during 1994 were obtained from a captive population maintained by the Patuxent Environmental Research Center (PERC) in Laurel, Maryland. Established propagation and release protocols were utilized in 1994. Prerelease conditioning involved pairing a brood of 12–15 2-week old chicks with a sterilized Texas male foster parent (Ellis and Carpenter 1981) in a standard Petersime poultry brooder unit. If the prospective foster parent displayed aggressive, protective behavior of a brood the adoption was considered successful. The foster parent was partitioned on the brooder shelf by a wire mesh wall that allowed the chicks to move in and out of the area confining the adult. This ensured the safety of the chicks if, for some reason, the adult did not adopt them. For all successful adoptions, foster parents and their respective broods were marked with individually numbered aluminum leg bands or wing-mounted patagial tags. Family groups were maintained in brooder units for 1 week, then transferred to elevated outdoor caged runs (20cm × 0.5m × 3m) where they were given water and commercial gamebird starter feed. The runs consisted of a wood frame with wire mesh floor and sides and an aviary netting top. Fiberglass roof panels (0.3 × 0.3m) on each end of the run provided shade and cover. Half of the groups remained in these runs for 2 weeks and then were released to the wild. The other half were placed on the ground in flight pens (4 × 5 × 10m) after spending 1 week in the runs and were held for an additional week before they were released. Flight pens were constructed of metal post frames, covered with aviary netting which were secured to the metal frame, and then planted to native grass and watered regularly to encourage lush herbaceous growth and insect abundance. Family groups had the opportunity to forage for native food although supplemental food and water were also provided. Family groups were gathered during the morning of the designated release day, a transmitter was attached to a chick and the adult, and the group was transported via a wooden release box (15cm × 0.5m × 0.7m) to a site. They were then released under a shrub with a dense herbaceous understory. At release, chicks were about 4.5-weeks old. Releases were conducted from early August to late September. During this period, 213 chicks were released as 15 family groups (average brood size = 14.2). Within these groups, 15 Texas bobwhite adults and 10 masked bobwhite chicks were fitted with transmitters.

Preconditioning Release Techniques: 1995

In an effort to improve postrelease chick survival, modifications were made to the established prerelease protocol in 1995. In addition to 2-week-old chicks, PERC also shipped 1-day-old chicks to the BANWR because biologists believed that day-old chicks would imprint more readily on the adult foster parents than 2-week-old birds. Both Texas bobwhite males and adult masked bobwhite males and females were used as foster parents. Twenty chicks were placed on each brooder unit shelf with their prospective foster parent. Heat and light levels in brooder units were slowly manipulated to ensure that chicks would be better adapted to natural conditions when they were moved outdoors. Heat in brooder units was maintained at approximately 32° C for 2 weeks and then was reduced a few degrees each day until a minimum temperature of 23.8° C was reached. Heaters were then turned off 2–3 days before family groups were moved outdoors. Fluorescent lights were initially utilized on a 24-hr basis to facilitate feeding and watering activities. However, continuous exposure to light seemed to stimulate cannibalism among chicks; therefore, exposure to artificial and natural light was minimized for several days. Chicks were then gradually exposed to natural light each day by adjusting miniblinds in brooder rooms. Full exposure to natural light was achieved 2 days prior to transporting each family group to the outdoors. While in brooders and runs, chicks were fed both commercially obtained and naturally occurring invertebrates, as well as the gamebird starter. Family groups were placed in flight pens 4.5 weeks after chicks were introduced to brooder units, and once in the flight pens they remained on the ground until they were released to the wild. Releases occurred during the early (September to October) and late (March) covey season to ensure that family groups remained intact as a covey unit. Each chick released was ≥ 8-weeks old. Temporary release pens (1.2 × 7.3 × 7.3m) were erected at selected release sites and were constructed of PVC pipe, 6.35mm wire mesh hardware cloth and aviary netting. Groups of 30–50 masked bobwhites (2–3 family groups) were placed in each release pen for 1 week. Within each release group, 2–4 chicks were fitted with transmitters prior to being placed into each pen. Commercial scratch grain was dispensed twice daily in release pens via automatic Moultrie feeders. Quail were released after a 7-day acclimation period and were permitted to leave pens undisturbed. Food was provided for an additional week to permit masked bobwhites more time to acclimate to the release site. Ten groups (average group size = 41.1) totaling 411 masked bobwhite were released during 1995–1996, and a total of 35 birds were fitted with radio transmitters.

Prerelease Conditioning Techniques: 1996

During 1995, cannibalism was responsible for higher rates of chick mortality in the brooders than had been observed in previous years. Numerous dead chicks had wounds on their feet, beaks and eyes. Additional potential sources of mortality included bacterial infections, light level and/or temperature. The poor survival rates observed in 1995 prompted prerelease protocol modifications in 1996 in an effort to increase the numbers of chicks released. Refuge biologists also hoped that the construction of a new propagation facility, and the relocation of the captive masked bobwhite population from the PERC to BANWR, would result in greater numbers of chicks being released on the refuge. Moreover, because the BANWR assumed complete responsibility for masked bobwhite propagation, refuge officials controlled every aspect of the propagation and release program. This provided biologists with the flexibility necessary to modify protocols in a manner that would improve the quality of masked bobwhite chicks released on the refuge.

For example, in 1996, biologists were finally able to transport every masked bobwhite chick hatched at the facility to brooder units at refuge headquarters within hours proceeding a hatch to maximize the probability that chicks imprinted on foster parents. Approximately 20 1-day-old chicks were placed in a brooder unit with individual Texas and masked bobwhite foster parents. Another protocol modification implemented in 1996 involved placing red light covers over the fluorescent lights in each brooder unit to reduce cannibalism. Also, curtains were hung around brooder heating units to minimize the cooling effects of drafts and to concentrate heat in one area of the brooder shelves. Biologists hoped that this would eliminate the temperature extremes that may have contributed to the excessive chick mortality that occurred in brooder units in 1995. The remaining prerelease conditioning techniques were consistent with those utilized in 1995. We hoped that the relocation of the captive flock to the BANWR, and the new modifications to the propagation and release protocols implemented in 1996, would result in the release of more chicks to the wild than was the case in 1995. However, the transition associated with constructing the new facility and moving the captive flock delayed the onset of breeding among captive birds. Consequently, the number of hatches was reduced which resulted in the release of fewer masked bobwhite chicks in 1996 than in previous years. Three groups (average group size = 32.3) totaling 97 chicks were released and 7 birds were fitted with transmitters.

Prerelease Conditioning Techniques: 1997 and 1998

The Texas bobwhite foster parent program was terminated during spring 1997 as a result of recommendations made by the Recovery Committee during a meeting convened during December 1996. Henceforth, only captive-reared masked bobwhite adults were used as foster parents. All other prerelease conditioning techniques remained consistent with those used in 1996. Twelve groups (average size = 29.8) totaling 358 quail were released in 1997. Fourteen chicks and 7 adults were fitted with radio transmitters. In 1998, 8 groups (average size = 32.6) totaling 261 birds were released. Three adults and 7 chicks were fitted with transmitters.

During the 5-year study period, radio telemetry was used to monitor postrelease chick survival and was measured in days. Average daily survival was calculated for each year; however, statistical analysis of the data set was not attempted due to small sample sizes and the many different variables introduced each year. Poncho-type transmitters (Kuvlesky 1990) were placed around the necks of selected adults and chicks prior to release. Radio monitoring commenced 1-day postrelease and any mortality that occurred 24-hours postrelease was classified as a zero because it was unlikely the bird survived 1 full day. Thereafter, monitoring occurred every other day until a mortality occurred or a signal was lost. We assumed that signal loss was a mortality and survival was calculated through the last day of detection.

RESULTS AND DISCUSSION

The radio-marked chicks propagated and reared under the altered protocols in 1995 (n = 34), 1996 (n = 5), and 1997 (n = 22) survived for a longer period of time (x = 12.03, 22.8, 7.86 days, respectively) than did those released under established protocols in 1994 (x = 3.26 days). Survival declined in 1998 (x = 2.75 days); however, the sample size was small (n = 4) due to limited radio availability. Although 1–3 weeks postrelease survival was poor, it was an improvement over survival of 3 days. Nevertheless, it is generally accepted among professional quail managers that survival of captive-reared quail is poor after release and Guthery (1986) noted that captive-reared birds die at a high rate once they are released to the wild. It is also possible that radio-marked captive-reared chicks suffered higher mortality than those released without radios. We suspect this did occur among radio-marked masked bobwhites on the BANWR. Despite reports by others (Boag et al. 1973, Lance and Watson 1977) that transmitter packages did not cause wild galliformes to suffer higher mortality than would be expected, contrasting evidence does exist. For instance, Urban and Klimstra (1972) evaluated the effects of several transmitter designs on northern bobwhites in Illinois and reported that a period of adjustment was necessary after a radio was attached as more than half of all mortalities occurred within the first 5 days of instrumentation. Similarly Lance and Watson (1977) suspected that radio-marking red grouse (*Dendragapus obscurus*) chicks could have a detrimental effect on chick survival even though they observed no such effect on adults. Therefore, we acknowledge that attaching radios to captive-reared masked bobwhite chicks likely elevates mortality probabilities; however, this elevated mortality should have been similar for all years. Results indicate radio-marked chicks released under the modified propagation and release protocols of 1995 to 1997 survived longer than did those released under the established protocols in 1994.

It is not possible to prove statistically that the new protocols adopted between 1995 and 1998 resulted in greater survival among all of the chicks released during this period. However, circumstantial evidence suggests that BANWR masked bobwhite population did increase from 1995 to 1998. Masked bobwhite sightings reported by BANWR personnel and visitors were among the highest recorded since the Refuge was established in 1986 and incidental sightings have continued to increase each year. Moreover, biologists were able to locate masked bobwhites on 1995 to 1998 release sites more easily than in previous years and were also able to monitor these coveys for longer periods of time. Covey sizes that were monitored were also larger (10–20 individuals) than had been observed previously. Annual call-counts are conducted on standard routes throughout the Refuge and the number of birds heard each year since protocols were modified has steadily increased. Nine birds were heard in 1995, 17 in 1996, 36 in 1997, and 51 in 1998.

The circumstantial observations obtained between 1995 and 1998 do not prove the masked bobwhite population increased as a result of the propagation and release modifications that were implemented in 1995. We recognize that we have no conclusive quantitative evidence of a masked bobwhite population increase. Nevertheless, the telemetry and call count data, as well as the circumstantial observations, were all obtained during varying weather patterns and habitat conditions. Northern bobwhites generally are less abundant during dry years and this is true of bobwhite populations whether they exist in Illinois (Roseberry 1989) or south Texas (Kiel 1976, Lehmann 1984). Masked bobwhites respond to drought in a similar manner. Significant population declines recorded during a 28-year call-count survey in Sonora, Mexico were associated with dry weather (Camou et al. 1998, Kuvlesky et al. *this volume*). One would therefore assume the dry conditions that occurred on BANWR during the fall, winter and late spring 1995–1996 would have depressed masked bobwhite survival and this might have indeed happened. Yet higher survival was apparent among radio-marked chicks during this period than occurred among radio-marked chicks during the same period in 1994–1995 which was a warm winter with at least average precipitation. We suspect the improved survival observed each year for radio-marked birds was representative of what occurred among all chicks released. We also hypothesize that the 1995 to 1998 protocol modifications enhanced postrelease survival of masked bobwhite chicks.

Quantifying the individual impacts of each protocol modification on postrelease survival was, of course, desirable. Unfortunately, designing an experiment to accomplish this was not possible due to personnel, financial and facility constraints. Moreover, during spring 1995, the Recovery Committee recommended immediate actions be taken to improve postrelease survival of captive-reared masked bobwhite chicks before a catastrophic event decimated the existing BANWR population. Furthermore, immediate measures were deemed necessary in 1995 in an effort to mitigate recent political pressures applied by adversaries of the recovery program (Kuvlesky et al. *this volume*). Consequently, we can only speculate as to the contributions individual protocol modifications may have had on the increased postrelease survival of masked bobwhite chicks that was observed in 1995 to 1998.

Exposing young chicks to insects prior to release not only allows the chicks to develop the skills necessary to capture and eat insects, but also provided an important nutritional source necessary for chicks. Brennan et al. (1996) stated insects were critical for feather growth and development and the more insects available to chicks, the quicker they grow, thermoregulate, fly and evade predators. The insects given to masked bobwhite chicks while in captivity could provide crucial nutritional requirements needed to meet the physiological demands of rapidly growing hatchlings. Insect supplementation may yield a stronger, more adaptable bird when it is eventually released to the wild. The benefits insects have on postrelease survival of masked bobwhite chicks are unknown, but based on knowledge about the nutritional needs of bobwhite chicks, continuing the use of insects as part of the prerelease protocol modifications seems practical.

Allowing chicks to spend a prerelease period in flight pens and temporary release pens enables the chicks to experience and adapt to the environmental factors that will confront them when they are released to the wild. Furthermore, providing chicks with the prerelease opportunity to gradually adapt to temperature extremes, learn to forage for natural foods, and select appropriate thermal and escape cover probably also improves postrelease survival probabilities.

Releasing chicks during the covey season instead of during July and August may also increase postrelease survival. Like other bobwhite subspecies, masked bobwhites form and remain in coveys during fall and winter (Tomlinson 1972, Brown 1989). Therefore, releasing masked bobwhite chicks in large groups during fall and winter increases the probability that these groups will remain together, and this likely results in higher survival rates among chicks at least through winter. Moreover, fall releases ensure that adult foster parents remain with chicks, whereas adults released during the bobwhite breeding season may have abandoned broods to search for a prospective mate. Finally, conducting later releases with older chicks, which were larger and stronger, may have been another factor that increased postrelease survival.

The 1995 modifications to the established prerelease conditioning protocol appear to have contributed to an increase in the postrelease survival of captive-reared masked bobwhite chicks. Masked bobwhite prerelease conditioning will continue under the current protocols though we will continue to refine them in an effort to improve postrelease survival every year. We therefore anticipate that the BANWR masked bobwhite population will slowly increase as recruitment among the established population increases and postrelease survival of captive-reared chicks improves each year.

MANAGEMENT IMPLICATIONS

The implementation of improved propagation and release protocols for captive-reared masked bobwhite chicks was deemed necessary and, although the results of applying these modifications are preliminary, it appears recovery efforts on the BANWR were enhanced. It will be necessary to continue to evaluate the modified protocols and we will make a serious effort to subject these modifications to more rigorous scientific scrutiny. Nevertheless, we are optimistic that the continued application of these protocols will improve masked bobwhite numbers on BANWR, and also will prove useful in reestablishing new populations in Sonora, Mexico and other areas in the U.S. (if suitable sites in the historic range are located). Additionally, we suspect that application of the modified propagation and release protocols will improve the survival probabilities of wild masked bobwhites when they are eventually translocated from Sonora, Mexico to the BANWR.

The results of this study also may have implications for quail managers throughout North America. The improved propagation and release protocols may prove useful to biologists or private landowners that wish to reestablish quail populations on areas that provide suitable habitat but are devoid of quail. Additionally, these protocols could be implemented when the intent is to simply supplement a wild population. We do, however, advise individuals that are considering these management options to adhere to the recommendations of Hurst et al. (1993). We also request that scientists interested in our preliminary results implement similar studies. Replicating studies is an important part of the validation process and we welcome any dialogue that will improve our abilities to successfully propagate and release captive-reared masked bobwhites.

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HABITAT AND WEATHER EFFECTS ON NORTHERN BOBWHITE BROOD MOVEMENTS

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ABSTRACT

We observed radio-marked northern bobwhite (*Colinus virginianus*) broods (adults with chicks ≤21 days old; $n = 12$) in Kansas during 1991–94 to test effects of weather (temperature and precipitation) and macrohabitat (composition, relative diversity, and mean distance to grassland) variables on brood home range size and daily movements at large (28.5 km^2), intermediate (3.14 km^2), and small (about 0.14 km^2) spatial scales surrounding habitats available for broods. Principal component analyses followed by stepwise multiple linear regression indicated neither weather nor habitat influenced ($P \geq 0.1$) home range size at the large and intermediate scales. However, the principal component representing mean distance to grassland and percent cropland within the home range (i.e., at a small scale) was positively related to home range size. Neither temperature nor habitat influenced daily distance of movements. We concluded that brood mobility was independent of landscape-scale features, but that habitat management at smaller spatial scales could influence movements. To create optimal habitat for bobwhite, managers should consider relationships among habitat attributes and the movement of individuals, including the spatial scales at which these relationships are most important.

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INTRODUCTION

Chick survival can influence annual recruitment, and hence fall population size, in some galliforms (Redfield 1975, Potts 1986, Hill and Robertson 1988). Therefore, increasing chick survival by improving brood habitat has been a high priority for the management of these species (Potts 1986, Hill and Robertson 1988). The efficacy of similar strategies to increase northern bobwhite productivity is unknown because few estimates of chick survival, let alone habitat attributes affecting survival, are available (DeVos and Mueller 1993, Taylor et al. 1999). Estimates of chick survival are difficult to obtain because rates of brood abandonment (Suchy and Munkel 1993, Burger et al. 1995), adoption (Burger et al. 1995), and mixing (Taylor 1997) are difficult to estimate. Such factors also make estimated changes in brood size unreliable indicators of chick mortality.

An inverse relationship between chick survival and brood movement has been well demonstrated for gray (*Perdix perdix*) and red-legged partridges (*Alectoris rufa*; Green 1984), ring-necked pheasant (*Phasianus colchicus*; Warner (1984), Hill and Robertson (1988), and willow ptarmigan (*Lagopus lagopus*; Erikstad 1985), and hypothesized for greater prairie-chicken (*Tympanuchus cupido*; Svedarsky 1988) and northern bobwhite (DeVos and Mueller 1993). Broods increase movements in response to low densities of insects and other food items (Green 1984) and contact with predators (Sonerud 1985, Svedarsky 1988), both of which may directly influence chick survival. If these relationships hold for bobwhites and are mediated by vegetation or other land cover attributes, those attributes associated with small relative brood movements and high chick survival could be used to define and identify high quality brood habitat. However, factors unrelated to habitat (e.g., temperature and precipitation) can also affect brood movements (Green 1984), so their influence must also be considered when using movements to make inferences about habitat quality.

To examine habitat-brood movement relationships, we measured home ranges and minimum daily distances traveled by radio-marked northern bobwhite broods in Kansas during 1991–1994, and identified macrohabitat and weather variables that could be potentially associated with the extent of movements. Habitat composition and configuration effects on bobwhite brood movements at landscape (Taylor and Guthery 1994*a*) and smaller (Lehmann 1984) spatial scales have been hypothesized; therefore, we tested movement-habitat associations at landscape (28.5 km^2), intermediate (3.14 km^2), and small (0.14 km^2) scales.

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STUDY AREAS

We studied bobwhite on 2, 28.5-km^2 areas south of Emporia in Lyon County, Kansas. The regional climate is mid-continental; the average maximum daily temperature during summer is 31°C (Neill 1981). Mean annual precipitation is 88 cm, 73% of which falls during April–September (Neill 1981).

The rangeland study area (RSA) consisted of 72% native tallgrass rangeland. Other habitat types included cropland (8%), native grass hayfield (8%), and fallow (9%), 62% of which was warm season native grass stands established under Conservation Reserve Program (CRP) guidelines. Woodland (generally limited to drainageways) and wetland combined to comprise <3% of the area. Dominant herbaceous plant species in all cover types except row crop, woodland, and wetland included big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), Indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*). Rangeland was seasonally grazed from mid-April through September–October and burned (usually during early April) every 1–4 years.

The cropland study area (CSA) was 24 km east of the RSA. Habitat types included row (grain sorghum, soybean, and corn) and cereal (primarily wheat) cropland (49% of the area), native grass hayfield (19%), native rangeland (16%), and fallow (14%), 52% of which was smooth brome (*Bromus inermis*) and native grass CRP fields. Woodland habitats were located along drainageways and as hedgerows [predominantly osage orange (*Maclura pomifera*)], along field borders. When combined with wetlands these habitats comprised <3% of the study area.

METHODS

Telemetry

During March–August 1991–1994, we captured bobwhites on the RSA and CSA using baited funnel traps (Stoddard 1931), decoy traps (Smith et al. 1998), and nightlighting techniques modified from Labisky (1968). We fitted each captured bird with a numbered aluminum leg band and a 6-g (about 3% of body mass) radiotransmitter. Transmitters were backpack-mounted in 1991–1993, and either backpack- or necklace-mounted in 1994. We located each radio-marked quail 4–7 times per week on foot by homing (White and Garrott 1990, Stauffer 1993), and consecutive identical location estimates identified incubating birds. Movements by broods resulting from these nesting attempts were used in subsequent analyses. Direct observations and the presence of chick feces at roost sites were used to determine whether radio-marked adults maintained association with chicks.

We located brood-tending adults twice daily, with >5 hours separating locations, until chicks reached 21 days of age. We recorded the hectare each location was within based on aerial photo-derived cover type maps (scale 1:9500) overlaid with a Universal Transverse Mercator coordinate grid. Brood home range sizes were estimated using the 95% isopleth of a kernel estimator (Worton 1989) with a grid size of 20 × 20. Home ranges were calculated only for adults with broods during the entire 21-day period posthatch.

In 1994, we also measured daily minimum distances traveled by broods. Using protocols similar to Taylor and Guthery (1994*a*), broods were located 5 times within a 24-hr period (including ≥1 roost location), and the sum of the distances between consecutive locations determined daily distance traveled. We collected these data once when chicks were 1–14 days old (prefledging), and again when they were 15–28 days old (postfledging).

Habitat Analyses

We measured macrohabitat composition, relative diversity, and mean distance to grassland (MDG) at several spatial scales surrounding broods. For relationships with home range sizes, we measured habitat attributes within home ranges (small scale; mean area = 0.14 km^2), within 1 km-radius circles centered at the geometric center of home ranges (intermediate scale; area = 3.14 km^2), and within study areas (large scale; area = 28.5 km^2). For relationships with daily movements, habitat at the small scale was measured within 418-m-diameter circles (418 m = mean daily distance traveled by broods; see below) centered at the mean of the 5 location coordinates in each daily series. Habitat at intermediate and large scales was defined the same as for relationships with home ranges.

To measure habitat parameters, we produced a computerized (raster) image of habitat present within each study area with a geographic information system (WSEAS, John Cary, Department of Wildlife Ecology, University of Wisconsin-Madison). Each pixel within these coverages represented a 10 × 10 m area and was assigned its appropriate habitat type (rangeland, hayfield, fallow, cropland, woodland, or wetland). Habitat compositions within defined areas (e.g., study areas or home ranges) were determined by adding the number of pixels assigned to each habitat type within the area and then multiplying each sum by the area of a pixel (0.01 ha). Relative diversity (i.e., evenness; Zar 1984: 34) of habitat compositions was also calculated. Finally, as a measure of grassland distribution, MDG (Brady et al. 1993) within defined areas was calculated by averaging the distances from each pixel within the area to the nearest pixel containing a grass-dominated habitat type (rangeland, hayland, or fallow), with grassland pixels assigned a distance of zero. Broods with >30% of their surrounding habitat at small or intermediate scales occurring outside the study area (i.e., unmapped) were excluded from analyses.

We also monitored temperature and precipitation during the 21-day rearing period for each brood. For comparison with home range size, the mean daily high and low temperatures (°C) and total precipitation (cm) (National Oceanographic and Atmospheric Administration 1991–1994) during each rearing period were calculated. For comparison with daily movements, the

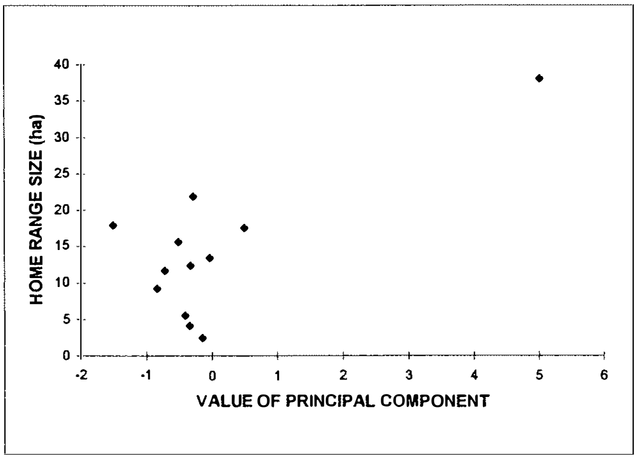

Fig. 1. Home range sizes of northern bobwhite broods (n = 12) in Kansas, 1991–94, versus a principal component derived from habitat variables measured within home ranges. The principal component had significant positive correlations with the mean distance to grassland and percent cropland within home ranges, and was positively associated (R^2 = 0.551, P = 0.006) with home range size.

daily high and low temperatures and precipitation were recorded.

We used stepwise multiple linear regression (Neter and Wasserman 1974) to detect relationships between movements and habitat or weather variables. Principal component analyses (Harris 1975) were used to reduce the effects of multicollinearity among weather variables, as well as among habitat variables in intermediate and small scales. The fewest components at each scale that cumulatively accounted for >80% of the standardized variance were included in the regression model as independent variables. Separate regression analyses were performed for home range size, daily minimum distance traveled by prefledging broods, and daily distance traveled by postfledging broods as dependent variables. Selection criteria for independent variable entry and removal from stepwise models was $P \leq 0.1$.

Table 1. Relationships between habitat variables within home ranges of northern bobwhite broods (n = 12) in Kansas, 1991–94, and a principal component derived from those variables that was positively associated with brood home range size. Absolute values of eigenvectors represent the relative contribution of each habitat variable to the value of the principal component.

		Linear correlation with principal component	
Habitat variable	Eigenvector	r	P
Mean distance to grassland	0.641	0.97	<0.001
Cropland (%)	0.633	0.96	<0.001
Rangeland (%)	−0.255	−0.39	0.205
Wetland (%)	−0.233	−0.38	0.222
Hayland (%)	−0.208	−0.33	0.294
Relative diversity	−0.112	−0.18	0.569
Fallow (%)	−0.106	−0.14	0.662
Woodland (%)	−0.033	−0.06	0.845

RESULTS

Home Range

Radio-marked adults reared 14 broods (8 on the CSA, 6 on the RSA), and sufficient habitat was mapped surrounding 12 (6 on each study area) for inclusion in analyses of habitat-movement relationships. Home ranges were similar for brood-rearing adults wearing different transmitter types (F = 2.41, 1 df, P = 0.159) and between study areas (F = 0.87, 1 df, P = 0.530); therefore, we pooled observations across these variables for subsequent analyses. Mean (± SE) home range size was 14 ± 3 ha.

We reduced the 3 weather variables to 1 principal component, the 8 intermediate scale habitat variables to 3 components, and the 8 small scale habitat variables to 4 components. Of these, only 1 small scale habitat component was associated (β_1 = 0.04, R^2 = 0.551, P = 0.006; Figure 1) with home range size. The habitat variables most heavily represented by this component (Table 1) were mean distance to grassland and percent cropland within the home range, both of which were positively associated with the component.

Minimum Daily Distance Traveled

Nine broods (6 on the CSA, 3 on the RSA) provided both prefledge and postfledge movement estimates, 2 (CSA) provided only prefledge estimates, and 1 (CSA) provided only a postfledge estimate. Movements were similar during both periods between study areas (F = 1.02, 1 df, P = 0.347, and F = 0.07, 1 df, P = 0.799, respectively) and transmitter types (F = 0.21, 1 df, P = 0.659, and F = 1.09, 1 df, P = 0.337, respectively); therefore, estimates were pooled across these variables.

Mean daily distance traveled was 337 ± 54 m and 503 ± 60 m for prefledging and postfledging broods, respectively. For broods with estimates during both periods, movements were similar (paired t = 1.40, 8 df, P = 0.199) between periods, and the overall mean of daily movements was 418 ± 44 m. However, because estimates during the 2 periods were not independent, we retained the period classification for subsequent analyses.

Precipitation occurred only 1 day during daily movement measurements, so we removed this variable from analyses. The 2 remaining weather variables (maximum and minimum temperatures) were highly correlated (r = 0.92, P < 0.001), so we used only maximum temperature in the regressions. Further, we reduced the 8 intermediate scale habitat variables to 2 principal components, and the 8 small scale habitat variables to 4 components. Regressions indicated neither habitat components nor temperature were associated (P > 0.1) with daily distance traveled by either prefledging or postfledging broods.

DISCUSSION

Taylor and Guthery (1994*a*) reported mean daily movements of broods in southern Texas rangeland

(277 and 589 m for prefledging and postfledging broods, respectively) that were similar to those we observed (337 and 503 m). Our mean home range size for 3-week-old broods (14 ha) is larger than data reported by DeVos and Mueller (1993) for 2-week-old (6.5 ha) and 4-week-old (10.0 ha) broods in northern Florida. However, these estimates are not directly comparable because different methods (kernel vs. minimum convex polygon) were used to determine range sizes.

Daily distance traveled did not vary with brood age. This is similar to the observations of Green (1984) for gray and red-legged partridges; however, investigators elsewhere have found changes in brood movements with age in bobwhite (Taylor and Guthery 1994*a*) and other galliforms (Warner 1979, Bergerud and Gratson 1988). Based on the apparent disparity between mean movements, our failure to detect a difference between prefledging ($\bar{x}$ = 337 m) and postfledging ($\bar{x}$ = 503 m) movements may have been due to our limited sample size (n = 9) and the resulting low power ($1 - \beta = 0.341$ at $\alpha = 0.1$) of our comparison.

We failed to detect temperature effects on brood home range size, or on daily movements. However, nest success was lower during wet than dry years (Taylor 1997), so relatively few broods were observed during periods in which precipitation and temperature effects may have been most extreme. Galliform chicks generally require more brooding during cool, wet periods. Thus their activity is restricted under such conditions (Green 1984, Bergerud and Gratson 1988). Insects also may become less active and presumably less available to chicks during periods of precipitation (Hill and Robertson 1988). However, cool, wet weather does not necessarily lead to low chick survival or overall productivity for bobwhite in the Midwest (Roseberry and Klimstra 1984) or other galliforms (Potts 1986).

Brood home ranges tended to be larger when they contained more cropland and greater mean distance to grassland values. However, 1 brood seemed to have a large influence on this relationship (Figure 1). This CSA brood had a 38-ha home range (the next largest observed home range was 22 ha) which contained 88% cropland (the next largest amount of cropland within a home range was 24%). The brood hatched on 26 July 1994, and was unique in that it primarily used linear grassland and woodland patches in the midst of large soybean and sorghum fields. Although the habitats used by this brood were not typical of those used by other broods we observed, they may resemble those available to bobwhite in more intensively cultivated regions (e.g., the highest apparent breeding bobwhite densities occurred in areas with only 12–25% grassland in Illinois; Roseberry and Sudkamp (1998).

If the relationships observed for other galliforms such as: (1) chick survival and movements are negatively related (Green 1984, Erikstad 1985, Hill and Robertson 1988), and; (2) brood movements are negatively related to habitat quality (Southwood and Cross 1969, Erikstad 1985) are true for bobwhites, then broods with less cropland and smaller mean distance to grassland within their home ranges had a lower risk of chick mortality. Whether grassland habitat types provided less exposure to predators (Sonerud 1985), greater availability of insects and other food items (Southwood and Cross 1969, Erikstad 1985), or greater microhabitat variability (Taylor and Guthery 1994*b*) relative to cropland is unknown; each has been experimentally or hypothetically related to brood mobility or survival. Until relationships among these factors and macrohabitat characteristics are understood, the link between bobwhite brood movements and the fitness value of macrohabitat attributes is speculative at best.

The associations we observed between movements and habitat at a small spatial scale did not persist at intermediate and large scales. This did not support the hypothesis that bobwhite brood movements are dependent on landscape-scale habitat features (Taylor and Guthery 1994*a*). However, whereas the CSA was much more extensively cropped than the RSA, it still contained 49% grassland (i.e., rangeland, hayland, and fallow). This is likely a higher percentage than exists in many other locations within the bobwhite range, and may not have been sufficiently different from the RSA (89% grassland) for landscape effects to have been evident. Regardless, our lack of replication at the landscape scale made our study area comparison exploratory rather than experimental, thus our results should be viewed in this context.

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THE DEVELOPMENT OF A GAMEBIRD RESEARCH STRATEGY: UNRAVELING THE IMPORTANCE OF ARTHROPOD POPULATIONS

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ABSTRACT

This paper describes work conducted in the United Kingdom (UK) on upland gamebirds, primarily gray partridge, that identified the importance of arthropod abundance in determining chick survival and in the overall population dynamics of this declining quarry species. Several sequential steps that were taken to quantify the importance of arthropods in determining levels of chick survival, ranging from laboratory studies with captive chicks, through field-based surveys to computer simulation are described. Next, various field-scale experiments to manipulate vegetation to increase arthropod densities are described. These included the management of cereal crop edges with reduced levels of pesticides.

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INTRODUCTION

The importance of arthropods in the diet of gamebirds, especially to young chicks, has been quantified by many studies throughout the world. In many species this importance has been considered crucial in determining levels of chick survival, for example in red grouse (*Lagopus lagopus scoticus*) (Savory 1977, Hudson 1986), black grouse (*Tetrao tetrix)* (Baines 1996), capercaille (*Tetrao urogallus)* (Baines et al. 1994) and ring-necked pheasant (*Phasianus colchicus*) (Hill 1985). In other studies, rates of chick survival and the importance of arthropods have been shown to be the key factor (Varley and Gradwell 1960) in determining annual variations in population densities, for example, in the gray partridge (*Perdix perdix*) (Blank et al. 1967, Potts 1986).

However, it would be fair to say that, historically, these studies that explored the relationships between gamebirds and arthropods have been primarily undertaken in Europe. For example, Potts (1986) cataloged studies of gray partridges where the crop contents of chicks had been examined to determine at least the numerical dominance of arthropod species in the chick diet. Such studies had been conducted in western Europe (Britain, France and Denmark) and eastern Europe (Poland, Hungary, Czechoslovakia and the Soviet Union).

In North America, studies of gamebird populations have tended to focus on problems associated with nesting cover and winter survival. However, as early as the 1930's biologists noticed the importance of insects in the diet of northern bobwhite quail chicks (*Colinus virginianus*) (Stoddard 1931). However, only recently have North American workers begun to focus on problems associated with arthropods and the role they play in determining levels of chick survival. Notable exceptions to this bold statement were studies reported at the Third National Quail Symposium (Quail III) held in 1992.

Workers in Kansas (Taylor et al. 1993), Florida (DeVos and Mueller 1993) and Missouri (Dailey and Seon 1993) reported work on arthropods. The most detailed work was reported from Missouri by Burger et al. (1993). This growing interest was also reflected in the strategies for quail management outlined at Quail III which stated the need "to determine the indirect effect of pesticides on quail populations" (Capel et al. 1993). Five years later, at the Fourth National Quail Symposium (Quail IV) arthropod studies were again reported by the same groups or researchers, most notably in Florida (Palmer and Bromley *this volume*) and Mississippi (Carver et al. *this volume*).

Little information is available on the insect diet of the chicks of quail species other than northern bobwhite. Furthermore the insect dietary studies already conducted for northern bobwhites scarcely cover the full extent of the inevitably large variations to be encountered in a species with such an extensive range in North America. Land use and climate variations in a species in habitats from Florida to southern Ontario, from Texas to Massachusetts and from intensive row crop farming in Iowa to timber plantations in Georgia will be large (Church et al. 1993). For those about to embark on researching relationships between quail chick survival and arthropod abundance, this paper therefore draws upon the experiences of British researchers and their studies on gray partridge chick survival, arthropod ecology and management of brood cover for insects consumed by chicks. Six approaches are described that have led to our understanding of insect-gamebird chick interactions.

Table 1. Effect of diet on the daily growth rates of partridge chicks (from Cross 1966).

	Average weight gain (% per day)	
	Gray Partridge (n = 45)	Red-legged Partridge (n = 60)
Starter crumb	11.0	17.0
Insects	6.0	12.0
Plant material	0.5	1.0

APPROACH 1. LABORATORY FEEDING TRIALS

In feeding trials, partridge chicks were fed various diets to investigate the role of insects in the growth of chicks, especially in relation to feather development. Batches of chicks were fed a high protein weed mixture comprising grass weed spikelets (*Poa annua),* and buds of forage legumes, especially clover and weed seeds of the genus *Polygonum* (a known component of adult diets) (Pulliainen 1966). Other chicks were fed insects collected from nearby cereal fields. Control batches of chicks were fed high protein poultry starter crumb and all chicks were fed quantities of particular diets *ad libitum* along with supplies of grit and water.

Growth rate was found to be greatly influenced by food type; those feeding on plant food grew so slowly that it was barely measurable. Chicks fed on insects grew much faster (Table 1).

Cross (1966) considered certain amino acids, particularly methionine and cystine to be particularly important for feather growth. Wise (1982) calculated availability of these two amino acids in the dry matter content of various foods for red grouse and found insects contained a greater percentage of available methionine and cystine than did vegetable sources (grass, beans, wheat) or even from meatmeal.

APPROACH 2. GUT DISSECTION

Direct evidence of the diet of young chicks was obtained from samples of chicks collected from the field and by examination of their crops and gizzards. Forty gray partridge chicks were obtained from an extensive study area of farmland in southern England over a 9-year period. Chicks were aged and food items removed from their crop and gizzards. Invertebrates, seeds and plant material were identified and counted under a binocular microscope.

During the first week, gray partridge chicks fed primarily on small invertebrates, (particularly cereal aphids, homopterans and Collembola), Coleoptera (particularly Curculionidae and Chrysomelidae) and sawfly larvae (Hymenoptera: Tenthredinidae) (Table 2). In contrast, after this first week, ants, a hitherto absent group became the most numerous dietary item followed by cereal aphids, Chrysomelidae and hemipterans (particularly Miridae). After the first week sawfly larvae and Collembola were rarely taken. At less than a week old, 95% (by item) of the diet of chicks were invertebrates. Up to 21 days old this proportion decreased to 48%.

Table 2. Numbers of invertebrates, plant seeds and leaves found in the crops of gray partridge chicks in the 1970's in southern England (from Vickerman and O'Bryan 1979).

	Age	
	1 week	1–6 weeks
Invertebrates		
Arachnida	22	40
Mollusca	6	3
Hymenoptera: Parasitica	18	25
Formicidae	0	2565
Tenthredinidae	34	1
Diptera	18	34
Coleoptera	77	188
Hemiptera: Cercopidae & Aphididae	63	717
Hemiptera: Miridae	4	113
Lepidoptera	6	24
Collembola	61	32
Others	4	44
Total Invertebrates	313	3786
Plant material		
Monocot. Seeds	12	2909
Dicot. Seeds	3	963
Leaves	2	267
Total Plant Material	17	4139
% invertebrate food	94.8	47.8
% plant food	5.2	52.2

Most chick mortality occurs during the first few weeks after hatching and peaks during the 10-day period of maximum dependence of insects (Potts 1986). Church (1986) estimated daily mortality to be 2.1% per day for the first 10 days and 0.5% per day from 10 to 74 days. A comparable study by Enck (1986) found the daily mortality rates to be 1.6% and 0.3% for the same age intervals.

Green et al. (1986) observed that gray partridge chicks <10 days old were unable to grind open grass seeds in their gizzards even though they were able to ingest such material. In contrast, red-legged partridge chicks could extract protein from weed seeds at 3 days old and gut dissection showed a plant and invertebrate composition in the diet of week old chicks of 72% and 28% (Vickerman and O'Bryan 1979). In tests with ant pupae dyed with vegetable coloring it was found that gray partridge chicks preferred green to yellow and green and yellow to blue, red or black (Vickerman and O'Bryan 1979). It also appeared that green insects occurred in chick diet more often than expected from their abundance in brood-rearing areas e.g., cereal aphids, Collembola, Miridae and sawfly larvae.

APPROACH 3. FAECAL ANALYSIS

Considerable expertise has now been developed to identify arthropod food items of galliform chicks, particularly gray partridges, from the fragments of exoskeleton remaining in their faecal material. This method has the advantage of being non-destructive and can readily be carried out as a adjunct to radio telemetry studies (Moreby 1988). Faecal material can easily be collected from roost sites located by telemetry and insect fragments identified by comparison with reference to a collection of species collected from the previous day's foraging areas. Preferred insects can also be identified in this manner by comparing presence in faecal samples with their relative abundance in brood-rearing areas. In general, insects are considered preferred when they occur more than twice as frequently in faecal samples as in vacuum insect net samples from the field where the faeces were collected (Green 1984). In studies reported at Quail III (Sotherton et al. 1993) following a multiple stepwise regression, there was a significant positive relationship between gray partridge chick survival per brood to 21 days old and the proportion (percentage) of sawfly larval and Chrysomelidae adult and larval fragments in the total arthropod fragment composition of chick faecal samples collected from roost sites (r = 0.78, 7 = df, P < 0.05). In a sample of 17 radio-tagged ring-necked pheasant hens 55% of the variation in chick survival was accounted for by the proportion of Heteroptera, sawfly larvae and Staphylinidae larvae in chick droppings (Sotherton et al. 1993).

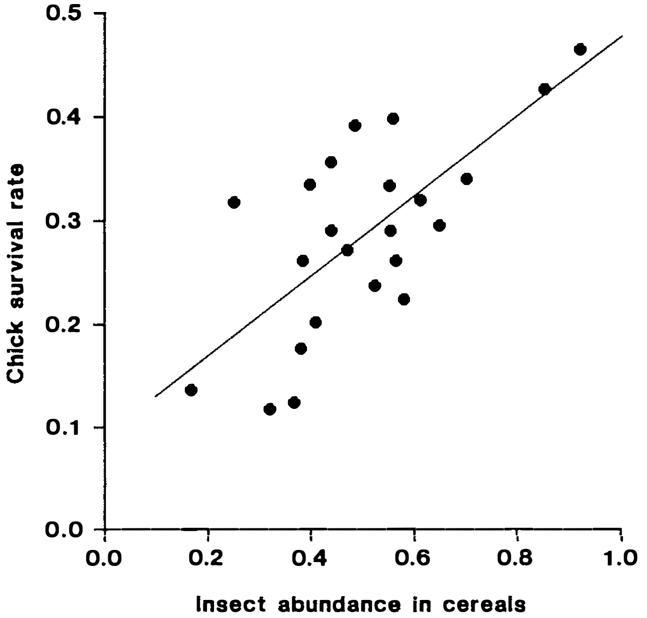

Fig. 1. Relationship between gray partridge chick survival (to 6 weeks) and chick-food insects taken from Sussex Study area 1970–1992 (from Aebischer, 1997).

APPROACH 4. CORRELATION

The Game Conservancy Trust has been collecting data on gray partridge chick survival in relation to the abundance of insects since 1968 in an attempt to investigate causes for the decline of this species in the UK. This research was carried out on 62km^2 of farmland on the Sussex Downs in southern England. Since 1970, annual counts of partridges have been made each year and insect abundance in cereal fields is measured on over 100 fields every June. Full details of this long-term monitoring project appear in Potts and Aebischer (1995).

Several sources of field data support the link between chick mortality and insect abundance. Evidence from faecal analysis has already been described. Annual chick survival rates from the Sussex study are positively correlated with an index of insect abundance in cereals obtained in the summer (Figure 1) (Aebischer 1997). The calculation of this index is explained later.

The introduction of Geographical Information Systems analysis has enabled the Sussex data to be mapped by field by year. The results of the annual gray partridge surveys from 1970 to 1994 were transferred to a computerized database, MAPINFO 3.0 (MapInfo Corporation, Troy, New York). The following series of maps of the abundance of caterpillar-like larvae (both lepidopterans and sawfly larvae) during June, and gray partridge coveys in the autumn for 1970 and 1994 shows the spatial correlation of broods to insects (Figures 2a–2d). These correlations are most pronounced in the more recent years after insect populations had declined on farmland subjected to increasing levels of intensified production technology (sawfly larvae by over 50% in 25 years, Aebischer 1991).

APPROACH 5. MULTIPLE REGRESSION

With such an extensive spatial and temporal database, we have been able to carry out multiple regression analyses to partition causes of annual chick survival. Multivariate regression models of chick mortality using weather as the dependent variable and different measures of insect abundance as the independent variables, were constructed. The insect data from the annual monitoring in Sussex and weather parameters from 10 June to 10 July each year were used. For the period from 1969 to 1985 inclusive the earliest model using weather variables collected 5 miles south of the center of the study area was constructed. A total of 58% of the variation in chick mortality was explained as follows (Potts 1986).

$$\text{Chick survival rate} = 1.532 - 0.016x_1 - 0.048\,x_2$$

where x_1 = sum density of preferred insects (m^{-2}) in cereal crops in June

x_2 = mean daily temperature between 10 June–10 July.

For the data from 1970 to 1987 a forward stepwise multiple regression was used to predict chick survival rate from a model and identify the most important

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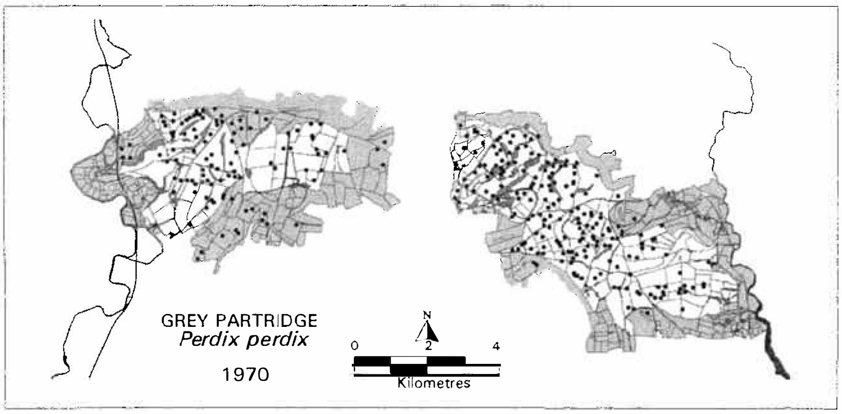
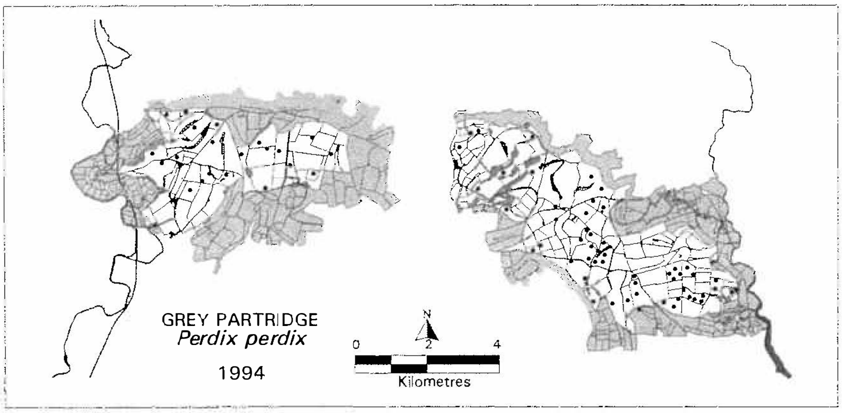
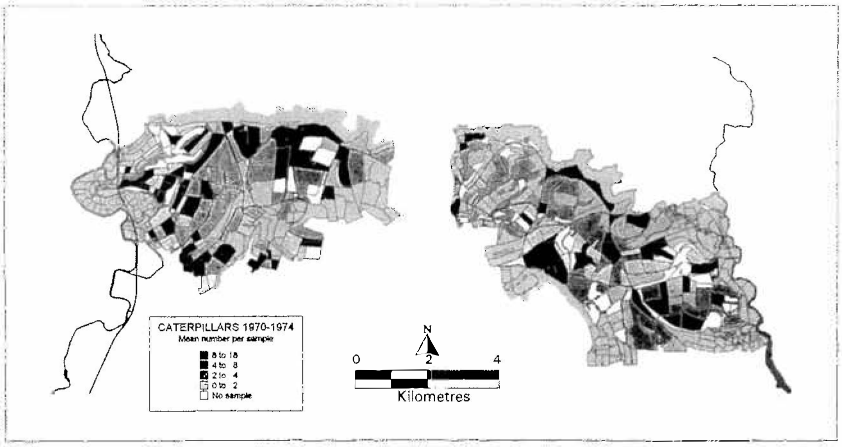
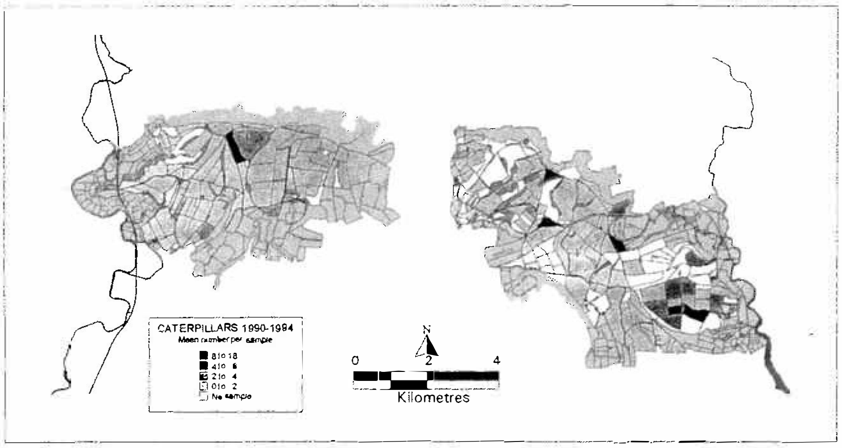
Fig. 2. (a) Gray partridge brood counts on the Sussex Study area, 1970. Each point represents a covey; (b) Gray partridge brood counts on the Sussex Study area, 1994; (c) Mean numbers per field of caterpillar-like chick-food insects sampled in cereal fields on the Sussex Study area in June between 1970 and 1974; (d) Mean numbers per field of caterpillar-like chick-food insects sampled in cereal fields on the Sussex Study area in June between 1990 and 1994.


GREY PARTRIDGE
Perdix perdix
1970
N
0
2
4
Kilometres


GREY PARTRIDGE
Perdix perdix
1994
N
0
2
4
Kilometres


CATERPILLARS 1970-1974
Mean number per sample
■ 8 to 18
■ 4 to 8
▨ 2 to 4
▨ 0 to 2
☐ No sample
N
0
2
4
Kilometres


CATERPILLARS 1990-1994
Mean number per sample
■ 8 to 18
■ 4 to 8
▨ 2 to 4
▨ 0 to 2
☐ No sample
N
0
2
4
Kilometres

chick-food groups. The following equation explains 52% of chick mortality (Potts and Aebischer 1991).

$$I = 0.141x_1 + 0.120x_2 + 0.083x_3 + 0.006x_4 + 0.0004x_5$$

where I = Index of insect abundance
x_1 = density of ground beetles (Coleoptera:Carabidae);
x_2 = caterpillar-like larvae;
x_3 = leaf beetles and weevils (Coleoptera: Chrysomelidae and Curculionidae);
x_4 = plant bugs and leaf hoppers (Hemiptera: Miridae and Cicadellidae);
x_5 = cereal aphids (Hemptera: Aphididae).

APPROACH 6. FIELD STUDIES

The approaches described so far represent a body of evidence which supports the hypothesis that gray partridge chick survival is dependent on the abundance of preferred chick-food insects in brood-rearing cover. The final approach sought to test this hypothesis in the field. Such tests have been carried out by controlled experiment and by circumstantial monitoring.

The first experiment describes the use of selectively-sprayed cereal crop headlands (field borders) now commonly known as Conservation Headlands to increase densities of chick-food insects at the edges of cereal crops. Radio telemetry data have shown these field borders to be the area most used by broods (Green 1984). Results of these experiments were presented at 2 North American gamebird symposia, both at Perdix V (Sotherton and Robertson 1990) and at Quail III (Sotherton et al. 1993). In summary, insecticides are excluded from the outermost edge of cereal crops (usually 6m wide) during the summer to preserve beneficial insects. Herbicides to control broad-leaved weeds are also excluded to provide host plants for these predominantly phytophagous insect species (Sotherton 1991).

Field experiments have demonstrated that the percentage weed cover in Conservation Headlands is over 4 times as high as in fully sprayed headlands, and that Conservation Headlands contain, on average, 3 times as many weed species (Sotherton 1991). In terms of insects, densities of the groups consumed by partridge chicks can be 3 times greater in Conservation Headlands than in fully sprayed headlands. The survival of partridge chicks follows suit: in each of 8 experimental years, the survival rate was higher where Conservation Headlands were present than where they were absent (Table 3). With Conservation Headlands, chick survival exceeded 30%, i.e., the minimum required to maintain a stable population (Potts 1986), in 5 of those years, whereas without Conservation Headlands it merely reached that level only during 1 year.

The field test of the hypotheses obtained by monitoring came from the annual counts of partridges and insects undertaken in the Sussex Study. Up until 1989, the use of insecticides to control cereal pests, particularly aphids in the summer, was slight. In 1989, for the first time, a broad-spectrum insecticide was applied to cereal crops across an entire farm (7km^2) to control aphids (Aebischer 1990). In all but 1 year between 1989 and 1995 (a 7-year period) most of the cereals on this farm were sprayed with insecticide up to 4 times per year. During these 7 years, the other farms on the study area either used no summer insecticides, or used much more specific aphicides (those less likely to kill chick-food insects or their insecticide use was very much less intensive). The study area could therefore be divided into 2 areas according to the intensive use of insecticides, (the 7km^2 area) and the other farms (21km^2). Chick survival rates (after Potts 1986) were calculated for each area each year, and compared between areas (paired t-test) in the periods before and during intensive insecticide use.

The annual chick survival rates on the intensive farm were lower in all 6 insecticide years than they were on the rest of the study area, whereas, before 1989, they had been higher in 16 out of 19 years ($X^2_1 = 7.28$, $P = 0.007$). On average, during these pre-insecticide years, the chick survival rate on the intensive farm was not higher than on the other farms ($t_{18} = 1.06$, $P = 0.303$). In contrast, the average chick survival rate was 22 ± 5% over the 6 insecticide years on the intensive farm, a third lower than on the other farms where it was 34 ± 3% ($t_5 = 3.53$, $P = 0.017$) (Table 4).

SUMMARY

The identification of the importance of insects in the survival of gamebird chicks, and the list of preferred insect species in the diet of chicks allows research to concentrate on the ecology of such beneficial insect groups, their requirements, and how they are able (or unable) to react to changes in agricultural practices. Only then can applied ecology begin to formulate management plans to increase their densities within brood-rearing areas for partridge chicks. In the UK, the example provided by the gray partridge and pheasant has led to the development of insect-rich Conservation Headlands and strategies to manage set-

Table 3. Percentage of gray partridge chicks that survived the first 6 weeks after hatching, in relation to the management of cereal headlands (outer 6m of the crop) on experimental farms in eastern England, 1984–1991, from Sotherton et al. (1993).

	Year							
Land use category	1984	1985	1986	1987	1988	1989	1990	1991
Conservation headlands	52%	22%	60%	46%	39%	48%	25%	21%
Fully sprayed headlands	27%	13%	28%	22%	25%	30%	23%	18%
Number of farms	8	8	9	11	12	9	20	18

Table 4. Mean chick survival rates (±1 Standard error, SE) on farms on the Sussex Study area before and during the intensive use of insecticides on 1 farm post 1989 (from Aebischer and Potts 1998).

	Chick survival rate (%)	
Years of study	Farms with slight or no insecticide use	Farms with intensive insecticide use (slight before 1989)
1970–1988 (n = 19)	27	34
SE	2	3
1989–1994 (n = 6)	34	22
SE	3	5

aside fallow areas to create high insect densities (Sotherton 1998).

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STATUS, ECOLOGY AND MANAGEMENT OF SCALED QUAIL IN WEST TEXAS

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ABSTRACT

Scaled quail (*Callipepla squamata*), more commonly referred to as "blue" quail, have always been viewed as a secondary species among Texas quail hunters and managers, who generally prefer to hunt northern bobwhites (*Colinus virginianus*). Scaled quail and bobwhites are sympatric over much of west Texas, and the 2 species share several habitat characteristics (e.g., similar loafing coverts). In areas where the 2 species are sympatric, they have essentially the same diets. However, scaled quail tend to prefer more open habitats, i.e., less and lower herbaceous cover, than bobwhites. Scaled quail populations have declined precipitously since 1988 across virtually all of their Texas range. Radio-marked scaled quail apparently had higher survival rates than sympatric bobwhites from February to July, 1995 at a study site in Irion County, Texas. Historically, scaled quail do not seem to decline as quickly as bobwhites in dry years, but neither do they increase quite as dramatically as bobwhites during wet years. The effects of common management practices like brush control, supplemental feeding, and predator control have not been investigated adequately for scaled quail. Additional studies conducted with radio telemetry will undoubtedly cause us to reconsider the current paradigms of scaled quail management, as it has recently done with bobwhites.

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INTRODUCTION

Perhaps because of their affinity for seemingly inhospitable habitats, or their propensity to run, rather than freeze in front of bird dogs, quail hunters make various references to scaled, or blue quail in Texas; most of which contain "wild ol' blues" and selected expletives. Scaled quail have been the subject of significant biological investigations over the last 50 years, including Wallmo (1957), Schemnitz (1961), Campbell et al. (1973), and Rollins (1980).

Scaled quail are sympatric with northern bobwhites over much of west Texas, specifically that area between the 100th meridian and the Pecos River. In southwestern Oklahoma, scaled quail and bobwhites had essentially identical diets (Rollins 1981) and shared common endoparasites (Rollins 1980). There tends to be some habitat segregation, with scaled quail preferring the more shallow sites with less herbaceous cover while bobwhites typically prefer sites with more brush cover (Schemnitz 1964). However, coveys of scaled quail and bobwhites can be commonly found in the same microhabitats.

Scaled quail numbers in Texas have declined over the last 30 years and especially since the late-1980's (Sauer et al. 1997) (Figure 1). Evidence suggests that populations are also declining range-wide (Church et al. 1993, Schemnitz 1993). They have virtually disappeared from my home county (Harmon) in southwestern Oklahoma since 1988. During the 1970's and early 1980's, scaled quail often comprised 50% or more of the quail population in that area (Jackson 1947, Rollins 1980), and during very dry years (e.g., 1984) perhaps 90% of the quail population. However, scaled quail numbers waned in 1988–1989 and have failed to recover since that time in southwestern Oklahoma and over much of northwest Texas. Most of these areas have maintained only relict populations (if any) since 1992.

Many biologists dismiss this decrease to "normal fluctuations" characteristic of irruptive quail populations in semiarid regions. However, bobwhite populations in west Texas, which also crashed in 1988, rebounded in 1991–1992, and have exhibited their "typical" irruptive population growth since that time (Sauer et al. 1997). Biologists have evaluated several theories for irruptive quail populations, including weather patterns (Jackson 1962, Campbell et al. 1973, Giuliano and Lutz 1993), vitamin A (Lehmann 1953), phytoestrogens (Cain et al. 1987), water deprivation (Koerth and Guthery 1991) and habitat change (Schemnitz 1993).

I have been intrigued by scaled quail for the last 25 years as both a hunter and a quail manager. This paper reflects observations on scaled quail management based mostly on my experiences in the Rolling Plains, Edwards Plateau and Trans-Pecos ecoregions of Texas. My objective here is to offer alternative hypotheses to why scaled quail have decreased and remained at low levels over most of their range in Texas. I integrate survey information from Texas Parks and Wildlife Department (TPWD) personnel and Breeding Bird Survey (BBS) data with my personal observations and experience.

BACKGROUND

Scaled quail occur over the western one-third of Texas, essentially west of the 100th meridian. Addi-

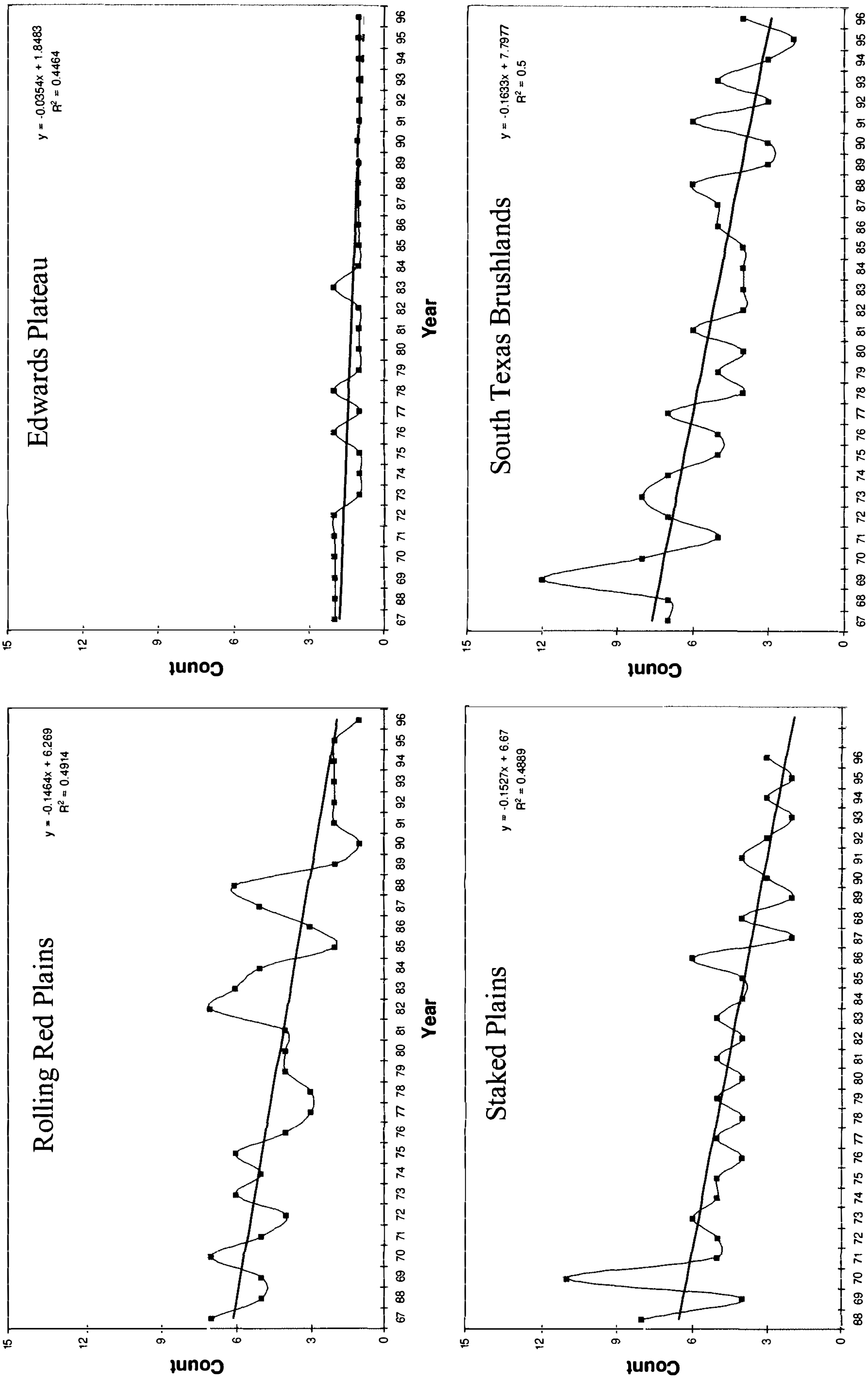

Fig. 1. Population trend of scaled quail in various regions of Texas as estimated by Breeding Bird Surveys, 1967–1996 (Sauer et al. 1997).

tionally, they occur in portions of western Oklahoma, southwestern Kansas, southeastern Colorado, most of New Mexico, southeastern Arizona and much of northeastern Mexico. In south Texas, scaled quail typically occur northwest of a line from Beeville to Hebronville to Zapata. These areas are within the Rolling Plains, Edwards Plateau, High Plains, Trans Pecos and Rio Grande Plains ecoregions. Annual precipitation ranges from about 600 mm along the eastern edge to about 250 mm in portions of the Trans Pecos. Vegetation varies from brush-infested prairie to hot desert scrub. Woody plants often associated with scaled quail range include honey mesquite (*Prosopis glandulosa*), lotebush (*Ziziphus obtusifolia*), and netleaf hackberry (*Celtis reticulata*). Dominant grasses in such areas include gramas (*Bouteloua* spp.), threeawns (*Aristida* spp.), and some bluestems (*Schizachyrium, Bothriochloa*) along the eastern periphery. Prickly pear (*Opuntia* spp.) and other cacti are common.

Scaled quail populations in the Rolling Plains and Edwards Plateau experienced a sudden, and inexplicable, decline during the winter of 1988–89. The weather during that time was not unusually cold or dry, and scaled quail experienced an above average production in 1987. During a hunt in Crockett County (Edwards Plateau) on 8 December 1988, I inspected 12 scaled quail, 4 of which had abnormal livers characterized by yellow nodules. After photographing the livers in the field, I dismissed the incident and discarded the affected birds. It was not until 3 weeks later during a hunt in southwestern Oklahoma (Harmon County) that I sensed that the quail populations (bobwhite and scaled quail) that were present in mid-November had virtually disappeared. Over the next several months, I queried other hunters and ranchers in the Rolling Plains and heard of similar experiences. One rancher who typically fed over 100 scaled quail in northern Harmon County, Oklahoma said the scaled quail numbers tapered off sometime during the winter. He found several dead birds and said they exhibited signs of diarrhea (e.g., stained vents), but did not submit any specimens for examination. Another rancher in Bailey County (about 300 km southwest of previous location) related to me that he had observed scaled quail that could be caught by hand in the spring of 1989. He also remarked about evidence of diarrhea, but he dismissed the incident at the time.

DECLINE OF SCALED QUAIL

During 1993, I polled TPWD biologists, quail managers and selected ranchers to assess the extent of the demise of scaled quail across Texas. Additionally, I used Breeding Bird Survey (BBS) (Sauer et al. 1997) data to assess trends in Texas and throughout the scaled quail's range. According to survey respondents, the demise in scaled quail was most pronounced in the Rolling Plains, High Plains and Edwards Plateau ecoregions. Roadside quail counts conducted by TPWD and reported by Peterson and Perez (*this volume*) and BBS surveys confirmed these observations (Figure 1). The Rolling Plains (identified in BBS as Rolling Red Plains) population exhibited "typical" irruptive behavior until 1988, but has remained at a steady, low level since that time. Most respondents from the Trans Pecos or Rio Grande Plains reported that scaled quail had not declined any more than the annual population changes ("boom-bust") inherent in quail populations on semiarid ranges.

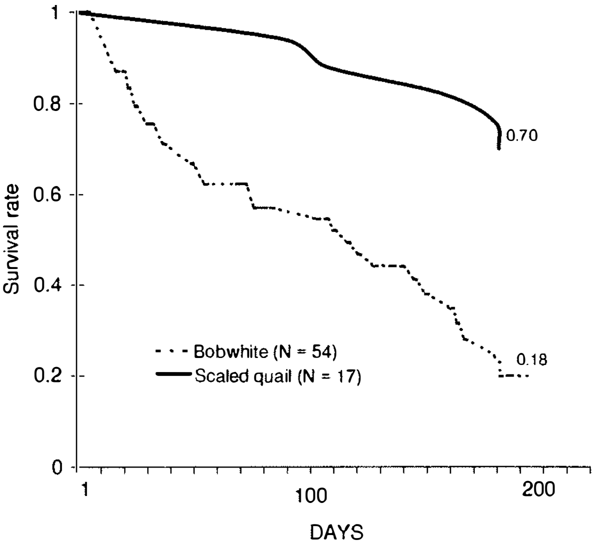

Fig. 2. Fate of radio-marked bobwhite (N = 54) and scaled quail (N = 17) on a sympatric site in Irion County, Texas, January–August, 1994–1995; bobwhite data include both years, but scaled quail monitored only during 1995 (Carter 1995 [bobwhite data]; P.S. Carter, Angelo State University, unpublished data [scaled quail]).

The decline of scaled quail relative to bobwhites is perplexing, as scaled quail are typically considered to be the better adapted of the 2 species to west Texas environs (Schemnitz 1964, Lehman 1984). This idea is supported by data from a pilot study on survival of sympatric bobwhite and a small sample (N = 17) of scaled quail (Carter 1995; P.S. Carter, Angelo State University, unpublished data) (Figure 2). Speculation about the decline of scaled quail, their failure to repopulate former range since that time, and their apparent replacement by bobwhites in some areas (e.g., Staked Plains; Sauer et al. 1997) suggests that several factors may be involved. These may include improving range conditions (i.e., more grass cover), changing land use practices (e.g., Conservation Reserve Program) (Schemnitz 1993), differential response to precipitation patterns (Guiliano and Lutz 1993), brush encroachment (which would favor bobwhites), higher predator populations, and possibly disease.

The importance of disease is usually dismissed as a concern in wild quail management. However, I speculate the decline of scaled quail in northwest Texas may have been related to epizootic disease in or about November 1988. My theory is based upon the anecdotal observations and circumstantial evidence mentioned earlier. Unfortunately, sick, dying or dead quail are rarely witnessed or reported. The symptoms observed (spotted livers, diarrhea) are consistent with "quail disease" (ulcerative enteritis) which is caused by a *Clostridium* bacterium (Davidson and Nettles 1988) or "quail bronchitis" (an avian adenovirus; Davidson et al. (1982). While ulcerative enteritis is a serious concern for pen-raised quail breeders, it has never been reported among wild quail (Davidson et al. 1982). Neither ulcerative enteritis nor quail bronchitis have been reported for scaled quail. Wallmo (1957) reported that 17 of 61 (28%) scaled quail collected from Brewster County in 1953 had enlarged livers with nodules; these birds were diagnosed with tuberculosis. Avian malaria (Hungerford 1955) and avian pox (Wilson and Crawford 1988) have been reported for scaled quail in Arizona and south Texas, respectively, but neither disease is considered an important mortality factor for scaled quail.

The decline of scaled quail and my theory of an undocumented disease are confounded with the inception of the Conservation Reserve Program, an apparently burgeoning predator population, brush encroachment and perhaps other unknown factors. My contention is that disease may have decimated the population in or about 1988, and high levels of nest predation (Slater 1996, Tolleson et al. *this volume*) have kept the population depressed since then. Krebs (1996) described the "predator-pit" hypothesis that suggests predators were capable of suppressing fecund prey species when prey populations were at low densities. I speculate that scaled quail may be mired in a similar predator-pit. Under such conditions, a quail population can decline quite rapidly (Jackson 1947) and undergo numerous local extinctions.

SCALED QUAIL VERSUS BOBWHITE MANAGEMENT

Attributes of scaled quail and bobwhite life history are summarized in Table 1. The sympatric range of bobwhites and scaled quail tends to change over time along an east-west gradient. Generally, it is believed that scaled quail tend to expand eastward during prolonged droughts, and that bobwhites move westward in a series of wetter years. BBS data suggest that bobwhites are indeed spreading westward and the western periphery of the bobwhite's range is one of the few populations showing an increase in recent years (e.g., Staked Plains; Sauer et al. 1997). In September 1995, I observed 3 coveys of bobwhites about 50 km south of Ft. Sumner, New Mexico. This area is some 150 km west of where I expected to find them. All coveys were flushed in the floodplain of the Pecos River in habitat similar to that found along the Canadian River in the Texas panhandle. In January 1989, I flushed a covey of bobwhites north of Ft. Stockton, Pecos County, Texas, an area where locals indicated that they had never seen bobwhites prior to that time.

Scaled quail tend to maintain their populations in prolonged drought better than the more mesic bobwhites (Schemnitz 1964). Conversely, scaled quail typically are not as productive as bobwhites under more "normal" precipitation conditions. As a result, scaled quail populations tend not to decline as quickly as bobwhites do during dry years, but neither do they increase as quickly as bobwhites during wet years. Bobwhite hens have been documented to produce multiple broods (Burger et al. 1995, Peoples et al. 1996). Double-brooding was documented in the small sample of scaled quail radio-marked in Irion County during 1995 (P.S. Carter, Angelo State University, unpublished data). Two instances of a female laying a clutch of eggs then leaving the male to incubate the eggs were recorded.

Mixed coveys of bobwhites and scaled quail are uncommon, but they do occur (Schemnitz 1961, Rollins 1980). Hybridization between the 2 species occurs occasionally (McCabe 1954, Sutton 1963, Webb and Tyler 1988), and the resulting offspring are true (i.e., sterile) hybrids (Shupe 1990).

During Carter's (1995) study on bobwhite survival in Irion County, Texas, 17 scaled quail were radio-marked with neck-loop transmitters (Wildlife Materials Inc., Carbondale, IL). Seventeen of these birds were monitored concurrently with a larger sample of northern bobwhites ($N = 54$) at a sympatric site in Irion County, TX. Because of the small sample size of scaled quail, no statistical analyses of survival data were calculated, but scaled quail survival during the 1995 breeding season appeared higher than bobwhites on the same site (Figure 2).

MANAGEMENT STRATEGIES

Brush management

The proper distribution and density of woody plants is just as critical to scaled quail as it is to bobwhites, albeit scaled quail may need less brush overall than do bobwhites. The availability of suitable loafing coverts is one of the first things I look for in evaluating habitat conditions for quail in west Texas. Suitable loafing sites are provided by some mesquites, larger lotebushes, sandplum (*Prunus angustifolia*), agarito (*Mahonia trifoliolata*) and other similarly shaped shrubs. On the High Plains, scaled quail use cholla (*Opuntia imbricata*) as loafing cover (Stormer 1981). Scaled quail readily use artificial coverts like half-cut mesquite trees (Rollins 1997), "teepee" brush shelters, and even abandoned farm machinery for loafing sites (Schemnitz 1961).

When contemplating brush management, managers should learn to recognize the structure of places that support high densities of quail and seek to maintain the integrity of such sites. Maintain at least 1 loafing covert per 20 ha, and preferably up to 3 per ha. Exactly how much brush to leave untreated has not been determined, but leaving at least 10 percent of the brush intact should be a minimum goal. Whether such brush strips cause nesting habitat to be more or less fragmented and vulnerable to nest predators needs to be determined. Mechanical control methods are generally preferred over chemical methods because of the forbs stimulated by soil disturbance. Mechanical con-

Table 1. A comparison of selected characteristics for blue and bobwhite quail in Texas.

Characteristic	Bobwhite	Scaled quail	References
Mass	160–170 g	175–190 g	Rollins (1980)
Diet	Seeds of forbs, grasses and woody plants; insects and greens seasonally important.	Diets essentially the same as bobwhites when the 2 species occupy same habitats.	Schemnitz (1964) Rollins (1981)
Home range (ha)	8–20	10–30 (Oklahoma) 40–180 (West Texas)	Schemnitz (1961) Wallmo (1957)
Foraging behavior	Usually limited to within 20–50 m of woody cover.	More likely to feed further from woody cover.	Rollins (1980)
Topography	Most dense along drainages.	Prefer more open hillsides or shallow sites on lowlands.	Schemnitz (1964)
Habitat preferences	Open to moderately dense stands of grasses with interspersed woody	Similar woody overstories, but usually occur in less dense understories.	Rollins (1980) Campbell-Kissock et al. (1984)
Fecundity	Multiple-brooding documented; perhaps up to 3 broods by some hens.	Multiple-brooding documented but frequency unknown.	Peoples et al. 1996, P.S. Carter (unpublished data)
Nest sites	Bunchgrasses usually, but will use woody cover or cactus if grass is limited.	More variable, including abandoned farm machinery, prickly pear.	Schemnitz (1964) Lehmann (1984:78), Carter 1995
Vulnerability to hunting	"more vulnerable"	"less vulnerable"	Ask any hunter!
Vulnerability to predators	"more vulnerable"	"less vulnerable"	Jackson (1947), P.S. Carter (unpublished data)
Endoparasite loads	higher cecal worm densities	lower cecal worm densities	Rollins (1980), Gruver (1984)
Reproductive strategies	"boom and bust" relative to environmental stimuli (rain)	neither bust as badly nor boom as wildly as bobwhites	Jackson (1947) Campbell et al. (1973)

trol also offers greater selectivity about which individual plants are killed. However, new technology incorporating "Individual Plant Treatments" (McGinty and Ueckert 1995) with herbicides also afford high selectivity.

Recent studies west of San Angelo (Carter 1995) suggest that prickly pear may provide important nesting habitat for scaled quail, especially during drought conditions where suitable herbaceous nesting cover is limited. Twelve of 21 bobwhite nests and 8 of 12 scaled quail nests were located in prickly pear clumps. Carter (1995) hypothesized that prickly pear provided some mechanical protection against nest predation. Subsequent studies conducted during 1995–96 confirmed that nests situated in prickly pear exhibited higher survival rates than nests placed in bunchgrasses on sites with <760 potential grass nest sites per ha (Slater 1996). Prickly pear is often targeted for control with a combination of fire and picloram (Ueckert et al. 1988), a treatment which provides > 95% control. Additional research is needed to further clarify the relationship between prickly pear and quail nest success.

Grazing Management

An observant quail hunter can look at the condition of a pasture (i.e., grass height and structure) and predict whether the pasture harbors scaled quail, bobwhites or both. This relationship suggests that grazing pressure and sward height/structure affect the relative habitat suitability for scaled quail versus bobwhites. Scaled quail tend to avoid areas that inhibit their ability to run from danger or perceived threats (Wallmo 1957, Lehman 1984, Schemnitz 1994).

Given that scaled quail tend to prefer more open (i.e., more heavily grazed) sites than bobwhites, it would seem that heavy continuous stocking would provide better scaled quail habitat. However, there is little consensus in the literature about which grazing methods are best for scaled quail management (Ligon 1937, Wallmo 1957, Campbell et al. 1973, Brown 1978, Campbell-Kissock et al. 1984). Campbell-Kissock et al. (1984) found higher densities of scaled quail on areas under a short duration grazing system than on a continuously grazed site in the western Rio Grande Plains. As one goes from east to west, range condition should be higher for the best scaled quail habitat just as Rice et al. (1993) suggested for bobwhites in the Rio Grande Plains. I suggest moderate (15 ha animal-unit^{-1}) to light (>30 ha animal-unit^{-1}) stocking rates as one goes from east to west, respectively.

The abundance of scaled quail relative to bobwhites shifted dramatically from 1969–1973 at the Chaparral Wildlife Management Area near Cotulla, purportedly due to improved range conditions brought about by implementing a rotational grazing scheme (D. Synatzke, Texas Parks and Wildlife Department, personal communication). The ratio of scaled quail to bobwhites shifted from roughly 60:40 in 1969 to 5:95 in 1980, and has remained similar since then. Several other biologists from the Rio Grande Plain of Texas suggested that improved range conditions (i.e., more grass) provide some adaptive advantage to bobwhites. Bare ground, which is sometimes cited as a management concern for bobwhites in the southeastern half of Texas (Guthery 1986), is rarely a management concern for scaled quail in west Texas.

Food Management

Historically, quail managers spend much of their efforts trying to increase food availability. Scaled quail diets are dominated by seeds of forbs and woody plants, with mast and fruits (e.g., tasajillo [*Opuntia leptocaulis*]), greens and insects seasonally important (Wallmo 1957, Rollins 1980, Burd 1989, Ault and Stormer 1983).

Soil disturbance caused by mechanical brush control, winter disking, and livestock grazing stimulates most of the early successional species that provide the bulk of the diet for scaled quail and bobwhites. Strip disking should be conducted during Dec–Feb in proximity to suitable woody cover for foods to be available to quail. Seeds of woody plants like mesquite, catclaw (*Acacia* spp.), hackberry (*Celtis* spp.) and chittam (*Bumelia lanuginosa*) are seasonally important foods, as are seeds of various cacti, including prickly pear and tasajillo. Larger trees of these species should be maintained during brush control operations.

Food plots are one of the most popular options for active habitat management with bobwhites. However, west of the 98th meridian, arid conditions usually limit the dependability and production of food plots. I have come to the conclusion that "*when you need food plots, you can't grow them, and when you can grow them, you probably don't need them.*" However, scaled quail readily use various sorghums, wheat and other agricultural crops where they occur. I have observed scaled quail feeding over 75 m from brush cover in wheat fields during the early fall (Rollins 1980). The greatest value of food plots in semiarid regions may be the (a) weeds associated with soil disturbance or (b) insects attracted to the food plots.

Supplemental feeding is another popular practice, but one that rarely results in production of any more quail than areas without feeders. No research has been conducted to evaluate the effects of supplemental feeding on scaled quail in Texas. Campbell (1959) speculated that supplemental feeding was ineffective, but his study was confounded with availability of water. Scaled quail readily use quail feeders, and hence become more available to hunters. I have photographed scaled quail with chicks <3 weeks old at feeders in Irion County. They also frequent deer feeders ("sling feeders" that broadcast corn) during the fall months. I have documented scaled quail during winter months feeding at free-choice deer feeders stocked with protein pellets. Quail management dogma maintains that supplemental feeding should be discouraged, as it may increase the incidence of predation, parasitism or disease. However such ideas have not been thoroughly tested on bobwhites or scaled quail in semiarid regions.

Water Development

While scaled quail will drink if surface water is available, there is no evidence that providing supplemental water benefits scaled quail populations (Wallmo 1957). Wallmo and Uzell (1958) summarized their efforts at enhancing scaled quail range with guzzlers and concluded "there in no correlation between water availability and population size." It appears that scaled quail are capable of meeting their water requirement from preformed water (e.g., dew) or metabolizable water contained in their foods (insects, greens, etc.).

Predator Control

Like livestock grazing recommendations, opinions often differ about the efficacy of predator control for enhancing quail populations (Hurst et al. 1996). Jackson (1947) suggested that scaled quail were less vulnerable to raptor predation than bobwhites in the Rolling Plains. Scaled quail appeared to be less vulnerable to predation (mostly mammal-related) in a study near San Angelo (P.S. Carter, Angelo State University, unpublished data).

If predator control is to be effective, it will most likely be related to a decreased incidence of nest predation. Beasom (1974) found that an intensive predator control program resulted in a moderate increase of bobwhites in the eastern Rio Grande Plains. However, Guthery and Beasom (1977) conducted a similar study in the western Rio Grande Plains and observed no difference in scaled quail population trends and abundance. Hernandez (1995) conducted a preliminary test on the use of lithium chloride for providing a conditioned taste aversion (CTA) of eggs to nest predators in west Texas. His results were equivocal; 1 site exhibited a higher nest survival following CTA trials, but the other did not.

During May–July 1996, I used cage traps to remove potential nest predators (e.g., raccoons [*Procyon lotor*]) for a 28-day period just prior to nest initiation (i.e., May) in Sterling County, Texas. Following the trapping regime, a total of 96 simulated quail nests (48 each in a trapped vs. untrapped site) were monitored weekly for 28 days. Nest success was 277% higher in the trapped site ($\bar{x}$ = 36%) than untrapped sites ($\bar{x}$ = 13%). This pilot study suggests that "prescribed" trapping of mesomammals should be evaluated further as a management practice. While not normally considered effective, today's more fragmented landscape and other factors may affect the viability of predator control for increasing quail populations (Guthery 1995).

RESEARCH NEEDS

What is known of reproductive ecology for scaled quail should be labeled with the footnote "B.T.," i.e., "before telemetry." When one looks at many of the recent discoveries into bobwhite behavior and reproductive ecology (e.g., multiple brooding) that were considered heretical not too many years ago, one should be cautious when interpreting existing information about scaled quail reproductive ecology. Future studies are needed to identify, and hopefully rectify, the agents responsible for the decline of scaled quail over the last 15 years. The relationships between sympatric bobwhite and scaled quail, especially along the western periphery of sympatry, need further investigation. The potential interactions of disease and nest predation as a suppressing agent for scaled quail populations warrant additional study. The role of predation in avian recruitment has received renewed interest in recent years (e.g., Hurst et al. 1996) and studies to evaluate the efficacy of "prescribed" mesomammal control to enhance nesting success are warranted. Finally, the assumption that diseases are unimportant in free-ranging quail may need to be revisited.

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HABITAT CHARACTERISTICS OF NORTHERN BOBWHITE QUAIL-HUNTING PARTY ENCOUNTERS: A LANDSCAPE PERSPECTIVE

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ABSTRACT

Landcover data and bobwhite hunting records were used to assess both hunter habitat preferences and the frequency of northern bobwhite encounters by hunting parties in relation to habitat composition during the 1994–1995 and 1995–1996 hunting seasons at the Joseph W. Jones Ecological Research Center in southern Georgia. Patterns of habitat use by hunters, and the frequency of bobwhite encounters varied within and between years, depending on habitat quality, food availability, and other factors. Landscape-scale analyses of standardized bobwhite covey densities (based on coveys pointed in the field) and habitat composition and configuration for the 1994–1995 hunting season revealed that bobwhite densities were: (1) positively associated with the overall percentage agriculture and food plot habitat (reaching a maximum at 30–35% agriculture); and (2) positively associated with edge complexity, and positively associated with agricultural mean patch size [reaching a maximum at 2–3 hectares (5–6 acres)]. Consequently, larger food plots may be more important for increasing bobwhite encounter rates than numerous very small food plots [< 0.1 hectares (0.25 acres)]. Results of this, and related ongoing studies, have important implications for both landscape design and multiple use resource management activities in the context of northern bobwhite habitat management in southern upland pine forest ecosystems.

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INTRODUCTION

Northern bobwhite (*Colinus virginianus*) populations have experienced precipitous declines in the southern region of the United States since the 1960's (Brennan 1991). Likely causes of the decline include broad-scale land use changes (e.g., increasing size of agricultural patches, increases in intensive pine silviculture, urbanization), loss of weedy fence rows and other edge habitats, and decreased use of prescribed burning (Klimstra 1982, Brennan 1991). Implementation of the Conservation Reserve Program (CRP) in the mid-1980's has not played a significant role in reversing the decline in bobwhite throughout their range (Roseberry and David 1994), although the CRP has been recently modified to benefit such wildlife species.

The spatial structure of habitat (e.g., size, shape, and degree of patch isolation) within a landscape is known to affect biodiversity and species' population dynamics (Martin 1992). Since the 1930's, significant research and management effort has been devoted to understanding, implementing, and promoting management practices (use of fire, field and food plot design, etc.) that benefit northern bobwhite populations (Stoddard 1931, Rosene 1969, Landers and Mueller 1989). The importance of landscape structure and composition for bobwhite populations was also initially recognized by bobwhite biologists. For example, Stoddard and Komarek (1941) reported that "good populations of quail can be maintained on heavily wooded lands provided at least 25% of the terrain consists of openings or small fields." Rosene (1969) described an optimal landscape for bobwhite that was comprised of small agricultural fields with complex edge habitats that were well-dispersed within a forest matrix. Despite the decades-long decline in bobwhite abundance, our understanding of the relationship between bobwhite population dynamics and landscape composition and structure has not improved appreciably since these earlier investigations. Consequently, in 1996 the Southeast Bobwhite Study Group (unpublished technical report) identified the "effects of landscape pattern (structure and composition) on bobwhite population dynamics" as a research topic that should receive priority attention.

Analyses of high-resolution Geographic Information System (GIS) data layers, coupled with extensive bobwhite hunting records, allowed us to assess habitat preferences by hunters and bobwhite encounter rates in different habitats within a longleaf pine-dominated ecosystem in southwestern Georgia. Although bobwhite encounter rates may be related to habitat preference, it is important to note that bobwhite detectability by dogs probably varies among habitats and that all habitats (e.g., wetlands) are not sampled at the same frequency throughout the hunting season. The objectives of this study were to: (1) compare habitat composition of hunt course routes (routes traveled by hunt parties within a course) with courses (22 large contiguous areas, each of which may be hunted during a half-day or a full-day hunt) by hunting season and month; (2) compare habitat composition of covey locations (points) with course routes by hunting season and month; (3) compare habitat composition of 2-hectare (5-acre) covey activity areas that surround points where coveys were initially sighted with course routes by hunting season and month; and (4) characterize the relationship between bobwhite covey density and habitat composition and structure. The long-term purposes of this study are to design and implement different landscape configurations that can meet differing landowner objectives (e.g., wildlife, silviculture, agriculture).

METHODS

Study Area

The Joseph W. Jones Ecological Research Center is located at Ichauway, a 115 kilometer^2 (45 mile^2) ecological reserve located in Baker County in southwest Georgia, 45 kilometers (28 miles) southwest of Albany (Figure 1). The site is located along the Flint River at its confluence with Ichawaynochaway Creek. Forested upland communities comprise 8,474 hectares (20,931 acres) and are dominated primarily by longleaf pine (*Pinus palustris*), slash pine (*Pinus elliotti*), and mixed pines and hardwoods (primarily longleaf pine and oaks, *Quercus* spp.) (Table 1). Other plant communities include hardwoods (dominated by live oak (*Q. virginiana*), laurel (*Q. hemisphaerica*), and water oak (*Q. nigra*)), forested wetlands (*Taxodium* spp. and *Nyssa* spp.), and herbaceous wetlands or open water. Agricultural fields and small wildlife food plots are scattered across the Ichauway landscape and comprise a total of 2,239 hectares (5,530 acres).

Northern Bobwhite Management at Ichauway

The landbase at Ichauway was first assembled as a hunting plantation in the late 1920's, and the northern bobwhite was a featured species on the property through the early 1990's. Southern-style hunting of wild bobwhites is a unique, historical landuse that is being maintained on Ichauway in selected areas. Prescribed fire, field, and woodland management play key roles in providing nesting, brood, feeding, escape, loafing, and roosting habitats for bobwhites. Harvest management, including daily, covey, and course limits, is also an important component of maintaining a long-term, sustainably harvestable population of bobwhites.

Food plots are managed to provide an old-field rim with a 3- to 6-year old rough of bluestem (*Andropogon* spp.) and blackberry (*Rubus* spp.) that also contains brushy cover, typically patches of Thunbergii lespedeza, Chickasaw plum, or dwarf live oak. The interior of the field contains a strip of summer crop, typically corn, and a winter crop, typically wheat, that are rotated through the field so that there is always current summer and winter agriculture and fallow summer and winter agriculture. Small food plots [0.1 to 0.4 hectares (0.25 to 1 acre)] in the woodlands are planted with a mixture of agricultural species (e.g., browntop millet, iron-clay peas, grain sorghum, Egyptian wheat) in late spring to provide bare ground, insects, and agricultural and weed seeds. Larger food plots also have woody escape cover. Approximately 500 hectares (1,235 acres) of agricultural crops are planted for bobwhites and other wildlife each year. Bobwhites are supplementally fed through the winter and early spring by broadcasting feed into heavy overhead cover throughout the hunting courses approximately every two weeks.

Current woodland manipulation consists of converting agricultural fields to woodlands, controlling hardwood encroachment into agricultural fields, and prescribed burning. Portions of some fields have been planted with longleaf pine in a window-pane pattern to produce smaller fields with more edge. Fire-maintained habitats are burned, typically in March and April, on a 1- to 3-year return interval. Five to six thousand hectares (12,000–15,000 acres) are burned annually.

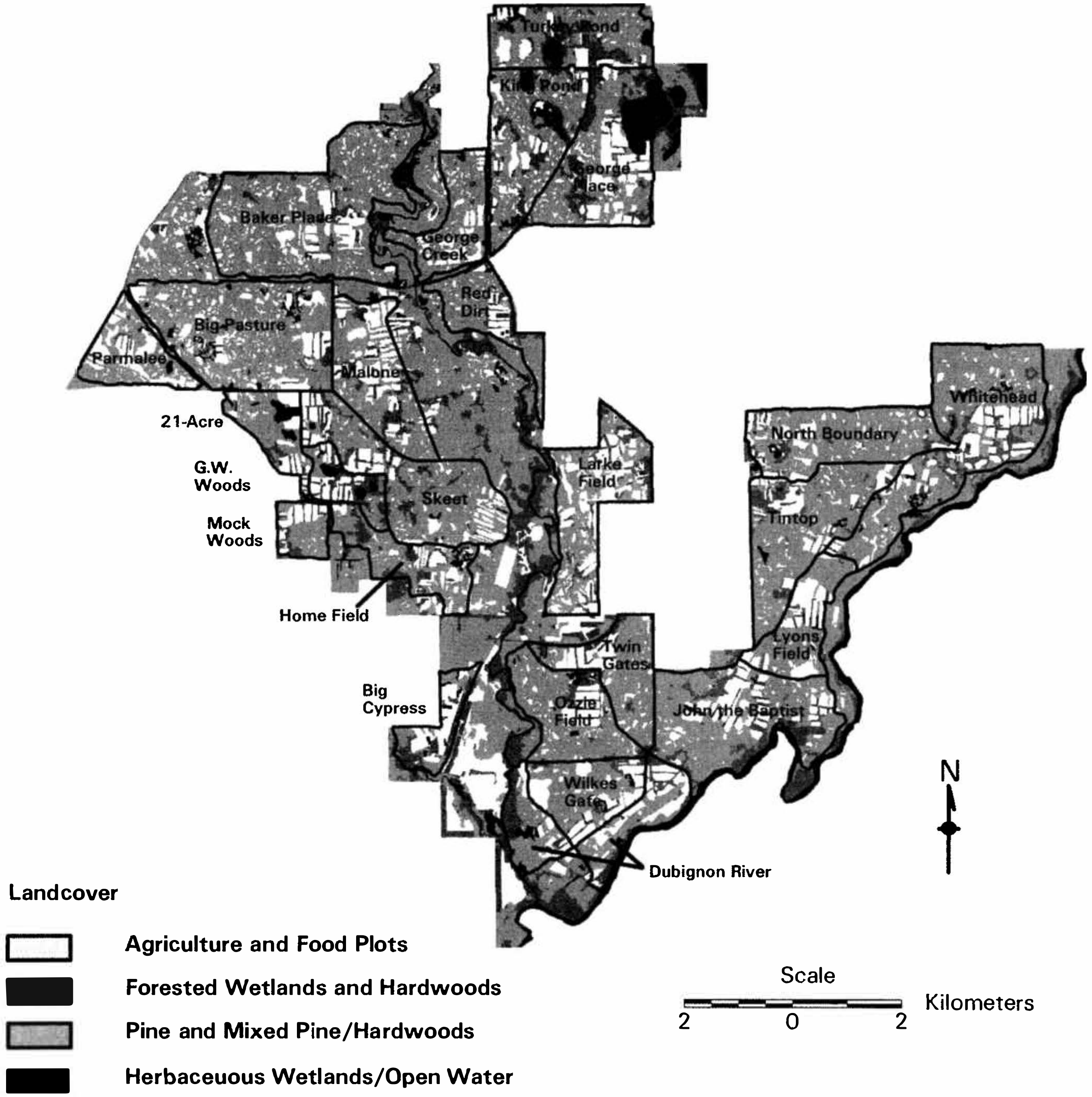

Fig. 1. Map of study site showing generalized landcover and hunt courses at Ichauway.

Table 1. Landcover classes for all active hunt courses and for Ichauway (total).

Landcover	Course (hectares)	Course (%)	Ichauway (hectares)	Ichauway (%)
Agriculture	1636	19.4	1958	16.7
Wildlife Food Plots	240	2.8	278	2.4
Forested Wetlands	87	1.0	100	0.9
Hardwoods	911	10.8	1463	12.4
Longleaf and Slash Pine	2790	33.0	3839	32.6
Mixed Pine/Hardwoods	2427	28.7	3169	26.9
Other (see text)	15	0.2	66	0.6
Pine Strips	133	1.6	188	1.6
Scrub/Shrub	116	1.4	184	1.6
Herbaceous Wetland/Open Water	92	1.1	509	4.3

Geographic Information System Database

Landcover data were developed in conjunction with the Mississippi Remote Sensing Center (MRSC) at Mississippi State University, Starkville, Mississippi. Detailed landcover classes were interpreted from 1:12,000 scale color infrared (CIR) aerial photographic transparencies and verified during field surveys. Data were transferred using a vertical sketchmaster to USGS quads, digitized, with attributes identified using Environmental Systems Research Institute's ARC/INFO software. Landcover classification attributes included tree species composition, age class, and stand density for all forested areas. Generalized landcover classes developed for this study included: agriculture, food plots, forested wetlands, hardwoods, mixed pines, mixed pines/hardwoods, scrub/shrub, planted pine strips, wetland/open water, and other (i.e., urban, borrow pits, etc.) (Table 1).

Field Observations

Bobwhite hunting records for the two seasons incorporated in the comprehensive analysis (November 1994–February 1995; November 1995–February 1996) included: hunt course routes and covey sightings mapped in field, habitat characteristics, weather, dogs, members of the hunt party, and other parameters. Typical hunt parties consisted of: 2 hunters, 1 dog handler, 1 scout, 1 horse holder, 1 data collector, 1 mule-drawn wagon and driver, as well as horses, pointers, and a retriever. Generally, hunt courses were hunted repeatedly during the season with a two-week lag between repeats. Hunt courses were hunted in a similar fashion each time by experienced personnel (i.e., dog handler and scout). Approximately 100 hunts were conducted each season.

Data Analysis

Covey sightings (points by hunting dogs) were assumed to represent centers of 2.0-hectare (5-acre) activity areas for the analyses, and hunt course routes were treated as 100-meter (330-feet) wide sampling transects (Figure 2). Three habitat indices (P_i) were similarly derived as follows:

$$P_i = U_i - A_i$$

where U (Use) = proportion of study area subunit [hunt course route, covey activity area, or individual covey sightings (points); respectively] associated with landcover type 'i', and A = proportion of study area (hunt course, hunt course route, or hunt course route; respectively) associated with landcover type 'i'. Although the index can theoretically vary from approximately −100 (avoidance; quail never or less frequently encountered than expected based on habitat availability) through 0 (no preference; quail encounters are directly proportional to habitat availability) to approximately +100 (preferred; quail are more frequently encountered than expected based on habitat availability), most of the values reported in this study ranged from approximately −25 to +40. [Note: inferences based on the magnitude of P_i are unwarranted, since the index is not standardized among different landcover classes; consequently, values of P_i are not presented.] Multivariate analysis of variance (MANOVA) based on habitat preference indices was designed to compare habitat composition between hunt course routes and hunting courses, covey activity areas and hunt course routes, and covey field sightings (points) and hunt course routes. Multivariate analyses were performed on both annual (hunting season) and seasonal (month within season) data for each year.

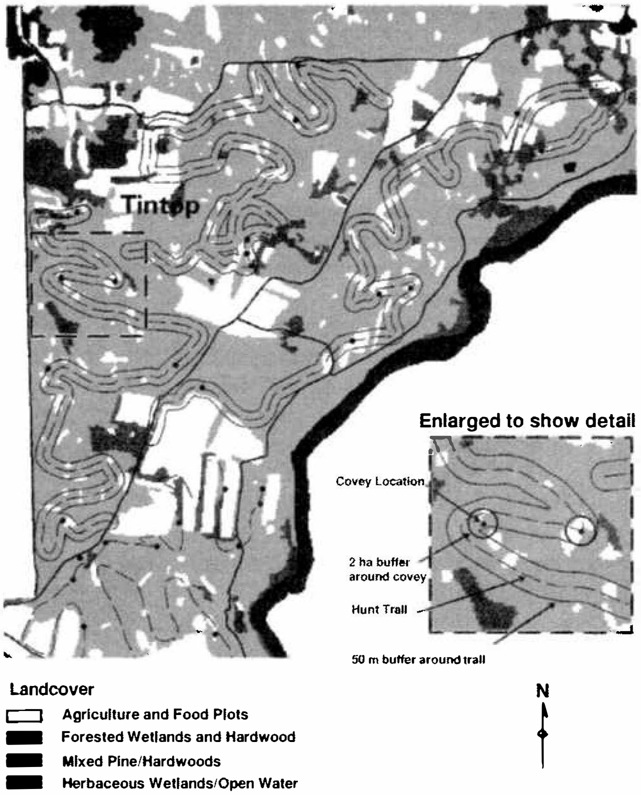

Fig. 2. Map illustrating hunt course routes (dashed line) within a hunt course, covey sightings (dots), and 2-hectare (5-acre) covey activity areas (circles) at Ichauway.

Landscape-level analyses were based on the comparison of agricultural field and food plot patches (a single class comprising 22% of the total hunt course area) to a single background matrix. The background matrix encompassed all remaining landcover types, but was comprised primarily of forested habitat (> 73% of the total hunt course area). Landscape metrics were calculated for each of the 22 hunt courses using FRAGSTATS (McGarigal and Marks 1995). Estimates of standardized bobwhite covey densities for each hunt course (average number of different coveys encountered per hour along hunt course routes) were derived from hunt records for the 1994–1995 hunt season. Backward stepwise regression analysis was initially used to assess the relationship between bobwhite covey densities and landscape metrics and to arrive at the most parsimonious multiple regression model. Three landscape metrics proved to be most closely associated with covey densities: percentage of agriculture and

Table 2. Hunter habitat preference at Ichauway by hunting season[1].

Landcover type	1994–1995[2]	1995–1996[3]
Agriculture	–	+
Food Plot	0	+
Forested Wetland	–	–
Hardwoods	–	–
Pines	0	0
Pine/Hardwoods	0	0
Other	0	0
Scrub/Shrub	0	0
Pine Strips	–	–
Wetland/Water	0	–

[1] Notes: (+) indicates use exceeded availability, (0) indicates no significant difference ($P > 0.05$) between use and availability, and (–) indicates availability exceeded use.

[2] MANOVA test criteria (Roy's Greatest Root): F = 17.4012; Numerator DF = 9, Denominator DF = 86; P = 0.0001.

[3] MANOVA test criteria (Roy's Greatest Root): F = 8.5521; Numerator DF = 9, Denominator DF = 88; P = 0.0001.

food plots, mean shape index of agriculture fields and food plots (a measure of edge complexity ranging from 1 for circular patches to 2 for complex shapes), and agricultural mean patch size. All statistical analyses (regression and MANOVA) were performed using SAS software (SAS Institute, Inc. 1989) following procedures outlined by Scheiner (1993) and Sokal and Rohlf (1995).

RESULTS

Hunter Preferences (Hunt Course Routes vs. Hunt Courses)

Approximately 50% of the total area set aside in hunt courses (see Table 1 and Figure 1) was hunted during each year of the study. The area "sampled" by hunting parties encompassed all landcover classes (Table 1). Hunter habitat preference (i.e., landcover composition of hunt course routes in comparison to landcover composition of hunt courses) varied by hunting season and month within a hunting season. For the two years of the study, hunting parties generally favored food plots, but avoided wetland/open water and forested wetland habitat (Tables 2, 3). Although agricultural habitat was not preferred or avoided on a monthly basis in 1994–1995, it was preferentially hunted during December and January of 1995–1996 (Table 3). This shift in preference to agricultural habitat in 1995–1996 coincided with the increasing age of pine strips that were planted in large agricultural fields to enhance landscape heterogeneity. Pine and scrub/shrub habitats were favored in 1994–1995, but were not consistently favored or avoided in the following year (1995–1996), except for a preference for pine habitat in February 1996. The apparent decreased hunting use of these two habitats in 1995–1996 coincided with an overall increased preference for agricultural habitat, especially in December 1995 and January 1996. Although hardwood habitat was avoided in 1994–1995 (especially December and January), this trend was less apparent in 1995–1996, a year coinciding with a heavy oak mast crop. Pine/hardwood and other habitats were not consistently favored or avoided in either of the two hunting seasons. Although results suggested that pine strips were avoided during both hunting seasons (Table 2), monthly data indicated that the relatively consistent avoidance of pine strip habitat observed throughout the 1994–1995 hunting season was not repeated the following year (Table 3).

Bobwhite Habitat Selectivity

Covey Activity Areas vs. Hunt Course Routes

Comparisons of habitat composition of 2.0-hectare (5-acre) covey activity areas and hunting courses indicated a higher than expected covey encounter rate during the hunting season for agriculture and food plots, and a lower than expected covey encounter rate for hardwood habitats (Table 4). However, the habitat composition of covey activity areas shifted seasonally as indicated by a higher than expected encounter rate for food plot habitat in February during both years (Table 5). The relatively consistent low covey encounter rates for hardwood, scrub/shrub, and "other" habitats in 1994–1995 was not evident in 1995–1996, a year of heavy oak mast production (Table 5). Trends in covey encounter rates for other habitats were generally not consistent between and within hunting seasons. For ex-

Table 3. Hunter habitat preference by month within hunting season[1] at Ichauway.

	1994–1995[2]				1995–1996[3]			
Landcover type	November	December	January	February	November	December	January	February
Agriculture	0	0	0	0	0	+	+	0
Food Plot	0	+	+	+	0	0	+	+
Forested Wetland	–	–	–	–	0	–	–	–
Hardwoods	0	–	–	0	0	0	0	0
Pines	0	+	+	+	0	0	0	+
Pine/Hardwoods	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	–
Scrub/Shrub	0	0	0	+	0	0	0	0
Pine Strips	0	–	–	–	–	0	0	0
Wetland/Water	0	–	–	0	0	–	–	–

[1] Note: (+) indicates use exceeded availability, (0) indicates no significant difference ($P > 0.05$) between use and availability, and (–) indicates availability exceeded use.

[2] MANOVA test criteria (Roy's Greatest Root): F = 6.2465; Numerator DF = 9, Denominator DF = 14; P = 0.0013.

[3] MANOVA test criteria (Roy's Greatest Root): F = 3.0246; Numerator DF = 9, Denominator DF = 14; P = 0.0312.

Table 4. Covey encounter rates (activity areas) in comparison to habitat composition of hunt course routes[1] at Ichuway.

Landcover type	1994–1995[2]	1995–1996[3]
Agriculture	+	+
Food Plot	+	+
Forested Wetland	0	0
Hardwoods	–	–
Pines	–	0
Pine/Hardwoods	0	0
Other	0	0
Scrub/Shrub	–	0
Pine Strips	0	–
Wetland/Water	0	0

[1] Note: (+) indicates covey encounter rate exceeded expectation based on availability of that habitat type, (0) indicates no significant difference ($P > 0.05$) between encounter rate and habitat availability, and (–) indicates covey encounter rate was lower than expected based on availability of that habitat type.

[3] MANOVA test criteria (Roy's Greatest Root): $F = 8.0813$; Numerator DF = 9, Denominator DF = 1011; $P = 0.0001$.

[3] MANOVA test criteria (Roy's Greatest Root): $F = 8.7932$; Numerator DF = 9, Denominator DF = 943; $P = 0.0001$.

Table 6. Covey encounter rates (points) in comparison to habitat composition of hunt course routes[1].

Landcover type	1994–1995[2]	1995–1996[3]
Agriculture	+	+
Food Plot	+	+
Forested Wetland	–	0
Hardwoods	0	0
Pines	–	0
Pine/Hardwoods	–	0
Other	0	0
Scrub/Shrub	+	0
Wetland/Water	0	0

[1] Note: (+) indicates covey encounter rate exceeded expectation based on availability of that habitat type, (0) indicates no significant difference ($P > 0.05$) between encounter rate and habitat availability, and (–) indicates covey encounter rate was lower than expected based on availability of that habitat type.

[2] MANOVA test criteria (Roy's Greatest Root): $F = 46.5093$; Numerator DF = 8, Denominator DF = 87; $P = 0.0001$.

[3] MANOVA test criteria (Roy's Greatest Root): $F = 81.3137$; Numerator DF = 9, Denominator DF = 85; $P = 0.0001$.

ample, although pine strips were hunted more frequently in 1995–1996, coveys were infrequently encountered in these habitats during all months sampled (Table 5). Similarly, a lower than expected bobwhite encounter rate for forested wetland habitat was apparent only during February 1996 (Table 5).

Covey Sightings (points) vs. Hunt Course Routes

Comparisons of covey sightings and habitat composition of hunting courses indicated higher than expected encounter rates for agriculture and food plots during both hunting seasons, as well as most months within a season (Tables 6, 7). Like the covey activity area comparisons, overall bobwhite field sightings indicated lower than expected encounter rates in pine habitat during 1994–1995 and no consistent trends during 1995–1996 (Table 6). However, monthly comparisons indicated that bobwhite coveys were not encountered as frequently as expected in both pine and pine/hardwood habitats throughout both hunting seasons (Table 7). Unlike the covey activity area comparisons, lower than expected encounter rates for forested wetland habitat were indicated during both January and February 1996, a period coinciding with higher water elevations and decreased availability and quality of *Nyssa* fruits (Table 7).

Bobwhite Covey Density and Landscape Pattern

Analysis of the relationship between standardized bobwhite covey densities and landscape habitat composition and configuration indicated that covey densities were positively associated with percentage agriculture and food plot habitat (reaching a maximum at approximately 30–35%; Figure 3a), positively associated with mean patch size for agriculture and food plot habitat [reaching a maximum at 2–3 hectares (5–7 acres); Figure 3b], and positively associated with mean shape index of agriculture and food plot habitat (Figure 3c). The most parsimonious model ($F = 6.765$; $P = 0.0033$; Adjusted $R^2 = 0.46$; $N = 22$) of the relationship between covey density and landscape metrics is expressed in Equation 1.

Table 5. Covey encounter rates (activity areas) in comparison to habitat composition of hunt course routes by month within hunting season[1] at Ichauway.

	1994–1995[2]				1995–1996[3]			
Landcover type	November	December	January	February	November	December	January	February
Agriculture	0	0	+	0	0	+	0	0
Food Plot	0	+	+	+	0	0	–	+
Forested Wetland	0	0	0	0	0	0	0	–
Hardwoods	–	–	–	0	0	0	–	0
Pines	0	0	–	0	0	–	0	0
Pine/Hardwoods	0	0	0	0	0	0	0	0
Other	–	0	–	–	0	0	0	0
Scrub/Shrub	0	–	–	0	0	0	0	0
Pine Strips	–	0	0	0	–	–	–	–
Wetland/Water	0	0	0	0	0	0	0	0

[1] Note: (+) indicates covey encounter rate exceeded expectation based on availability of that habitat type, (0) indicates no significant difference ($P > 0.05$) between encounter rate and habitat availability, and (–) indicates covey encounter rate was lower than expected based on availability of that habitat type.

[2] MANOVA test criteria (Roy's Greatest Root): $F = 3.8505$; Numerator DF = 9, Denominator DF = 244; $P = 0.0001$.

[3] MANOVA test criteria (Roy's Greatest Root): $F = 3.1341$; Numerator DF = 9, Denominator DF = 194; $P = 0.0001$.

Table 7. Covey encounter rates (points of individual covey sightings) in comparison to habitat composition of hunt course routes by month within hunting season[1] at Ichauway.

	1994–1995[2]				1995–1996[3]			
Landcover type	November	December	January	February	November	December	January	February
Agriculture	0	+	+	0	0	+	0	+
Food Plot	+	+	0	+	+	+	+	+
Forested Wetland	0	–	0	+	0	0	–	–
Hardwoods	0	0	–	0	0	0	0	0
Pines	–	–	–	–	0	–	–	–
Pine/Hardwoods	0	–	–	–	–	–	–	–
Other	0	–	–	–	0	–	–	0
Scrub/Shrub	0	0	0	0	0	0	0	0
Wetland/Water	0	0	–	0	0	–	0	0

[1] Note: (+) indicates covey encounter rate exceeded expectation based on availability of that habitat type, (0) indicates no significant difference ($P > 0.05$) between encounter rate and habitat availability, and (–) indicates covey encounter rate was lower than expected based on availability of that habitat type.

[2] MANOVA test criteria (Roy's Greatest Root): $F = 25.7386$; Numerator $DF = 8$, Denominator $DF = 15$; $P = 0.0001$.

[3] MANOVA test criteria (Roy's Greatest Root): $F = 21.9953$; Numerator $DF = 8$, Denominator $DF = 15$; $P = 0.0001$.

$$SCD = 2.562 + 2.820(AgMSI) + 0.373(AgMPS) - 0.197(AgMPS^2) \quad (1)$$

where SCD = standardized covey density in hunt course, AgMSI = mean shape index of agriculture and food plot patches in a hunt course, and AgMPS = average size of patches of agriculture and food plot habitat in a hunt course. Examples of landscape (hunt course) composition and patterns associated with high and low bobwhite covey densities are depicted in Figure 4.

DISCUSSION

Analyses of habitat composition of covey activity areas and points associated with individual covey sightings indicated higher than expected encounter rates of bobwhite coveys for food plots and agricultural fields in a forest-dominated landscape (Tables 4–7). Previous studies have demonstrated a similar "preference" for field habitat (Bell et al. 1985, Fuller 1994, Lee 1994, Dixon et al. 1996) that was related to availability of food and roosting and escape cover. All habitat types were "sampled" during each year of the study. Not surprisingly, hunting parties generally hunted more frequently in or near those habitats where bobwhite coveys were more frequently encountered (i.e., food plots and agricultural fields; Tables 2, 3). The apparent increase in hunter use of agricultural habitat during the 1995–1996 hunting season, which may have been related to the perceived increased quality of the aging pine strip habitat, was not reflected in higher bobwhite encounter rates in those habitats (Tables 4–7). Similarly, hunting parties appeared to utilize (or exhibit less avoidance) pine and pine/hardwood habitat more than would be warranted on the basis of habitat composition of covey activity areas and individual covey encounters (Tables 2–7). These findings likely reflect the necessity for hunters to travel through the forested background matrix to reach new patches of perceived bobwhite habitat as well as the importance of horseback riding through the forested savannas as an integral aesthetic component of the bobwhite hunting experience.

Analysis of covey sightings (Table 7) revealed that covey encounter rates for hardwood and scrub/shrub habitats were not as low as would have been inferred from similar analyses of the habitat composition of covey activity areas (Table 5). These findings probably reflect the importance of these habitats for escape and foraging (e.g., oak mast), as well as the importance of supplemental feeding activities. Furthermore, it should be emphasized that differences in habitat use based on analyses of covey activity areas or home ranges as opposed to points associated with individual covey sightings can often be attributed to the scale of the observer. For example, the minimum mapping unit for landcover in this study was approximately 0.01 hectares (0.025 acres), despite the fact that landcover data were based on photointerpretation of high resolution (1:12,000) color infrared photos. Consequently, small patches of suitable quail habitat that are missed or under-represented in analyses based on covey activity areas may, nevertheless, be disproportionately used by bobwhite coveys for foraging or escape.

Although analyses demonstrated the importance of specific habitats for encountering bobwhite coveys (i.e., food plots and agricultural fields), results of such analyses can not be readily incorporated into the design of optimal landscapes for northern bobwhite quail since they provide no indication of the ideal composition and configuration of habitats. The landscape-scale analyses performed as part of this study do, however, indicate that bobwhite covey densities are related to the specific composition and configuration of habitat. For example, covey densities increased as the percentage of the hunting course comprised of agriculture increased, reaching an apparent maximum at 30–35% agriculture (Figure 3a). This finding supports the recommendation by Stoddard and Komarek (1941) that at least 25% of forested lands should be comprised of small fields to support good quail populations. We have found only one other study documented in the literature where the investigators attempted to identify optimal combinations of different land uses for supporting bobwhite populations. In an analysis of the relationship between covey densities and composition

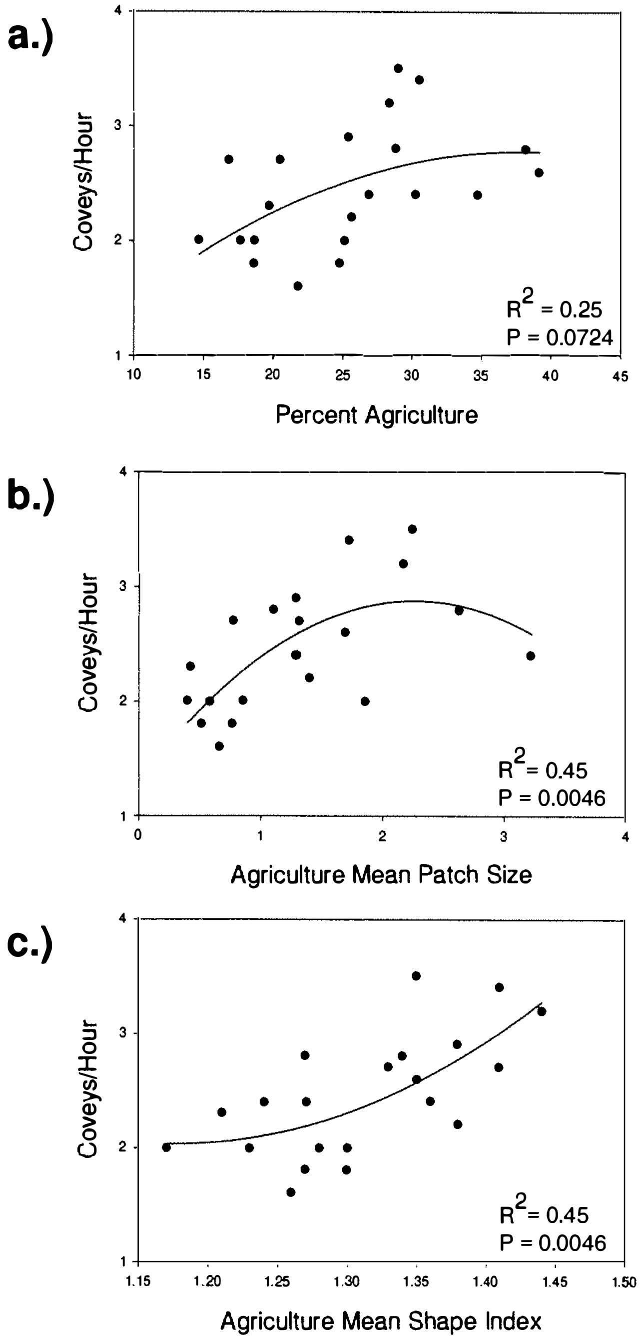

Fig. 3. Relationship between standardized covey densities and (a) percentage agriculture and food plot habitat; (b) mean shape index of agricultural fields and food plots; and (c) mean patch size of agricultural fields and food plots using a 30-meter (98-foot) buffer.

(pasture, woodland, cropland) of small [20–120 hectares (50–299 acres)] Tennessee farms, only approximately 5% of the total variability in covey densities could be attributed to percentage pasture or cropland (Schultz and Brooks 1958, Schultz 1959).

The positive relationship between covey density and increased edge complexity (Figure 3c) supports the contention by Rosene (1969) that optimal landscapes for bobwhite populations are comprised of small, well-dispersed agricultural fields with complex edge habitat. Results of other studies of the association between bobwhite and edge habitat are mixed. For example, Best (1983) observed a positive relationship between bobwhite quail and fencerow habitat, whereas Dixon et al. (1996) reported that bobwhite quail avoided edge habitat. The positive association between covey densities and agricultural patch size is more complex, but indicates the relative importance of fewer large food plots and small- to medium-sized agricultural fields [>0.1 hectares (0.25 acres)], as opposed to the use of large numbers of very small food plots [<0.1 hectares (0.25 acres)] (Figure 3b). Increased sample sizes and replication of this study on other areas are required to further clarify the relationship between bobwhite covey encounter rates and landscape characteristics, including the influence of multiple habitat types.

IMPLICATIONS FOR CONSERVATION, MANAGEMENT, AND FUTURE RESEARCH

Less than 14% of the historical 282,283 kilometer^2 (108,989 mile^2) longleaf pine-dominated forest remains in the southeastern United States (Noss 1989). Increasing conversion of longleaf pine forests for agriculture, timber plantation production, and urban needs (Ware et al. 1993) probably threatens the continued existence of many bird (Hunter et al. 1993), reptile, and amphibian species (Dodd 1995). Increased recognition of the importance of forest structure for ecosystem function and biodiversity has recently led many ecologists and foresters to recommend alternative management approaches for maintaining multiple values (such as commodity production, ecosystem function, etc.) in anthropogenic forested landscapes by controlling spatial structure and dynamics (Franklin and Forman 1987, Franklin 1993, Noss 1989, Hansen et al. 1993, Sharitz et al. 1992). Unfortunately, very little is known about the effects of specific forest structures on timber and non-timber values (Baskent and Jordan 1996).

This study represents an initial attempt to understand how one important game species, the northern bobwhite, responds to different landscape configurations in a longleaf pine-dominated ecosystem. Analyses of bobwhite covey sightings and activity areas in relation to habitat composition indicated higher than expected encounter rates for agricultural fields and food plots, as well as monthly and seasonal differences in encounter rates for other habitats. Landscape-level analyses of habitat composition and configuration in a forest-dominated landscape demonstrated increased bobwhite covey encounter rates with increasing amounts of agriculture (reaching an apparent peak at 30–35% agriculture). Results also indicated the importance of fewer large food plots with complex edge habitat for increasing bobwhite encounter rates, in contrast to many small [<0.1 hectares (0.25 acres)], well-dispersed food plots.

This study focused on hunter habitat selectivity as

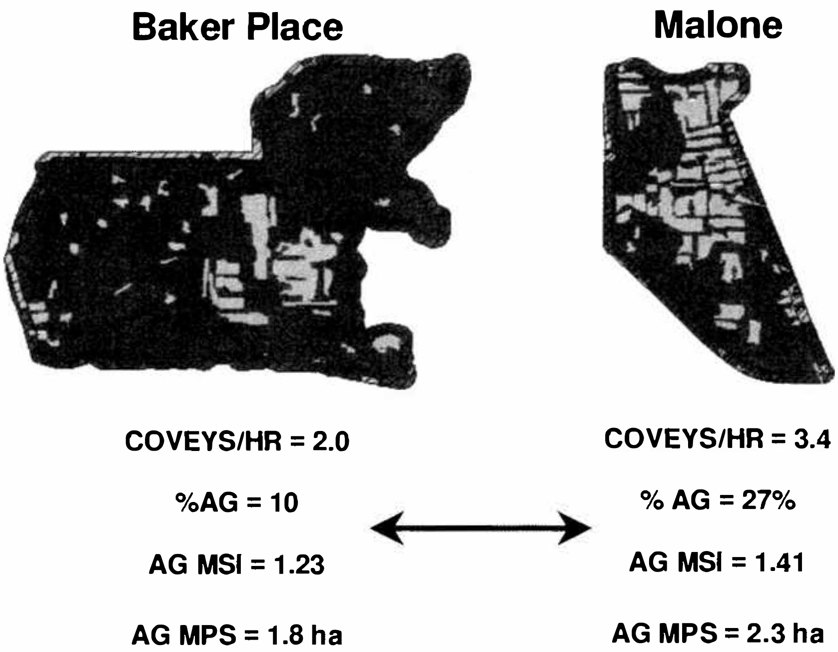

Fig. 4. Examples of landscape patterns associated with high and low bobwhite covey encounter rates.

well as landscape structure and other habitat features that may support bobwhite populations and facilitate bobwhite-hunting party encounter rates. In addition to managing landscape structure and composition, the importance of prescribed fire, harvest management, and field-woodland management in the longleaf pine ecosystem cannot be overemphasized; all are crucial for maintaining sustainable and harvestable bobwhite populations and providing essential nesting, brood, feeding, escape, loafing, and roosting habitats. For instance, prescribed burning in forested uplands promotes open savanna-like conditions, reduces hardwood encroachment and midstory canopy development, and produces habitats that support diverse wildlife communities, including northern bobwhite quail. Similarly, the weeds and insects associated with soil disturbance in fields at different times are critical for foraging by bobwhite quail and other species.

Additional analyses are underway to (1) characterize bobwhite food habits on a monthly and annual (hunting season) basis; (2) develop a spatially explicit model of bobwhite covey population dynamics in relation to landscape composition and structure; and (3) design and examine bobwhite population dynamics in response to landscape units differing in composition and structure. We anticipate that additional research throughout the range of the northern bobwhite quail will be necessary to identify optimal habitat composition (e.g., Schultz 1959) and configuration (e.g., Robel et al. 1974), as well as to document year-round responses by bobwhite populations, predators (e.g., Bowman and Harris 1980), and other species (e.g., neotropical migrants; Martin 1992). Future forest landscape management and restoration of the longleaf pine ecosystem in the Coastal Plain of the southeastern U.S. will ultimately depend to a large degree on understanding how we can: (1) design forested landscapes that can maintain an economic timber supply; (2) meet seasonal food and habitat requirements of bobwhite and other game species; and (3) support healthy, functioning pine ecosystems complete with endangered species, associated habitats, and other ecological amenities.

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MONTEZUMA QUAIL MANAGEMENT IN ARIZONA

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ABSTRACT

The Montezuma quail (*Cyrtonyx montezumae mearnsi*) has substantially different habitat requirements than other quails found in the U.S. They inhabit evergreen oak woodlands of mountain ranges in the Southwest and feed primarily on underground bulbs and tubers. Populations respond to summer precipitation because the vegetation which provides food and cover for Montezuma quail flourishes after the summer rains. Moderate to heavy grazing increases availability of Montezuma quail food plants, but resultant lack of cover precludes use of such sites. Montezuma quail avoid areas with greater than 50% forage utilization by ungulates. As with other Arizona quail species, hunting has been shown to have limited or no impact on the population level during the following years. Birds may be depleted in localized areas temporarily, but available habitat is re-occupied when pre-nesting dispersal occurs. Annual pre- and post-hunt flush counts were conducted 1988–1996 by the Arizona Game & Fish Department, United States Forest Service, volunteers, and local quail hunters. Average covey size decreased during the hunting season, but the magnitude of the decrease was similar in unhunted populations. Montezuma quail populations fluctuate in response to habitat and weather conditions. A state-wide hunter questionnaire program estimated total harvest trends for Arizona. In addition, wing collection barrels had been placed in heavily hunted areas from 1981 to 1996 to obtain hunter-effort information and sex/age characteristics of the harvest. Data from these wings indicate average percentage of juveniles in the harvest was higher for Montezuma quail ($\bar{x}$ = 74.4%, range = 55.9–84.9%) than other Arizona quail species, such as Gambel's ($\bar{x}$ = 65.6%, range = 23–77%). Hunters harvested an average of 2.2 Montezuma quail per day. In 3,107 hunter-days during this period, only 13 (0.4%) resulted in a limit of birds. Three of these limits occurred in 1996 when the bag limit was reduced from 15 to 8 Montezuma quail.

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INTRODUCTION

Montezuma (also known as Mearns', Fool, Harlequin, Massena) quail *(Cyrtonyx montezumae mearnsi)* are present in most of the mountain ranges in Mexico, southeastern Arizona, southwestern New Mexico, and southwestern Texas (Leopold and McCabe 1957, Johnsgard 1973, D. Brown 1989; Figures 1 and 2). The range of Montezuma quail overlaps almost entirely with evergreen oak woodlands from 3,500 to 5,500 feet elevation (1,077–1,692 meters), which in the United States is almost entirely National Forest land (Figure 3). Montezuma quail habitat is best described as an open woodland consisting of evergreen oaks (*Quercus spp.*) and junipers (*Juniperus spp.*). A perennial grass understory (<45% utilization by cattle) and tree cover greater than 20% are essential, because Montezuma quail rarely venture farther than 45 yards (41.5 meters) from the edge of the trees (R. Brown 1978).

At night, Montezuma quail roost on the ground in tall grass. They huddle close to conserve heat. The roost site varies each evening, but is generally on a hillside near habitat structure which provides additional thermal cover (Stromberg 1990). As the morning air begins to warm, the covey will leave the roost site and begin feeding in a close group. Foraging generally begins low on the slope in the morning and progresses uphill. Crops are generally full by late afternoon, when the quail work their way back down to the base of the slope to roost. Daily movements are typically very restricted with estimated covey use areas less than 15 acres (6 hectares; R. Brown 1976, Stromberg 1990).

Montezuma quail feed exclusively on the ground using long curved claws to scratch and dig for bulbs and tubers. Their annual diet is primarily (50–85%) bulbs from wood sorrel *(Oxalis amplifolia)* and flat sedge *(Cyperus rusbyi)*; the remainder is made up of seeds and insects (Bishop and Hungerford 1965, R. Brown 1978). Small depressions and scratches resulting from this digging behavior are common in Montezuma quail habitat, and provide evidence of recent habitat use (Leopold and McCabe 1957). Acorns become important during the years when they are abundant but are not a reliable food source every year. Although Montezuma quail occasionally drink water, they appear able to procure enough moisture in the foods they eat, and are apparently not dependent on free water (Leopold and McCabe 1957, Bishop 1964, D. Brown 1989).

The maintenance of grass cover over 6 inches (15 centimeters) in height is extremely important to this quail species because of its defensive behavior of hiding from predators. Montezuma quail are known for their habit of holding extremely tight in cover when approached (Leopold and McCabe 1957). It is easy to nearly step on these cryptic birds before they flush.

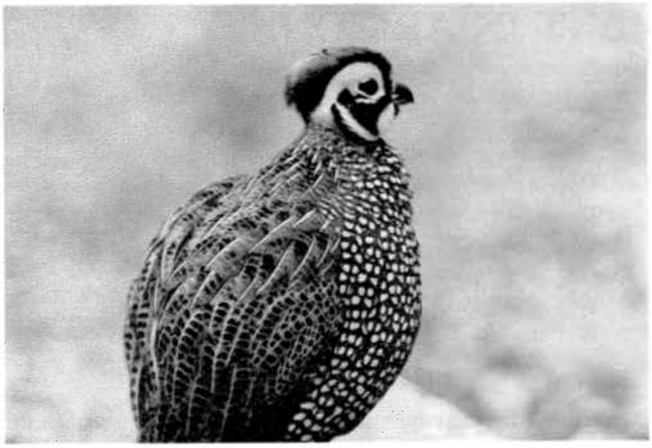

Fig. 1. Montezuma quail are as unique in habits as they are in plumage.

Fig. 2. Montezuma quail occupy steep areas, which affords protection from intense grazing and excessive exploitation by hunting.

Removing too much cover eliminates this bird's primary defense mechanism and thus probably decreases survival.

Montezuma quail initiate pair bonds during late February. Breeding normally begins in mid-June (Bishop 1964). Nesting starts in late June and young birds are hatched during August (Wallmo 1954, Bishop 1964). This reproductive timing coincides with the summer phase of southern Arizona's bimodal precipitation pattern. Summer "monsoon" storms normally begin during early July, and provide more than 60% of the annual precipitation. Nearly all of the plants Montezuma quail rely on for food and protective cover throughout the year grow in response to summer rains.

The notes of early explorers indicate Montezuma quail were probably more abundant and widespread at the time of settlement than today. During the 1940's and 1950's, interest in this little-known game bird increased. Some people questioned whether it might be numerous enough to offer a unique hunting opportunity, while others thought hunting might jeopardize its existence. In the 1930's, Arizona did not allow the collection of these birds for scientific purposes (Spaulding 1949).

In 1960, the Arizona Game and Fish Commission authorized an experimental 2-day Montezuma quail season in the Santa Rita Mountains, which resulted in the harvest of 45 quail (D. Brown 1989). The following 2 years, until 1963, a 9-day season was authorized. At that time, the season was opened statewide for 25 days (Bishop 1964). By 1965, the season included all of December and January, and 875 Montezuma quail were reported harvested. Today, the season runs from late November to early February and thousands of Montezuma quail are harvested annually.

POPULATION INFLUENCES

Precipitation Relationships

In southeastern Arizona, rainfall occurs in a bimodal distribution, with a peak during winter (November–March) and a larger peak in summer (June–September). Montezuma quail population fluctuations are highly correlated with the amount and timing of precipitation that occurs in the summer period (D. Brown 1979). The late-summer flush of food and cover must sustain them until the following summer, because perennial bunch grasses and other oak woodland vegetation do not respond substantially to precipitation during the winter months (Cable 1975). Furthermore, Leopold and McCabe (1957) observed that heavy winter snows suppressed populations because it created a barrier between the quail and their below ground foods.

R. Brown (1978) reported that average fall covey

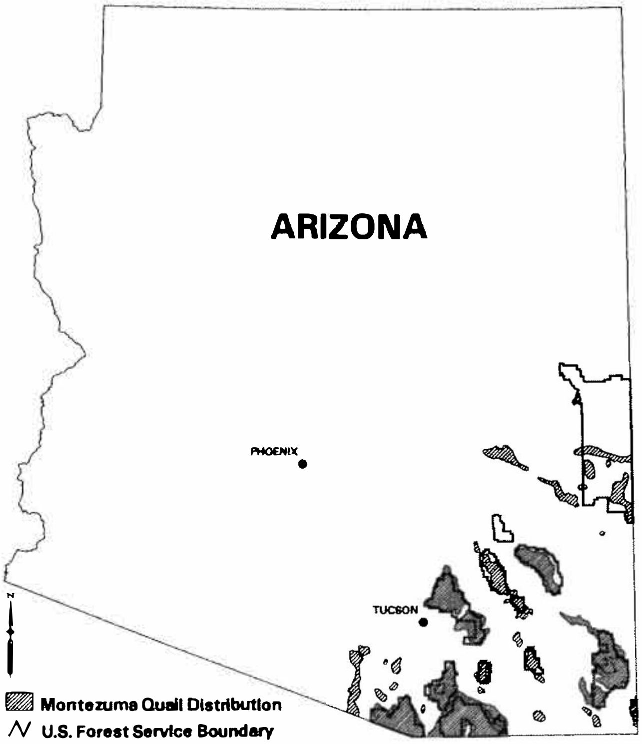

Fig. 3. Montezuma quail in Arizona inhabit the evergreen oak woodlands which occur almost exclusively on U. S. National Forest land.

size was significantly correlated with preceding June–September rainfall. He observed that egg laying normally began before the summer rains started, and the annual differences in reproductive success were most likely a function of differential survival of young quail. The production of the 2 most important Montezuma quail foods (wood sorrel and flat sedge) shows a positive correlation with rainfall during June–August (R. Brown 1978).

Wing envelopes mailed annually to Montezuma quail hunters were used to calculate trends in reproductive success from 1965 to 1977 (D. Brown 1979). Montezuma quail reproductive success was found to be positively correlated with summer precipitation. These data also suggested that precipitation during the previous summer was also important in determining population levels and accounted for 28% of the annual variation in hunting success (D. Brown 1979). This indicates survival may play a more important role in annual abundance than reproductive success during the current year.

Effects of Grazing

Since the perennial bunch grasses essential to Montezuma quail for year-round cover are strictly summer-growing species, any removal of grasses after the summer growing season (i.e., October) reduces the amount of cover available until the summer rains occur during the subsequent year. Much of Montezuma quail habitat is managed by the U.S. Forest Service under a mandate for multiple use. One of the many user groups of National Forest lands are ranchers who hold long-term leases on allotments for the purpose of grazing privately owned livestock. Under normal precipitation and light or moderate grazing levels, Montezuma quail typically have adequate cover to escape predators and satisfy their thermoregulatory needs.

Leopold and McCabe (1957) hypothesized that livestock grazing in Mexico was by far the most critical factor in regulating the numbers of Montezuma quail. R. Brown (1978) found a direct relationship between the percentage of grass used by cattle and Montezuma quail food production. Since most of the Montezuma quail diet consists of foods that grow below the ground, overgrazing after the summer growth period does not generally remove their primary source of food. In fact, the highest Montezuma quail food production is often found on the most heavily grazed areas. Heavy grazing seemingly increases the amount of Montezuma quail food available by removing grass competition and allowing bulb-producing forbs to flourish.

This increase in abundance of Montezuma quail food produced is, however, almost entirely offset by the resultant lack of cover. The abundant food resources in heavily grazed areas are virtually unused by Montezuma quail because of the lack of protective grass cover. R. Brown (1978, 1982) documented that grazing available forage in excess of 55% by weight can nearly eliminate local Montezuma quail populations. Ninety-five percent of the mated pairs counted during his study were found in areas having average utilization levels of 45% or less for their entire home range.

Thus, overgrazing limits the total amount of habitat available to breeding pairs and directly limits the size of the breeding population (R. Brown 1978). Dry summers with inadequate or delayed precipitation exacerbate the effects of grazing, because of the below-average production of herbaceous cover and the extension of the survival period with inadequate cover.

Effects of Hunting

Several studies have shown that hunter-caused mortality does not significantly affect the annual population fluctuations of Gambel's and scaled quail populations in Arizona (Gallizioli and Webb 1958, 1961; Gallizioli and Swank 1958; Gallizioli 1965). The steep topography and oak overstory occupied by Montezuma quail provide additional protection for the birds from hunters. Hunters often find it hard to get second (or even first) shots on a covey rise and have great difficulty observing where singles sift back into the grass. The Montezuma quail habit of holding tight further complicates efforts to relocate singles from a flushed covey.

Following extensive research on other Arizona quail species, the Arizona Game and Fish Department began 9 years of Montezuma quail research in 1967. As part of this research, 2 study areas 1,280–1,600 acres (518–648 hectares) were established in the most heavily hunted areas of the state. During the next 6 years, livestock grazing intensity, rainfall patterns, and Montezuma quail population levels were closely monitored on both areas. As predicted, (R. Brown 1969, Yeager 1966, Gallizioli 1967), it was apparent that climatic effects and subsequent changes in food production, rather that the relatively intensive harvest (annual harvest rates ranged from 31–75%), were largely responsible for population changes (R. Brown 1971, 1973, 1975, 1977, unpublished data). R. L. Brown (Arizona Game and Fish Department, unpublished data) reported that annual mortality rates between hunted and non-hunted areas were not different.

The bag limit was reduced from 15 to 10 birds per day for a portion of this study (1970–72), but this did not appreciably reduce the percentage of the population removed during the hunt (R. Brown 1977). An increase in season length during this period also did not result in excessive harvest.

SURVEY DATA

Montezuma quail have proved a difficult bird to survey because of the steep topography and diverse habitat they occupy. In addition, they do not call in a consistent manner, and they are reluctant to flush from cover.

Early attempts to locate coveys were made by playing audio tapes of a calling female (Bishop 1964, Levy et al. 1966). Males consistently answered calls, but only during the period when hens were sitting on the nests (June 15–July 20). This provided a crude method for locating coveys and calculating an index of the number of breeding pairs on the study area.

R. Brown (1976) investigated an extensive array of possible survey techniques. Attempts to calculate a Mark-Recapture (Lincoln) Index were unsuccessful because he could not capture a sufficient number of birds. An intensive investigation of the use of recorded calls (call counts) was disappointing, with only 43 responses in 2,690 minutes of censussing (39.3 minutes per response, R. Brown 1976). It was estimated that between 0 and 50% of the resident males responded during the sampling period.

Diggings within belt transects were recorded and mapped in an attempt to delineate covey home ranges. This was found to be valuable as a supplement to other census methods, but problems of accurately identifying and interpreting quail diggings in areas of high rodent populations confound this census technique (R. Brown 1976).

R. Brown (1976) determined that the most accurate method for determining distribution and habitat use of Montezuma quail was repeated use of pointing dogs to locate and map covey home ranges. After sufficient time afield in a 2.5-mi^2 (6.5-km^2) study area, he was able to reliably estimate the number of coveys present. By multiplying this figure by the average covey size, he calculated a population estimate. The method appeared to be accurate when the pre-hunt to post-hunt population change was compared to the known harvest of birds from the area. The obvious disadvantage of this method is that field effort required to obtain a reliable population estimate exceeds available personnel resources.

Holdermann (1992) located coveys with the aid of pointing dogs to document occurrence, distribution, habitat use, and relative abundance among different locations in New Mexico. The number of minutes spent searching per covey served as an index to relative abundance. This method provided relative abundance data, but was not subjected to statistical analysis to determine the confidence intervals surrounding these relative differences.

Currently, the Arizona Game and Fish Department coordinates volunteers to conduct pre-hunt and post-hunt flush counts to index changes in the population on the most heavily hunted area of the state (Santa Rita Mountains). Flush counts have been conducted during the weekend before the Montezuma quail season opens and during the weekend after it closes, 1988–1997. Volunteers consist mostly of experienced Montezuma quail hunters and their dogs, although there is variation in the number and quality of dogs. Survey teams consisting of 1–3 dogs and 1–4 people follow a standard route plotted on topographic maps and work the area as if they are hunting. The routes are approximately 1 mile (1.6 km) up the wide, flat-bottomed canyons in typical Montezuma quail habitat. Survey crews work the area where the base of the canyon slope meets the bottom along the canyon and return to the starting point by following the other side of the canyon bottom.

Table 1. Results of pre- and post-hunt flush counts in Hog and Gardner canyons, Santa Rita Mountains, Arizona, 1988–1996.

	Pre-hunt counts			Post-hunt counts		
Year	No. of coveys	No. of birds	Mean covey size	No. of coveys	No. of birds	Mean covey size
1988–89	26	220	8.5	12	50	4.2
1989–90	13	82	6.3	2	7	3.5
1990–91	9	46	5.1	12	37	3.1
1991–92	30	257	8.6	11	40	3.6
1992–93	11	86	7.8	12	47	3.9
1993–94	7	43	6.1	11	38	3.5
1994–95	8	45	5.6	3[a]	11[a]	3.7
1995–96	9	57	6.3	3	9	3
1996–97	3	7	2.3	4	20	5
1988–96 Mean	12.9	93.7	7.3	7.8	28.8	3.7

[a] One of 5 routes could not be run because canyon was washed out.

When a dog goes on point, observers get in position to see and classify the birds as the covey flushes. Male Montezuma quail are easily distinguished by the black rump observable as the covey flushes. An effort is made to maintain consistency in the number of people and dogs on each route from year to year, as well as how intensively the canyon is covered. Due to variation in the number and quality of participants, a high degree of consistency is not always possible.

The sex ratio and number of birds in the covey are recorded on a data sheet and the location is plotted on a topographic map. These data allow the monitoring of trends in average covey size, number of birds seen, and number of coveys flushed (Table 1). Variations in scent conditions, quality of dogs, area covered by dogs, number of dogs per observers, ambient temperature, and humidity, can potentially confound the number of birds and coveys flushed per route. Average covey size, however, is independent of these conditions as long as the entire covey is flushed and counted accurately.

These data are not used directly to set seasons or bag limits, but are useful to predict the relative hunt success in the upcoming season, and monitor large scale changes and trends in the population. Such data are useful for making land use and management decisions. The process of getting Arizona Game and Fish Department biologists, U.S. Forest Service biologists, quail hunters, and local residents together in Montezuma quail habitat twice a year to look at and talk about quail management, and land use practices, is probably the most valuable aspect of this program.

Average covey sizes determined by flush counts conducted in 1988–1996 ranged from 2.3 to 8.6 for pre-hunt ($\bar{x}$ = 7.3) and 3.0–5.0 ($\bar{x}$ = 3.7) for post-hunt surveys (Table 1, Figure 4). These estimates are similar to average covey sizes reported in the literature (Leopold and McCabe 1957, Yeager 1967, R. Brown 1978, Stromberg 1990, Holderman 1992). The reduction in average covey size from the pre- to the post-hunt surveys parallels natural attrition reported in unhunted populations (Stromberg 1990, Holderman 1992).

Multiple regression analysis of average pre-hunt

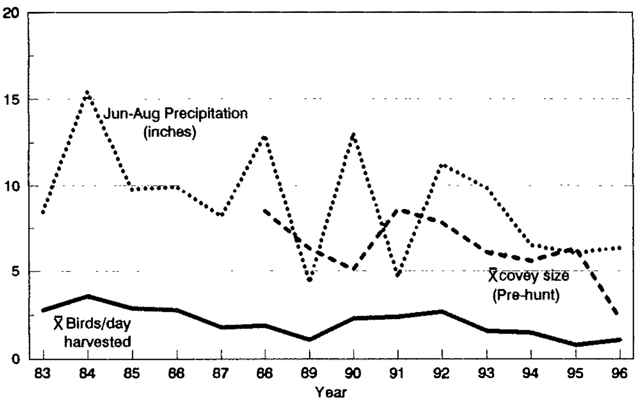

Fig. 4. Mean number of Montezuma quail harvested per day, mean covey size, and summer precipitation from flush counts and wing barrels, southeastern Arizona, 1983–1996.

Table 2. Montezuma quail harvest data gathered from post-season statewide hunter questionnaire mailed to sample of small game hunters, 1969–1995.

Year	Total Arizona quail hunters[a]	Total Montezuma quail harvested
1969–70	63644	6000
1970–71	59497	9836
1971–72	46092	9460
1972–73	41730	28835
1973–74	63009	42308
1974–75	65163	29469
1975–76	74511	41568
1976–77	73735	45418
1977–78	66702	32849
1978–79	78142	51719
1979–80	95814	80702
1980–81	92949	no data
1981–82	84322	no data
1982–83	78428	no data
1983–84	71772	no data
1984–85	71208	no data
1985–86	75806	no data
1986–87	77754	no data
1987–88	65111	17447
1988–89	55828	14670
1989–90	45143	17007
1990–91	43924	21772
1991–92	54868	33068
1992–93	64021	43101
1993–94	74716	27482
1994–95	73108	24320
1995–96	63060	20055
1969–95 Mean	67410	29854

[a] This includes all quail hunters, only a portion of which hunt Montezuma quail.

covey size and precipitation totals for the preceding summer and the previous summer were not significant ($R^2<0.32$, $P>0.16$). A simple linear regression of average pre-hunt covey size and the total precipitation in last 2 summers combined was also not significant ($r^2<0.30$, $P>0.12$). This is counter-intuitive since coveys are primarily family units (R. Brown 1978) and abundant rainfall during the summer months should result in higher reproduction and lower mortality. This may suggest that the factors influencing population fluctuations are more complex than a simple model using summer rainfall. Alternatively, the lack of a statistically significant relationship could be a function of low sample sizes.

HARVEST DATA

A statewide hunter questionnaire is mailed to a random sample of small game hunters in Arizona after each hunting season. This questionnaire provides an estimate of the number of hunters pursuing quail, the number of birds harvested, and average daily bag (birds/hunt-day). Because only a small proportion of the questionnaire respondents actually hunt Montezuma quail, extrapolation of these harvest data must be viewed with caution. However, questionnaire data show annual fluctuations in number of hunters and Montezuma quail harvested. These fluctuations generally follow the habitat-induced variations in abundance (Table 2).

Wing collection barrels are erected beside roads which provide access to the most heavily hunted Montezuma quail habitat. Four barrels have been placed in consistent locations for 9 years (1988–1996). Each barrel is fitted with a weather-proof box containing wing envelopes. Each envelope has a short hunter questionnaire printed on it. A sign encourages hunters to complete the questions and place one wing from each bird harvested in the envelope and to deposit the envelope in the wing barrel. At the end of the season, data are tabulated from the questions on the envelopes and the sex/age of wings contained therein recorded for that hunting party. These data are used to identify trends in variables such as the reproductive success (percent juveniles), birds harvested per day and hour, success with and without dogs, wounding loss, and bag limits attained (Table 3).

The average number of birds harvested per day estimated by the wing barrel data for the period 1983–1996 ranged from 0.8 to 3.6 ($\bar{x}$ = 2.2). Hunters averaged 0.50 birds harvested per hour of hunting effort during that same period (Table 3). Out of 3,107 hunter-days recorded at wing barrels from 1983–1996, only 13 (0.4%) resulted in a limit of birds. Reproductive success averaged 74.4% juveniles during the period 1984–1996.

Multiple regression analysis did not detect a significant relationship between the reproductive success (percent juveniles) and precipitation totals for the preceding summer ($R^2<0.37$, $P>0.13$). The average number of birds harvested per day was related to the total amount of precipitation in the preceding summer ($R^2 = 0.51$, $P<0.01$), but not the previous summer ($P>0.10$). The regression of average birds/day against the combined total precipitation in the preceding and previous summers, showed a weaker, but still significant, relationship ($P<0.02$). The combined precipitation of the previous two summers explained less of the variation in average birds/day ($R^2 = 0.38$) than the preceding summer alone.

Reproductive success as measured by percent ju-

Table 3. Harvest data gathered by voluntary wing barrels in Montezuma quail habitat, Santa Rita and Patagonia Mountains, Arizona, 1983–1996.

Year	Hunter-days reported	Mean birds/day	Mean birds/hour	Limits reported	% juvenile
1983–84	144	2.8	0.45	0	83.7
1984–85	277	3.6	0.8	0	80.9
1985–86	367	2.9	0.71	2	68.5
1986–87	181	2.8	0.51	0	69.4
1987–88	188	1.8	0.43	0	71.5
1988–89	331	1.9	0.42	1	82.1
1989–90	213	1.1	0.27	0	56.9
1990–91	232	2.3	0.56	3	79.8
1991–92	319	2.4	0.52	2	75.6
1992–93	257	2.7	0.59	1	78.3
1993–94	172	1.6	0.34	0	72.9
1994–95	133	1.5	0.34	1	45.6
1995–96	150	0.8	0.19	0	75.3
1996–97	143	1.1	0.22	3[a]	75.2
1985–96 Mean	224	2.2[b]	0.50[b]	1.1	74.4[c]
1985–96 Total	3,107			13	

[a] Bag limit reduced from 15 to 8 in 1996.

[b] Based on 6,550 birds, 13,221 hunter-hours, and 2963 hunter-days, 1984–1996.

[c] Based on 4,268 juvenile and 1,468 adult birds aged during the period 1984–1996.

veniles in the harvest was not correlated with pre-hunt covey size ($P = 0.62$) or average birds harvested per day ($P = 0.15$). These results seem counter-intuitive, but may be an artifact of small sample sizes and lack of robust data. Average pre-hunt covey size was not correlated with average birds harvested per day during the hunt ($P = 0.146$), which may indicate the number of coveys is more important in influencing hunter success than the number of individuals per covey.

DISCUSSION

Precipitation patterns in the Southwest are extremely erratic. This results in large annual fluctuations in the amount of Montezuma quail food available and also the cover necessary for the birds to exploit those resources. These unstable food and cover resources influence reproduction and survival of adult birds.

In addition to the total amount of rainfall during this summer period, the timing of the precipitation is also important. Short duration, heavy rainfall events are less beneficial than long duration, light rainfall events. Also, if rainfall is delayed until late in the summer period, vegetation has less time to respond before cool weather and shorter day length slows growth.

Periods of low or poorly timed rainfall are exacerbated by the detrimental effects of inappropriate grazing. When minimal vegetation growth occurs during the summer period, grazing only 30% of the biomass may not leave sufficient residual vegetation to meet the cover requirements of Montezuma quail through the following summer. Even grazing at levels less than 40% during one year may cumulatively result in inadequate cover the following year, if summer precipitation is lacking during the second year (D. Brown 1978).

In exceedingly dry summers when grass production is negligible, any grazing in Montezuma quail habitat is likely to be detrimental to the population. Ranchers have long-term grazing agreements for their allotment. Should the U.S. Department of Agriculture, Forest Service require the rancher to remove all cattle from his grazing allotment and find other means of income until adequate summer rains return? This issue is probably the major challenge facing Montezuma quail managers and land management agencies in the Southwest. Unfortunately, there are no easy answers. Most importantly, Montezuma quail management requires proper range management and flexibility in grazing plans to eliminate range overuse during dry years.

The U.S. Forest Service established interim Montezuma quail grazing management guidelines in 1986. These guidelines were to: (1) identify and map Montezuma quail habitat, (2) allow grazing utilization levels of 35–40% in Montezuma quail habitat, and (3) retain an average residual stubble height of 6 inches (15.2 cm). Efforts to determine an effective method for measuring stubble height in the steep, sparse bunch grass community have been largely unsuccessful. Montezuma quail habitat has been mapped, but funding to support the U.S. Department of Agriculture, Forest Service range staff necessary for adequate monitoring has been lacking in recent years. This problem is only getting worse; the U.S. Forest Service's range management budget has been cut drastically in the last 2 years. As a result, interim guidelines cannot be enforced and monitoring is lacking on many allotments.

"Managing" quail during periods of adequate rainfall is easy. However, when a series of dry summers happens, some individuals become interested in restricting hunter harvest to ameliorate the Montezuma quail population declines. Suggestions to reduce seasons and bag limits frequently ensue.

Much of this concern stems from the fact that intensive, localized shooting can eliminate quail from easily-accessible canyon bottoms until pre-breeding dispersal repopulates vacant habitat (R. Brown, Arizona Game and Fish Department, personal communication). Drastically reduced season lengths have the potential to reduce total quail harvest moderately, but data show reductions in bag limits will have little effect (Engel-Wilson 1995).

Using data from the 1968–69 hunt in Gardner Canyon in the Santa Rita Mountains, R. Brown (unpublished data) estimated that a reduction of the bag limit from 15 to 10 would only result in a 5% decrease in total harvest. In spite of this, during 1970, the statewide bag limit was reduced to 10 because of concerns of overharvest. In 1973, the bag limit was restored to 15 birds. Data from the hunted portion of the study area showed that the highest harvest during the study actually occurred when the bag limit was 10 and the season length was 62 days. The lowest harvest was recorded during the 77-day hunting season with a bag limit of 15 (R. Brown, Arizona Game and Fish Department, unpublished data).

Furthermore, wing data indicate the average daily bag is 2.2 birds. Less than half of 1% of the hunter-days recorded in wing barrels from 1983–1996 resulted in a limit (15 birds). Data summarized from the hunter questionnaire program indicate that a reduction in bag limit from 15 to 8 would have reduced the total Montezuma quail harvest by only 6% and 0% in 1992 and 1994, respectively (Engel-Wilson 1995). Over 90% of the Montezuma quail hunters took less than 7 and 4 birds per day in 1992 and 1994, respectively.

During 1996, the statewide bag limit was reduced to 8 birds per day. Arizona historically has had an aggregate bag limit for all 3 species of quail, allowing hunters to harvest up to 15 total quail of any species. Lowering the bag limit of only 1 of 3 quail species forced the Arizona Game and Fish Department to require that hunters retain evidence of legality by leaving one fully feathered wing, head, or foot attached to all quail until they reach their home.

A majority of the opinions expressed by the hunters at public meetings, at regional open house, and at the commission meeting were opposition to the 1996 reduction in the bag limit for several reasons. During years of abundant summer rainfall and high quail densities, recreational opportunity is limited unnecessarily by reduced bag limits. In dry years with low quail densities and small covey sizes, birds are exceedingly difficult to locate because of the nature of the habitat and their behavior. Also, the law of diminishing returns causes many hunters to pursue other small game that are more abundant and provide more recreation per unit of time expended, or devote more time to other recreational pursuits (Figure 5). The total number of hunter-days recorded with wing barrels was positively correlated with the average pre-hunt covey size ($P<0.02$).

Future management needs include improving methods of indexing Montezuma quail populations and sampling Montezuma quail hunters. Future research should include Montezuma quail movements in relation to varying cattle grazing intensities. Management may be improved with an increased awareness of the optimal size, shape, timing, and juxtaposition of grazed areas within various topographic and vegetative components of Montezuma quail habitat. Current research is focussing on: (1) indexing Montezuma quail populations; (2) determining effects of hunting; (3) determining effects of grazing; and (4) documenting hunter demographics.

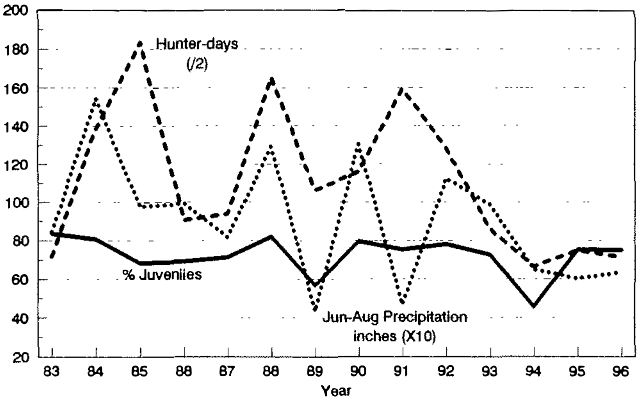

Fig. 5. Summer precipitation, hunter effort, and reproductive success of Montezuma quail based on information collected with wing barrels, southeastern Arizona, 1983–1996.

Good Montezuma quail management is essentially good livestock management. Although we can not predict or manage summer rainfall, managing the range properly to protect the health and integrity of the grass species will maintain the required elements for abundant Montezuma quail.

ACKNOWLEDGMENTS

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QUAILS IN MEXICO: NEEDS AND OPPORTUNITIES

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ABSTRACT

Recently, McGowan et al. (1995) completed a worldwide conservation strategy for all species of partridges, quails, and francolins. They identified priority species and projects for the next 5 years. Mexico was identified as a critical country in Latin America because of the presence of a large number of species of quails (15) and presence of several species and one subspecies which received conservation status; the bearded tree-partridge (*Dendrortyx barbatus*), ocellated quail (*Cyronyx ocellatus*) and masked bobwhite (*Colinus virginianus ridgwayi*). We are presently undertaking research and conservation efforts on the critically endangered bearded tree-partridge and use this to highlight concerns and opportunities related to quails in Mexico. This program includes local educational programs advertising the plight of this species, development of survey techniques, collection of life history data, and a complete survey of distribution of the species. From our efforts so far, we have found that local involvement and interest in rural communities is possible. We are finding that techniques, such as play-back of tape recorded calls, show great potential for both census and surveys of the bearded tree-partridge. Finally, we are finding that lack of basic life history and population data of these species can result in misguided development of conservation strategies.

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INTRODUCTION

The New World quails range from southern Canada through Central America to Bolivia and Argentina (Carroll 1995). It is believed that the New World quails probably evolved in the vicinity of southern Mexico because the greatest diversity of genera and species occurs in this geographic region (Carroll 1995). However, there is a profound lack of information on taxonomic status, distribution, biology, and conservation status of most species of quail that inhabit Mexico (Carroll et al. 1995, McGowan et al. 1995). This is unfortunate because many species are harvested whether they are common or rare, and all are subject to threat of habitat destruction.

Mexican quails deserve a much higher profile in international conservation efforts. Increasing the amount of attention directed at quails in Mexico provides an opportunity to develop closer ties between U.S. wildlife biologists and Mexican biologists. This has begun, in part, through cooperative efforts for masked bobwhite *Colinus virginianus ridgwayi* population recovery (Kuvlesky et al. *this volume*) and the conservation program for the bearded tree-partridge described here.

STATUS AND NEEDS

The status of many quails in Mexico is difficult to assess, because of the poor state of knowledge about their biology, and the limited data on their distributions and/or populations (Carroll et al. 1995). This includes even basic techniques for accurately censussing these species. Based on limited data, Carroll et al. (1994) determined that the bearded tree-partridge, ocellated quail, masked bobwhite, and possibly the southern Mexican subspecies of the Montezuma quail *Cyrtonyx montezumae sallei* deserve the highest conservation priority.

The bearded tree-partridge has been given the highest conservation priority of all quails in Mexico because of: (1) historically small distribution; (2) potentially low and isolated populations; (3) proximity to high human populations; (4) deforestation in its historic geographic range.

BEARDED TREE-PARTRIDGE: CASE STUDY

The distribution of the bearded tree-partridge is centered on the State of Veracruz, Mexico. There are additional, isolated populations in the adjoining states of Hidalgo, Queretaro, and possibly Puebla and San Luis Potosi as well (Figure 1). Until this present work, very little information was available on the conservation status of this species, other than some surveys by Leopold (1959) and Johnsgard (1973) and anecdotal observations from Howell and Webb (1992). It is known that there has been a great deal of human impact and deforestation of the montane habitats of the bearded tree-partridge in this part of Mexico. Many of the sites where the species was formerly found have

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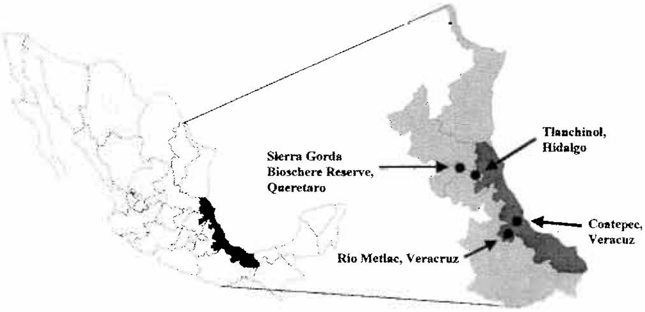

Fig. 1. State of Veracruz in Mexico (shaded). Individual locations show known populations of bearded tree-partridge in 1997 (This study, Garcia et al. 1993).

been impacted to the point that there is little chance that the bearded tree-partridge is still present. In addition, there are potential threats due to the rapidly increasing human population in Mexico and the resulting conversion of forest to agricultural purposes (Carroll et al. 1994). Local farmers and hunters take this species for food. Sport hunters from the city also bag an unknown number of individuals. Recently, some local farmers have poisoned bearded tree-partridges because of depredation of bean crops in the mountains (S. Aguilar, personal communication).

In 1995, we knew of only one population that seemed to be persisting in remnant forests in Veracruz. Therefore we developed a cooperative project based on a study area near Coatepec, Veracruz. This program attempted to address the problems of the bearded tree-partridge on a number of levels: (1) using the local biologists we developed survey and habitat analysis techniques on the Coatepec Study Area; (2) we began collecting information on radio-tagged individuals in order to obtain much more specific life history data. Information on nesting and brood rearing as well as food habits and survival are lacking for this species; (3) we began to use the play-back techniques developed at Coatepec to survey and map the distribution of the species in Veracruz State and adjoining states; (4) education efforts began with production of additional caps and shirts with a conservation message, and we also produced a poster identifying the bearded tree-partridge as an important species. Several billboards were erected in the area around Coatepec; (5) local contacts petitioned the Governor of Veracruz to establish the bearded tree-partridge as the State Bird.

Preliminary results on the Coatepec study area suggest that the play-back census techniques can be useful for locating populations of bearded tree-partridge, but that timing during the year is crucial to make sure that the birds will respond (J.C. Eitniear, S. Aguilar, J.P. Carroll, and J.T. Baccus, unpublished data). Unfortunately, bearded tree-partridge populations are low and isolated. These problems hamper development and testing of play census techniques. Development of statistical inference is difficult when dealing with only a few dozen birds on a patch of forest only a few hundred hectares in size.

Observations of birds made during surveys, along with subsequent radio-telemetry data suggest that the birds can tolerate habitats other than primary forest. Traditional shade coffee grown throughout the study area appears to be used regularly by bearded tree-partridges. Population surveys suggest that there are about 12 to 15 individuals on the study area.

Although bearded tree-partridge populations appear to be small and fragmented, they still occur in much of their recorded historical distribution. A recent survey completed by J.E. Eitnier et al. documented additional populations further north and west of the historical distribution. Therefore, human impact on the bearded tree-partridge is still difficult to judge. Within a year at Coatepec we went from being relatively confident about the short-term survival of the species to having much more concern. Conversion from the predominantly shade coffee to more plantation (sun) coffee varieties could dramatically change the landscape and potential habitat for this species. A short plane ride over the study area in May 1996 revealed large numbers of new sun coffee fields being cleared.

However, the bearded tree-partridge populations found in Hidalgo and Queretaro appears to be located in much more remote habitats and might be more secure because the habitat is owned by the local municipality or located in the Sierra Gorda Biosphere Reserve.

OPPORTUNITIES

The most important areas for research and conservation efforts for quails in Mexico should be directed towards those species that have some kind of conservation status. So far, much of the emphasis has been on species with limited distribution, but there are many subspecies and populations of common species such as the northern bobwhite (*Colinus virginianus*), for which we know very little and could also be threatened (Brennan 1999). Other species such as the elegant quail (*Callipepla douglasii*) or barred quail (*Philortyx fasciatus*) are not thought to be threatened and may be common, but we know little of their biology. Both species are endemic to Mexico.

Mexico has a long history of sport hunting by both residents and foreigners. Regulation of bird hunting has been highly variable. Poaching of species such as the bearded tree-partridge is known to occur. Common species offer the opportunity for sustainable management in some circumstances.

Any conservation or research effort on these species must include local collaboration and support. We have worked with two different nongovernmental organizations, Pronatura Veracruz and Grupo Ecologico Sierra Gorda, without whom little progress on the bearded tree-partridge project could have been made. However, the collaborative relationship must be flexible to deal with the particular strengths and weaknesses of local cooperators.

SUMMARY

There are many potential problems facing the quails of Mexico. Many of these problems are high-lighted by the plight of the bearded tree-partridge. Our efforts in Mexico represent the kinds of fundamental efforts needed to conserve this species. These efforts have only just been started. Mexico has a number of endemic species that represent the center of the evolution of the New World Quails. Mexico and its quails deserve much greater support and attention than they have received to date.

ACKNOWLEDGMENTS

A large number of people are involved in this project on many levels. S. Aguilar has been coordinating much of the effort in Veracruz. P. Mota has provided a great deal of local natural history expertise and shared his knowledge of the bearded tree-partridge. J. Baccus is providing logistical and research advice. Alvaro Aragon Tapig is coordinating field efforts in Hidalgo and Queretaro. Funding has been provided by the P. van Vlissingen Foundation, Prince Bernhard Nature Trust, Chicago Zoological Society, World Pheasant Association, and Southwest Texas State University Faculty Grant Program.

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HISTORIC DISTRIBUTION OF MOUNTAIN QUAIL IN THE PACIFIC NORTHWEST

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ABSTRACT

Mountain quail (*Oreortyx pictus*) are among the least studied of the North American quails. The prehistoric and early historic distributions of this bird are uncertain. In the Pacific Northwest, mountain quail were first recorded by Lewis and Clark in 1806 near the Columbia River adjacent to the Cascade Range in Oregon. Written evidence relating to the original distribution of mountain quail in this area indicated that the birds were found from the Oregon Coast Range to the Cascades along the Columbia River and southward. Translocations of birds into this region began in 1860 and continued for several decades, which further confused the historic status. Eventually, mountain quail were distributed from southern British Columbia throughout Washington and into western Idaho and eastern Oregon by the early 20th century. Archeological evidence revealed it is possible that mountain quail existed in west-central Idaho, likely as refugia populations, 700 to 1000 years ago. Populations in Idaho and the interior Columbia River Basin have declined substantially during the past several decades. Similar declines have not been observed in the Pacific Northwest (western Oregon) or in the humid coastal region of western California.

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INTRODUCTION

Mountain quail (*Oreortyx pictus*) currently range from extreme southwestern British Columbia south to Baja and eastward to Idaho and Nevada (Johnsgard 1973:345–347). Although introductions have been made in the southern portion of their range (Linsdale 1951), most translocations took place in northerly areas, such as British Columbia (Guiguet 1955), Washington (Dawson and Bowles 1909:564–568), Idaho (McLean 1930, Bent 1932:42–43), and Oregon (Baird et al. 1874, Aldrich and Duvall 1955). There are numerous written sources of information about the range of mountain quail in the Pacific Northwest, which begin with the notes of Lewis and Clark in 1806 (see Strong and Strong 1995:270). The history of translocations of this species dates to the mid-19th century (Cooper 1860, Baird et al. 1874, Merrill 1898, Guiguet 1955). Nevertheless, much of the information from the 1800's is anecdotal. Because of the relatively long history of translocations, the native, recent range of mountain quail in the Pacific Northwest (defined herein as British Columbia, Idaho, Oregon, and Washington, all north of 42° north latitude) is unclear.

The objective of this paper was to compile historic information from a 200 year (1800–2000) period, and use this information to clarify the native and introduced ranges of this species in the Pacific Northwest.

Early Historic Distribution

The earliest written comment relating to mountain quail in the Pacific Northwest is from the journals of Lewis and Clark (Strong and Strong 1995:270) for 1806 wherein this species is first noted at "The Breakers" (near what is now known as Rooster Rock State Park in Multnomah County) in Oregon, situated 30 km east of Portland (Figure 1). Subsequently, Douglas (1829:143), who obtained a specimen from the Umpqua drainage in Douglas County, Oregon in 1829, commented that the range of mountain quail extended northward to near 45° north latitude within a few miles of the Columbia River. Audubon (1844:69–70) recounted information from J. K. Townsend that indicated mountain quail were found in dense woodland habitats from the tributaries of the Columbia River south through the Willamette Valley to California. Further, he stated that Townsend considered these birds rare and that he had not actually observed any during his travels throughout Oregon. A specimen of an albinotic bird, now in the National Museum in Washington, D.C., was taken in November 1860 in the Willamette Valley near the area of Mount Hood (see Crawford 1978).

Translocations During the 19th Century

Translocations of mountain quail in the Pacific Northwest began as early as 1860 (Cooper 1860). Suckley (in Cooper 1860:225) stated that all mountain quail in the Willamette Valley of Oregon resulted from introductions (Figure 2). The extensive grasslands of the Willamette Valley in prehistoric times (Franklin and Dyrness 1973:120) may not have provided suitable habitat. Translocations of birds into British Columbia began during the 1870's (Guiguet 1955) with populations established eventually on Vancouver Island and in the Fraser Valley (Bent 1932:42–43). Without citing a source, the American Ornithologists' Union (1957:144) noted that mountain quail were probably native to Vancouver Island. Dawson and Bowles (1909:564–568) commented that mountain

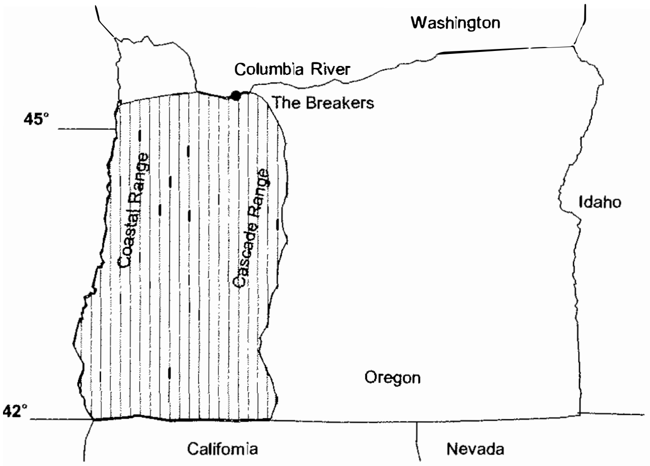

Fig. 1. Early historical distribution of mountain quail in the Pacific Northwest (from Lewis and Clark in Strong and Strong 1995, Douglas 1829, Audubon 1844), showed by hatched area.

Fig. 2. Locations of early records of mountain quail in Oregon, (from Suckley in Cooper 1860; Anthony 1911,1912), sites of translocations of mountain quail in Washington and British Columbia (from Dawson and Bowles 1909, McLean 1930, Bent 1932, Guiguet 1955), translocations of mountain quail (from Merrill 1898, Wyman 1912, Phillips 1928) and locations of archeological evidence of mountain quail (from Gruhn 1961, Murphey 1991) in Idaho.

quail, perhaps, were indigenous to a portion of Washington and then, confusingly, went on to state that mountain quail were not native to Washington and that the distribution of birds in the state at that time (Figure 2) resulted from repeated introductions of birds from California between 1880 and 1890. Jewett et al. (1953: 225–227) commented about extensive transplants of mountain quail in Washington, and Taylor (1923) noted that mountain quail were repeatedly translocated into various places in Washington. McLean (1930) noted these transplants took place in both western and southeastern Washington and made a vague reference to mountain quail possibly being indigenous to the southwestern portion of the state. Bent (1932:42) noted that quail were introduced to Whidbey Island, San Juan Island, and elsewhere in Washington. Johnsgard (1973:347) commented that the birds translocated into Washington apparently were *O. p. palmeri,* but Jewett et al. (1953:225–227) indicated multiple sources of birds from several races were introduced, which resulted in racial mixing.

Mountain quail also were translocated successfully into Idaho where populations were established during the 1800's; for example, Merrill (1898) stated that 10 pairs were obtained from the Puget Sound area and released near Mica Peak in Kootenai County in 1897 (Figure 2). Introductions took place near Nampa (Ada County), Silver City (70 km south of Nampa) in Owyhee County, and near Shoshone in Lincoln County (Phillips 1928). McLean (1930) likewise noted introductions of mountain quail into Idaho.

Late Historic Distribution

Naturalists, biologists, and others published reports on the distribution of mountain quail (Figure 3) during the early part of the 20th century that provide insight into mountain quail distribution in relation to earlier records. In Washington, Dawson and Bowles (1909:564–568) commented that the birds were rather broadly distributed by the early 20th century. An early mention of mountain quail in eastern Oregon was made by Ridgway (1896:191) in the late 1800's. Anthony (1911) noted the appearance of 12 mountain quail near Vale, Malheur County, Oregon and suggested that their presence was accounted for by severe winter weather that year. Anthony (1911) commented that the nearest known population resided in the Burnt River Mountains (Figure 2), approximately 120 km northwest of Vale. Subsequently, Anthony (1912) reported the occurrence of mountain quail along Bully

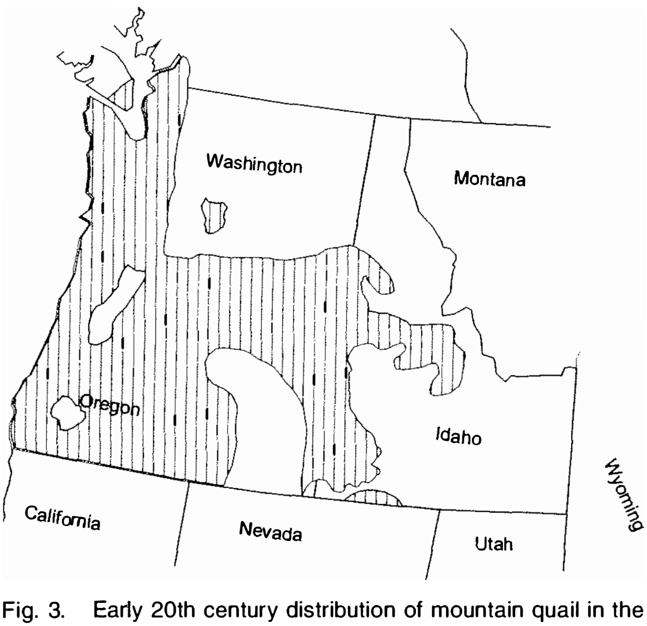

Fig. 3. Early 20th century distribution of mountain quail in the Pacific Northwest (from McLean 1930, Bent 1932, Guiguet 1955).

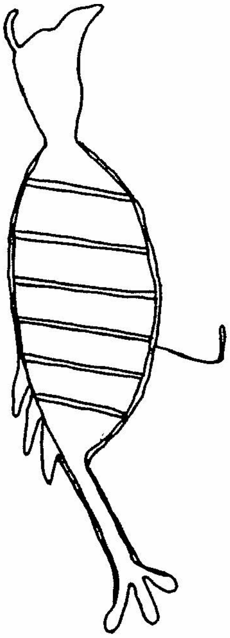

Fig. 4. Pictograph of gallinaceous bird resembling a mountain quail from approximately 800 to 1000 years ago (redrawn from Murphey 1991).

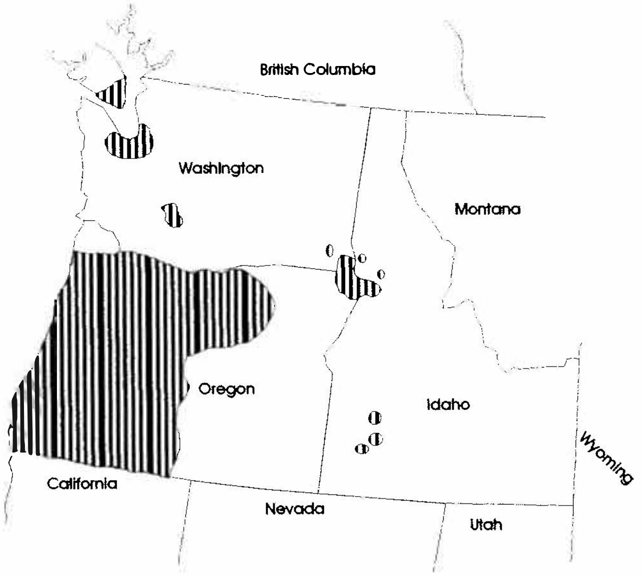

Fig. 5. Current distribution of mountain quail in the Pacific Northwest (from Johnsgard 1973; Vogel and Reese 1995; M. Pope, personal communication).

Creek (24 km northwest of Vale), near Skull Springs (80 km southwest of Vale), and near Ironside (70 km northwest of Vale). Evidently, these observations were sufficiently unusual to warrant publication and Anthony (1912) concluded that mountain quail were expanding their range eastward in Oregon. Van Rossem (1937) took a type specimen near Ironside, Oregon in 1919, and Willett (1919) noted the presence of mountain quail along streams west of the Warner Valley in Lake County, Oregon. Translocations into eastern Oregon are poorly documented, but McLean (1930) and Aldrich and Duvall (1955) both indicated that mountain quail were introduced into that part of Oregon. In contrast to the comments of Anthony (1912) about eastward expansion of mountain quail distribution, Wyman (1912) stated that mountain quail were long established at that time in Idaho. He noted that they were becoming plentiful near Shoshone, and commented that they had recently appeared near Twin Falls (Figure 2). Wyman (1912) considered mountain quail in the area of Nampa "explorers".

Archeological Evidence

Archeological evidence for the occurrence of mountain quail in the Pacific Northwest is scant. Gruhn (1961) identified one specimen from remains dating to within the past 700 years in a cave, located in Jerome County, Idaho, approximately 24 km north of the Snake River and 24 km southeast of Shoshone (Figure 2). In addition, Murphey (1991) described a pictograph of a bird (identified by the author as a grouse) that bears resemblance to a mountain quail (Figure 4). The pictograph portrays a gallinaceous-like bird with prominent barring on the side of the body, heavy bill and feet, and a top-knot, which is quite short and curved over the top of the head as in California (*Callipepla californica*) or Gambel's (*C. gambelii*) quail. This figure was found in an area, located south of Buhl, Jerome County, Idaho, near the Nevada border and was dated 800 to 1000 years ago.

Current Distribution

Mountain quail in the Pacific Northwest (Figure 5) currently range from Vancouver Island, British Columbia through portions of western, south-central, and extreme southeastern Washington to scattered areas of western Idaho, and throughout western, north-central, and northeastern Oregon into the humid belt of northwestern California (Johnsgard 1973:345–347, Vogel and Reese 1995, M.D. Pope, personal communication). Populations have declined substantially in number and distribution in Washington, Idaho, and central and eastern Oregon (Vogel and Reese 1995). As a consequence, reintroduction efforts are underway in Oregon.

Conclusions

From the early historical data, I concluded that the native distribution of mountain quail in the Pacific Northwest during the early 19th century ranged from the Coast Range of Oregon eastward to the Cascade Range along the southernmost part of the Columbia River and, thence, southward. Mountain quail were probably not present in the Willamette Valley but, undoubtedly were found along foothill regions of both mountain ranges. Translocations of birds in this region began by, at least, 1860 and continued through the turn of the century. The geographic extent of mountain quail distribution was probably largest during the early 1900's as a function of translocations and natural expansion of these populations. Seemingly, the distribution of mountain quail remained relatively constant during mid-century, but within the past 25 years, populations outside of the early historic distribution suffered substantial declines, whereas populations in the Coast and Cascade Ranges of Oregon remain abundant.

The archeological evidence for mountain quail in Idaho is particularly intriguing. Bones and a possible pictograph of mountain quail, both dating from a relatively similar time period and from locations within approximately 50 km, may indicate the presence of mountain quail in the south-central part of Idaho 700 to 1000 years ago. Perhaps, these birds represented remnant populations of Pleistocene glaciation. Gutiérrez (1975) commented that mountain quail once apparently had a broader distribution in the southern part of their range because three investigations revealed the occurrence of these birds throughout southern New Mexico (Wetmore 1932, Howard and Miller 1933, Howard 1962). An analogous situation may have occurred in the Pacific Northwest.

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POTENTIAL EFFECTS OF GLOBAL WARMING ON QUAIL POPULATIONS

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ABSTRACT

Populations of scaled quail (*Callipepla squamata*) and northern bobwhites (*Colinus virginianus*) have declined in North America coincident with global warming. We speculate on a cause-effect relation between global warming and quail declines. Quail are sensitive to operative temperatures >38.7 C, which commonly occur under natural conditions in southern latitudes. Based on empirical results, the laying season for quail may be reduced by as much as 60 days because of high temperatures. We provide mechanistic models that show how reduction in length of the laying season suppresses per-capita annual production. Global warming could be associated with declining quail populations through suppression of reproduction; it also could exacerbate the effects of habitat loss and fragmentation. These possibilities should be explored in field and laboratory research.

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INTRODUCTION

Despite controversy over the nature of global warming, the average air temperature on earth has been rising for about 130 years (Gates 1993:2). Increasing temperatures are associated with increases in the quantity of greenhouse gases in the atmosphere (e.g., H_2O, CO_2, CH_4, N_2O, O_3). These gases transmit shortwave radiation (sunlight) but trap longwave radiation, resulting in warming of the atmosphere and cooling of the stratosphere (Schneider 1993).

The warming effect of greenhouse gases is noncontroversial. Indeed, life as we know it would not be possible without natural greenhouse warming. However, the rate of addition of greenhouse gases to the atmosphere, due to human activities, and the rate of atmospheric warming, are largely unprecedented in geological history (Schneider 1993).

Populations of scaled quail and northern bobwhites have declined (Brennan 1991, Church et al. 1993) coincident with global warming. Undoubtedly, habitat loss and fragmentation explain declines in some regions. However, in portions of the Southwest, scaled quail populations have dwindled in areas where habitat quantity has apparently been constant. Could there be a cause-effect relationship between global warming and quail declines?

After briefly reviewing the biophysical background, we examine empirical and theoretical effects of higher temperatures on quail. The northern bobwhite serves as our primary model, because the thermal biology of this species is well known. We will demonstrate the importance of heat-driven habitat selection as a process that influences quail abundance and productivity and review the empirical basis for heat effects on reproduction. Finally, we use mechanistic models to explore the process of heat-based suppression of reproduction.

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BIOPHYSICAL BACKGROUND

The physiological goal of warm-blooded animals is maintenance of a stable body temperature. This goal is realized when the following identity holds:

$$\text{rate of heat gain} = \text{rate of heat loss}. \qquad (1)$$

Heat is energy in transit, either moving into or out of an animal's body. Heat always flows from a body of higher temperature to a body of lower temperature, and the rate of heat flow increases in proportion to the difference between the temperatures of 2 bodies. We will use watts (W) to describe rates of heat flow: 1 W = 1 J sec^{-1}, where J = Joule, a measure of energy. In terms of calories, 1 J = 0.2389 cal and 1 cal = 4.186 J. Heat may flow into or out of a quail's body by convection (body-air), conduction (body-solid object), and longwave radiation. Additional sources of heat gain are shortwave radiation (sunlight) and longwave radiation from objects with temperatures higher than that of a quail.

When heat flows into the body, quail may increase the rate of heat loss by evaporation (gular flutter). Under extreme conditions, quail are unable to balance heat loss and gain; the ultimate consequence may be death.

Quail always produce heat by metabolism. The basal metabolic rate for fasting bobwhites in a thermoneutral environment is about 0.95 W (Case and Robel 1974, Curtis 1983, Spiers et al. 1983). In terms of calories, basal metabolism produces about 0.23 cal sec^{-1} (19.6 kcal day^{-1}).

Air temperature provides a poor landmark for determining whether heat potentially flows into a quail's body. A better landmark is operative temperature, T_e, which is a composite of air temperature, wind, and sunlight effects at a fixed orientation of the animal relative to the sun's rays. Operative temperature is similar to the air temperature in a dark room that would be equivalent, in terms of heat flow, to the temperature experienced by an animal standing in sunlight (heat added) with known wind speeds (heat usually subtracted). Operative temperature will be higher than air temperature when an animal is exposed to sunlight and low wind speeds. Operative temperature and air temperature are the same at night with no wind.

Laboratory experiments indicate that at an operative temperature between 35 and 40 C, the maximum possible rate of heat dissipation falls below the rate of heat gain; as a result, body temperature increases. At 35 C bobwhites may use gular fluttering to increase heat loss via evaporation (Spiers et al. 1983). Bobwhites exposed to 40 C for >24 hours may die from hyperthermia (Case and Robel 1974). We estimate from models that the minimum operative temperature that leads to hyperthermia is about 38.7 C for bobwhites. This temperature is below mean body temperature of about 41.5 C (Spiers et al. 1983, White 1995). An operative temperature below body temperature may lead to hyperthermia because of heat produced by metabolism (see earlier).

Quail are said to have low thermal inertia, because a small quantity of heat gain produces a marked response in body temperature. The specific heat of quail tissue is estimated to be 3.43 J g^{-1} C^{-1} (Goldstein 1984). This number means that a net gain of 3.43 J of energy will raise the temperature of 1 g of tissue by 1 C. Heat capacity is the product of body mass times specific heat. For a Texas bobwhite (*C. v. texanus*), the heat capacity is about 160 g times 3.43 J g^{-1} C^{-1} = 549 J C^{-1}. This latter number implies that if a Texas bobwhite's body gains 549 J of energy, its body temperature will rise by 1 C. The heat capacity of bobwhites in northern climes is around 686 J C^{-1} based on a 200-g body mass.

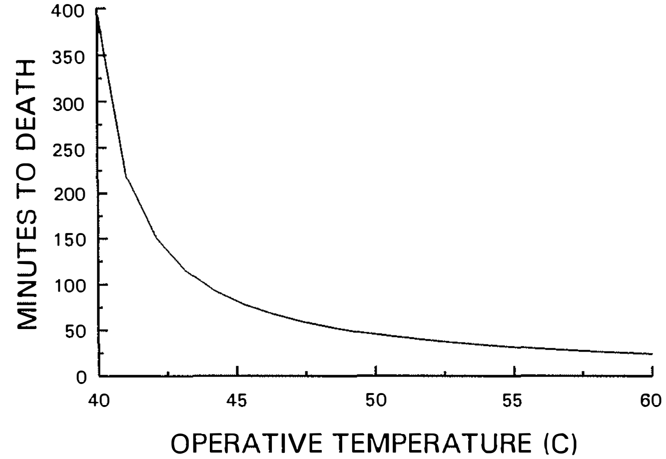

Fig. 1. Approximate time to death from hyperthermia (core body temperature = 46.5 C) as a function of operative temperature for northern bobwhites. The function is based on a 180-g bobwhite.

The low heat capacity of quail indicates that small quantities of net energy gain may produce severe physiological effects through elevated body temperature. Three outcomes are possible if heat flows into the body. First, the body temperature may rise and stabilize at some nonlethal value above normal body temperature. This will occur if it is possible for the bird to experience net loss of longwave radiation as its body temperature rises above the temperature of surrounding objects. Second, the bird may experience nonlethal hyperthermia and recover as the thermal environment improves, for example, the sun goes down. The third outcome is death from hyperthermia, which probably occurs at a core body temperature of <46.5 C (Goldstein 1984). Time to death varies hyperbolically with operative temperature (Figure 1).

OPERATIVE TEMPERATURES IN THE FIELD

On 11 June 1996 we analyzed operative temperatures at 23 points within a brush thicket (350 m^2) on a ranch near Laredo, Webb County, Texas. The brush consisted primarily of regrowth honey mesquite (*Prosopis glandulosa*) ≤3 m tall. Hourly trends in operative temperature near ground level showed considerable variability within and among points (Figure 2).

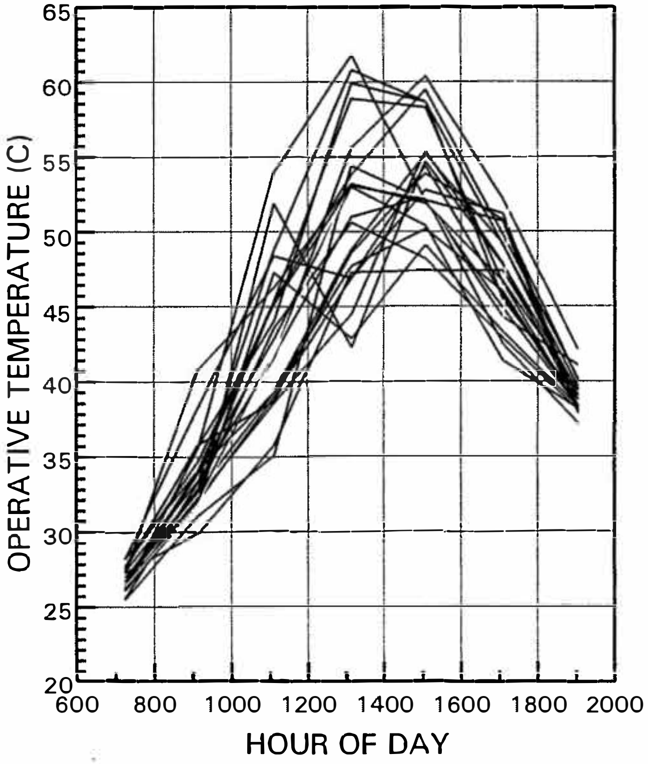

Fig. 2. Hourly trends in operative temperature at ground level at 23 points in a thicket composed of honey mesquite, Webb County, Texas, 11 Jun 1996. Drought conditions prevailed when these data were collected.

This variability arose primarily from variability in shading effects as the sun passed from east to west. All points reached operative temperatures critical to bobwhites (>38.7 C) and probably other quail species. Maximum temperatures observed were potentially lethal to bobwhites in <10 minutes of exposure.

Gambel's quail (*C. gambellii*) in Arizona may die of hyperthermia in <1 minute if they leave shady coverts on hot summer days (Goldstein 1984). This fate accrues because of above-normal beginning body temperature, the added heat load from solar radiation, and increased heat production (metabolism) from activity. Goldstein's (1984) finding shows that in certain environments, heat may be an important factor in quail behavior and habitat selection. In fact, heat avoidance may explain field behavior as well as predator avoidance (Forrester et al. 1998).

EFFECTS OF HEAT ON BEHAVIOR

Habitat Use

Thermal effects on habitat selection, behavior, and productivity of bobwhites have been documented or hypothesized based on field and laboratory research. Bobwhites in the Rio Grande Plains of Texas select loafing coverts with tall, dense canopies during hot days, whereas those selected during cool days have low canopies (Johnson and Guthery 1988). During summer, air temperature at loafing sites (35.7 C) averaged 5.2 C below that at random points. Light intensity was reduced 92.1% at loafing sites in comparison with random points. The intensity of solar radiation decays rapidly as it passes through plant canopies, thereby nullifying a potential source of heat gain.

The calling activity of male masked bobwhites (*C. v. ridwayi*) in Sonora, Mexico, is correlated with relative humidity (W. P. Kuvlesky, Jr., unpublished data); Texas bobwhite males call more frequently after summer showers; they also do this in Florida and elsewhere throughout the southeastern U.S. (L.A. Brennan, personal communication). These observations are consistent with heat-driven behavior, because ambient humidity would be associated with evapotranspiration and evaporation near the ground, both of which dissipate heat. Calling males would have cool thermal refugia to discharge heat and lower body temperature (see Goldstein 1984). Moreover, humidity reduces incident shortwave radiation by absorption.

Kassinis and Guthery (1996) observed shorter flights of bobwhites in summer than in other seasons; this behavior could be associated with body temperature regulation, i.e., longer flights would elevate body temperature more than shorter flights. We have found in southern Texas that bobwhites land at points with cooler temperatures than at take-off points or points in the random environment (N. D. Forrester, unpublished data).

Bobwhites in the western Rio Grande Plains apparently require higher seral stages than those in the eastern Rio Grande Plains of Texas (Spears et al. 1993). This phenomenon is consistent with a thermal response, because higher seral stages in the hotter, drier environments would foster cooler conditions at quail level than lower seral stages. Cooling would occur by the insulating and shading effects of perennial grasses and by evapotranspiration of soil water by deep-rooted perennials. However, it must be noted that alternative hypotheses, e.g., similarity in vegetation structure (Spears et al. 1993), may explain variable seral stage associations of bobwhites in different regions.

Forrester et al. (1998) evaluated operative temperature preferenda of bobwhites in the Rio Grande Plains and Gulf Coast Prairies of southern Texas. During July–September birds exhibited strong selection for operative temperatures within the range 18.8–35.4 C (Figure 3). Forrester et al.'s (1998) results indicate that ≥50% of habitat space-time was thermally stressful (operative temperature ≥39 C). Bobwhites exhibited preferential use in about 28% of available space-time and avoided 72%. In rounded figures, about half of available habitat space-time was thermally stressful (potentially lethal) and about three-fourths was avoided. Management for desirable thermal conditions conceivably could double the habitat space-time available to bobwhites based on these results.

Reproduction

A striking pattern of bobwhite demography in the United States is higher productivity in northern latitudes than in southern latitudes (Figure 4). According-

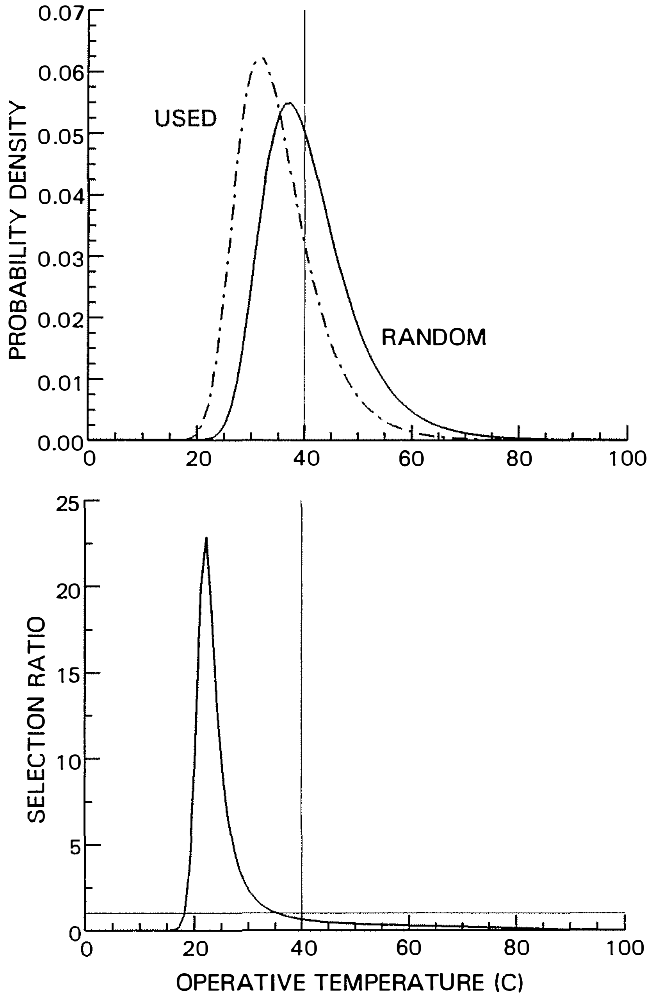

Fig. 3. Probability distributions (top) for operative temperatures at used (flushing and landing, $n = 296$) and random points ($n = 289$) for northern bobwhites and the resulting selection ratio function (bottom), Rio Grande Plains and Gulf Prairies of Texas, July–September 1994 and 1995. Values <1 indicate avoidance and values >1 indicate preference for operative temperatures.

ly, annual survival rates must be lower in northern than in southern portions of bobwhite range. One cannot state unequivocally whether survival or productivity lead to the geographic pattern, because these variables are tautologically intertwined. One can hypothesize, however, that lower temperatures in northern latitudes reduce winter survival and foster productivity, whereas these effects reverse in southern latitudes.

High air temperatures have several adverse effects on laying chickens (North 1972). These include decreases in feed intake, egg production, eggshell quality and thickness, and interior egg quality.

Based on direct results and derivations from Case and Robel (1974), high temperatures have similar effects on laying bobwhites. The body mass of laying bobwhites maximizes at about 20.1 C; this temperature provides an estimate of the optimum temperature for laying in the field and is similar to the optimum temperature for domestic poultry (Card and Nesheim 1972). The body mass of female bobwhites declines at 0.174 g C^{-1} for temperatures >20.1 C. The body mass of males under a 15-hour photoperiod maximizes at 17.4 C and declines at 0.074 g C^{-1} for operative temperatures >17.4 C.

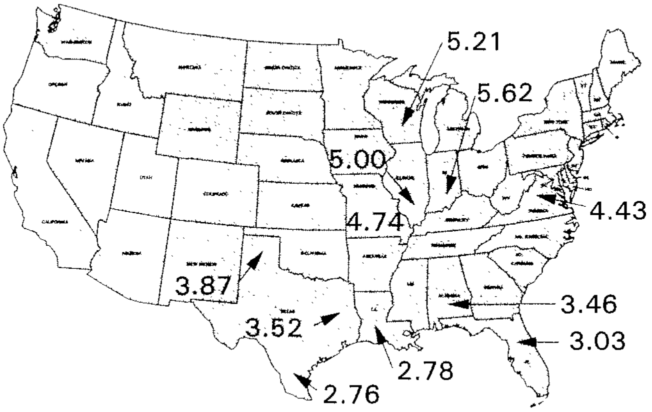

Fig. 4. Geographic variation in mean age ratios of northern bobwhites. Data are from Jackson (1969:9), Rosene (1969:385–386), Lehmann (1984:133), and Roseberry and Klimstra (1984: 218).

High temperatures suppress the reproduction effort of bobwhites in the wild. Effects in Missouri include earlier completion of hatching and lower autumn age ratios than in normal years (Stanford 1972). Klimstra and Roseberry (1975) showed that each rise of 1 C in the mean maximum daily temperature in July–August reduced the laying season by about 12 days in Illinois. The last clutch was laid in early July during hotter summers (34.5 C for mean daily maximum) compared with early September for cooler summers (30.5 C); i.e., higher temperatures reduced length of the laying season by ≤2 months. In the Rio Grande Plains of Texas, the laying season in a hotter, drier portion of the region (western) was about 2 months shorter than in a cooler, wetter portion (eastern) (Guthery et al. 1988). Based on inferences from Guthery et al. (1988), we estimate the average hen was in laying condition for about 60 days in the hotter environment versus 80 days in the cooler environment.

The effects of a reduction in the number of days in the laying season may be gauged with mechanistic models of production as indexed by an age ratio. The number of nesting attempts per hen (n) is a function of several variables:

$$n = f(m, L, p, D_s, D_f, H)$$

where

m = the elapsed time (days) from start of the laying season to 100% effort (all laying hens laying),

L = the number of days from first to last egg of the season,

p = the probability of success on an attempt,

D_s = the time (days) committed to a successful attempt,

D_f = the time (days) committed to a failed attempt, and

H = the mean number of days in laying condition per hen.

Define $q = 1 - p =$ the probability of nest failure on an attempt.

Let $f(t)$ be a density function that gives the proportion of hens that start laying on day t, $0 \leq t \leq m$. Then the average number of days in laying condition for a hen may be defined as

$$H = \int_0^m [f(t)(L - t)]\, dt. \qquad (2)$$

Equation (2) sums days times probabilities and gives, essentially, a weighted average for hens.

The mean time (d) committed to a nesting effort may be defined as

$$d = pD_s + qD_f. \qquad (3)$$

Equation (3) is a weighted average of days committed to successful and unsuccessful nesting attempts.

The number of attempts per hen is laying days per hen divided by days per attempt, i.e.,

$$n = H/d. \qquad (4)$$

Suppose $f(t)$ may be described as a parabola on $[0, m]$, i.e.,

$$f(t) = at - bt^2.$$

The coefficients a and b are estimated as

$$a = 6/m^2$$

and

$$b = 6/m^3.$$

With these coefficients the area under the curve $f(t)$ from 0 to m will sum to 1.0; i.e., $f(t)$ will be a density function. Then

$$H = \int_0^m [(at - bt^2)(L - t)]\, dt.$$

Solution of this integral and substitution for a and b leads to the simple result,

$$H = L - 0.5m.$$

We may approximate the autumn age ratio ($R =$ juvenile/adult) under single-brooding as (Guthery and Kuvlesky 1998)

$$R = wzc(1 - q^n) = wzc(1 - q^{H/d}) \qquad (5)$$

where

$w =$ the proportion of hens in the adult population,
$z =$ the proportion of hens that lays, and
$c =$ effective clutch size (viable eggs/clutch).

Equation (5) implies production increases asymptotically with the number of nesting attempts, holding the other variables constant.

If we define $L = 150$ days from first to last egg of season, $m = 30$ days for all laying hens to become active, $D_s = 75$ days devoted to a successful nest, $D_f = 40$ days devoted to a failed nest, and $p = 0.3$ for probability of nest success, then under the parabolic model, we obtain

$$H = 135 \text{ days hen}^{-1},$$

$$d = 50.5 \text{ days attempt}^{-1}, \quad \text{and}$$

$$n = 2.67 \text{ attempts hen}^{-1}.$$

At $w = 0.45$, $z = 1.0$, and $c = 12$ we obtain an age ratio of

$$R = (0.45)(1.0)(12)(1 - 0.7^{2.67}) = 3.32 \text{ juvenile/adult}$$

Now suppose, hypothetically, the number of days in the laying season declines from 150 to 90 because of a late-summer heat wave. Holding other input variables as specified above, we find the number of days in laying condition for each hen becomes $H = 75$, leading to $n = 1.49$ and $R = 2.23$ juvenile/adult. In this hypothetical example, an empirically reasonable reduction in the laying season of 60 days due to heat (Klimstra and Roseberry 1975, Guthery et al. 1988) reduced per-capita production by 1.09 juvenile/adult.

DISCUSSION

The negative effects of high temperatures on reproduction by gallinaceous birds are well established empirically and theoretically. The effects are based on matters of physics and chemistry, which are not subject to debate at this point in the history of the universe. However, whether global warming could be responsible for declining quail populations remains speculative.

Average temperatures in the atmosphere have increased by about 0.5 C since the current warming trend began (Gates 1993, Schneider 1993). Projections subject to uncertainty indicate mean temperatures may increase by up to 5 C in the next century or so. These increases seem small, but if increases in the average occur primarily because of increases during summer, then a small increase in the average could potentially have strong impact on quail populations.

The global warming trend is consistent with an insidious and widespread decline of quail in warmer climates. If the average length of the laying season in a particular area declines through the years, there might be an early stage where density dependent processes and other adjustment mechanisms result in a stable population. However, with larger reductions in the laying season (1–2 months), adjustments in survival would not be expected to keep pace with reductions in production. This could lead to a slow annual rate of decline. Continued warming might be expected to increase the annual rate of decline in the next century. Under this scenario, global warming would exacerbate the effects of habitat loss and fragmentation in populations subject to global warming effects.

Certain populations may not be susceptible to the negative influence of global warming, if the influence exists. Populations of California quail (*C. californica*), Gambel's quail, and mountain quail (*Oreortyx pictus*) were stable from 1966 to 1991 (Church et al. 1993). The effects of latitude, altitude, and ocean masses could theoretically mitigate global warming effects on these species. This possibility fits Gambel's quail poorly, because they are largely an interior species of low latitudes. Church et al. (1993) reported a decline in Gambel's quail during the decade preceding 1991.

The above paragraph demonstrates that any effects of global warming on quail populations will vary with the prevailing climate to which populations are adapted; in other words, the response of quail populations to increased heat loads will vary geographically. Biotic factors including the quantity and quality of thermal refugia will exacerbate variation among populations. This variation will occur despite intrinsic similarity in the bioenergetics (e.g., Guthery 1999) and biophysics of quails.

A question that arises concerning global warming and quail production is whether populations might adapt genetically to higher temperatures. Breeding experiments with domestic poultry indicate little genetic variation with respect to heat tolerance (El-Gendy and Washburn 1995). This finding is perhaps not surprising because heat tolerance has a strong basis in biophysical chemistry. Alteration of laying phenology through natural selection seems feasible; if global warming is affecting quail populations, then selection should favor those individuals that lay earlier in the season when temperatures are cooler. Whether the rate of selection can keep pace with the rate of temperature change remains problematic.

Another potential effect of global warming is a change in the distribution of quails from more southerly (hotter) to more northerly (cooler) latitudes. Biogeographic changes have ample precedent in geologic time (Gates 1993).

Two barriers presently confront a northerly shift in the distribution of wildlife (Gates 1993). First, the vegetation that provides habitat for a species follows climate change at an extremely slow rate relative to the dispersal capabilities of the species. Second, modern fragmented landscapes may prevent distribution shifts for both plants and animals; i.e. modern landscapes contain agricultural and urban areas that represent barriers to dispersal.

We conclude this discussion by observing that there is no single cause of quail declines in the real world, because multiple factors increase mortality and suppress production in declining populations. Selection of any 1 factor from a set of potential factors is arbitrary. The best science can do in a multiple-cause milieu is to estimate the proportional impact of agencies contributing to an effect (Chamberlain 1890). Although global warming could be associated with an accelerated rate of quail decline in some areas, its importance relative to other potential problems remains unknown.

MANAGEMENT IMPLICATIONS

The sensitivity of quail to high temperatures is neither widely recognized nor fully appreciated in applied ecology. If global warming has contributed to the decline of quail populations, then the management response is to reduce temperatures at quail level. Cooler microenvironments may be created by management of herbaceous and woody cover. The more such cover, the better, within the limits of the habitat structure to which quail are behaviorally and morphologically adapted.

The response of individuals and populations to high heat loads is a fertile area for field and laboratory research. Historical data such as breeding bird surveys (Church et al. 1993) or Christmas bird counts (Brennan 1991) might be examined to ascertain population trends in areas more sensitive and less sensitive to global warming. Regions with higher altitudes and latitudes or a marine influence should be less sensitive to global warming than interior regions at low altitudes and latitudes. The global warming hypothesis predicts higher rates of decline in more sensitive than in less sensitive regions.

The research community might want to address the role of heat in variation in quail production. Field data relative to this question are limited and somewhat anecdotal. For example, we have no idea of the dynamics of heat loads in different vegetation types relative to the thermal biology of quails. A critical question is determining whether acute as opposed to chronic heat events suppress production. Suppression could occur by causing hens to quit laying, addling eggs (Leopold 1933:297), or killing chicks (Sumner 1935). Our research group has initiated combined laboratory and field studies to better understand the influence of heat on bobwhite demographics in a subtropical environment.

We suggest that researchers examining the influence of heat loads on quail dynamics pay close attention to the length of the laying season and the proportion of hens that lays in a given season. The proportion that lays has a particularly strong influence on production (Guthery and Kuvlesky 1998). Because the proportion that lays could be misleading, we also recommend analysis of the average number of days in laying condition for hens. This variable can be estimated as the integral of an equation that describes the proportion laying as a function of time (Julian day).

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ONTARIO MINISTRY OF NATURAL RESOURCES SOUTH-CENTRAL REGION BOBWHITE QUAIL REHABILITATION PROGRAM

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ABSTRACT

Archaeological and historical evidence on status of northern bobwhites (*Colinus virginianus*) in southern Ontario prior to European settlement is not clear. The bird was documented on the Essex and Kent County prairies at the time of European settlement in the early 1700's.

Early farmsteading increased available habitat space for quail. That landscape, combined with mild winters in the 1840's, enabled bobwhites to expand their ranges. By the mid-1850's, bobwhites ranged generally throughout Ontario's tallgrass prairie and savannah communities extending from the Detroit River approximately 300 miles north into Simcoe County, the southeast limit of Georgian Bay, and 400 miles east to Kingston, the eastern limit of Lake Ontario.

Bobwhites became a valued upland bird in pioneer Ontario for hunting, viewing and controlling farm garden weed seeds and insects.

The detrimental impacts of harsh winters were a major contributor to quail declines from the late 1850's to the 1980's. Additionally, more subtle factors which also contributed detrimental stresses were loss of tallgrass prairie and savannah, intensive agriculture, continued deforestation, urbanization, pesticide use, the taking of wild stock for pen-rearing and the low survival rates of introduced cultured stocks into the wild. In summary, bobwhites in Ontario declined due to the destruction, impairment and fragmentation of wildlife habitat. The population stabilized at low numbers during the early 1980's.

Recreational harvesting of the species continued into the 1970's. Gun harvests probably at no time exerted a controlling influence on the quail populations. The harvest diminished to non-existence in the 1980's. The hunting seasons for wild populations were eliminated in the 1990's. People continued to appreciate the bird for recreational viewing and dog training opportunities.

In spite of agricultural trends towards less intensive land uses, new emphases on resource and environmental conservation and rehabilitation, as well as milder winters in the 1980's and 1990's, bobwhite numbers have not rebounded in southwest Ontario. Approximately 185 birds in 16 coveys throughout Elgin, Lambton and Middlesex counties were documented in 1990. Although large areas of suitable land are unoccupied by bobwhites, populations remain small, disjunct and isolated.

Ontario Ministry of Natural Resources formed partnerships with a number of other governmental agencies, non-governmental organizations and landowners, to initiate the rehabilitation of bobwhite quail in southern Ontario. The Ontario Federation of Anglers and Hunters, their affiliate and individual members, are a key sponsor to this rehabilitation initiative. These groups have participated in an advisory committee, raised funds, and offered volunteer labor, predator control services adjacent to release sites, and professional services. The committee recommended the transfer of wild bobwhites from other North American populations as a means of rehabilitating Ontario populations.

The program's goal is to reestablish larger, sustainable populations of quail in southern Ontario to provide recreational viewing and hunting opportunities. It is anticipated that large numbers of urban and rural Ontarians will be pleased with the reestablishment of northern bobwhites and the recreational viewing and hunting benefits they provide. Restoration of quail hunting opportunities will generate economic benefits in Ontario and may be a suitable method for monitoring the grass-shrubland ecotone. Healthy quail populations also have the potential to function as natural control agents for some crop pests.

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HOW ECOLOGICAL DISTURBANCES MAY INFLUENCE MOUNTAIN QUAIL IN THE PACIFIC NORTHWEST

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ABSTRACT

Mountain quail (*Oreortyx pictus*) populations have declined throughout the Intermountain Region of the Pacific Northwest. The decline of mountain quail is most likely related to the loss of habitat. We suggest that disturbance may play a critical role in providing the structure, composition, and density of vegetation needed to sustain mountain quail populations. Conversely, lack of disturbance (fire suppression) may result in conditions unsuitable for mountain quail. We examined the historic role and ecological influences of fire on vegetation in the Intermountain Region, and how the elimination of fire as a successional determinant may have facilitated the decline of mountain quail. Limited cattle grazing, prescribed burning, and silvicultural practices may provide alternatives to natural fire for establishing and/or maintaining mountain quail habitat.

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EFFICIENCY OF BAIT TRAPPING AND NIGHT LIGHTING FOR CAPTURING NORTHERN BOBWHITES IN MISSOURI

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ABSTRACT

We evaluated the efficiency of bait trapping and night lighting for capturing northern bobwhites (*Colinus virginianus*) from October 1993–March 1996 in central Missouri. Fifty-two percent of all birds were captured in bait traps and 48% were captured by night lighting. Of all birds captured for the first time, 59% were captured by trapping and 41% by night lighting, demonstrating the value of using both techniques to capture a large sample size in a limited time. Four percent of all birds captured died before being released. Of the bait-trapped birds, 4% died in the trap and 1% died during processing. Of the night-lighted birds, <1% died during capture and <1% died during processing. Comparing cost and efficiency, it was 3–4 times faster to capture birds by night lighting, but 1.5–2 times more expensive, depending on time of year. Distribution of the survival probabilities did not differ between methods for 1993 and 1995, but did in 1994.

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INTRODUCTION

Bait trapping and night lighting are common northern bobwhite (*Colinus virginianus*) capture techniques in the Midwest. Knowledge of capture efficiency and cost, and quail mortality are important to planning and conducting research. The Kaplan-Meier method (Kaplan and Meier 1958) is commonly used to estimate seasonal and annual survival of bobwhite quail (Burger et al. 1995, DeMaso and Peoples 1993, Robinette and Doerr 1993, Curtis et al. 1988). One assumption of this method is that capture and handling do not affect survival (Pollock et al. 1989*b*); however, this assumption has not been rigorously tested. Rather, biologists commonly assign an arbitrary habituation period (e.g., 1 week) after radio marking when an animal's survival time is not considered until it has survived that period (Pollock et al. 1989a). As part of a study on the effect of harvest on quail survival, we evaluated the efficiency of bait trapping and night lighting for capturing bobwhites. Our objective here is to show the utility of using night lighting to rapidly increase the number of quail captured. We also examined post-capture survival to evaluate if potential trapping biases might influence survival probabilities.

STUDY AREA

This study was conducted on Blind Pony Lake Conservation Area in Saline County, Missouri. The area contains 772 ha of upland habitat, 205 ha of crop field, 422 ha of old fields, and 145 ha woody cover. Topography is gently rolling to flat.

METHODS

Bait Trapping

Bait trapping was conducted during the fall (15 September to 15 November), and winter (January). Between 150 and 250 funnel traps (Stoddard 1931) were set during the fall trapping period and 20 to 40 were set during January. Traps were placed in areas considered to be frequently used by quail and were covered with vegetation to conceal captured birds from predators. Traps were baited with cracked corn, milo, and millet. Traps were checked twice daily, approximately 2 to 3 hours after sunrise, and at dusk. Bait lines were checked by 1 person using an all terrain vehicle.

Night Lighting

We dropped an 8- by 6- m nylon net over roosting coveys. During the second and third field seasons we used a second, smaller net (5 × 3 m). We placed this net directly opposite the primary net overlapping its leading edge. We believe this increased our night lighting efficiency by capturing birds that flushed away from the leading edge of the primary net. Night lighting was limited to coveys roosting in herbaceous vegetation with a relatively open canopy. To reduce thermal stress, we night lighted when temperatures were > -6.7 C. Night lighting required at least 6 persons: 2 for telemetry, 2 to 4 on the large net, and 2 on the small net when used. Telemetry observers used triangulation to approximate location of radio-marked quail and directed net handlers to these sites. Night lighting occurred during the fall (15 September to 15 November), and winter (January and March 1994, March 1995, and February 1996).

Capture and Processing

We leg-banded all individuals and recorded age, sex, weight, and body fat. Birds were almost always released on the same day or night as captured. In September and October of the first field season (1993) birds weighing >100 g were equipped with a radio transmitter. In November of that year birds weighing > 90 g received transmitters. The remainder of the study (1994–1996) birds weighing >120 g received transmitters. Radio transmitters were necklace style with a mortality sensor (Burger et al. 1995). Radio-marked birds were located ≥ 6 days per week.

Capture Efficiency

Capture summaries are based on data from all 3 field seasons. Time and cost analyses are from the second (1994–1995) and third (1995–1996) field seasons. Capture efficiency is defined as hour per bird captured regardless of the number of people required for different techniques. Cost is defined as labor expense only. Cost per bird captured is calculated assuming a 6-person night lighting crew and a 1-person bait line crew. Actual cost figures were not calculated because of varying pay scales; therefore, cost comparisons are reported. Capture events were classified as "new" if the bird was not wearing a leg band or radio transmitter. Hour and cost per new birds only were also calculated. Both capture methods were conducted in the same habitat with similar quail densities. Because quail densities and habitat types were constant throughout the study, differences in capture efficiency were assumed to be due to use of funnel trap versus night lighting techniques.

For comparison of times we assumed that: (1) time required for handling and processing is equal between trapping methods; (2) stress associated with handling and processing is equal between trapping methods; and (3) time required for set up of each technique is equal. Generally little to no prebaiting occurred for bait trapping. Set up time for bait trapping consisted of clearing a trap area, covering the trap with vegetation, and baiting. Trap lines were moved on the average of once per week. Night lighting set up time consisted of 1 to 2 persons using telemetry locating potential coveys to night light and checking the covey's location for habitat suitability. The time required for set up of each technique is not included in the analysis. Bait trapping time was logged from the first trap of the line to the last. Night lighting time began when the telemetry crew set out towards the covey, and ended when the covey flushed or was captured.

Survival

We used the Kaplan-Meier method (Kaplan and Meier 1958) to estimate survival, using the staggered entry technique (Pollock et al. 1989*a,b*). Birds were right-censored if their fate was unknown due to radio failure. Survival analyses were calculated for all 3 field seasons individually, using the fall trapping season only. Log-rank tests were used to compare survival distributions between trapping techniques.

Table 1. Number of northern bobwhite captured by bait trapping and night lighting in central Missouri, 1993–1996.

	Bait Trapping		Night Lighting	
Year	Number new birds	Number recaptures	Number new birds	Number recaptures
1993–94	177	35	133	95
1994–95	220	106	169	23
1995–96	203	55	114	92
Total	600	196	416	310

RESULTS

We captured 1,522 quail (including recaptures) from October 1993 to March 1996. Of these, 1,016 (67%) were new captures and 506 (33%) were recaptures. We captured 796 birds (52%) in bait traps and 726 (48%) by night lighting. Seventy-five percent of all bait-trapped birds were new captures, with 25% being recaptures. Fifty-seven percent of all night-lighted birds were new captures, with 43% being recaptures. Fifty-nine percent of all new captures were captured by bait trapping and 41% of all new captures were captured by night lighting (Table 1.)

Four percent of all birds captured died immediately or during processing. Of the bait- trapped birds 4.1% (n = 33) died in the trap and 1.2% died during handling. Seventy-six percent of the bait trap deaths were the result of predation while in the trap. Less than 1% of the birds night lighted died during the night lighting process, and less than 1% of the night lighted birds died due to handling. The overall physical appearance of quail captured by night lighting is outwardly better than quail captured in the funnel traps. Quail tend to hit the top of the trap repeatedly resulting in varying degrees of head and wing scalping. Less obvious injuries may have occurred by both methods, but were not observed. In order to reduce scalping, trap-related stress, and predators, we checked the trap lines soon after morning feeding periods and close to dusk. By comparison, personnel are available on site at the time of capture when night lighting is used.

During the fall, it was 3 times faster to capture a bird by night lighting than by bait trapping; it took 0.9 hours to capture 1 bird by bait trap and 0.3 hours to capture 1 bird by night lighting. However, since our night lighting crew consists of 6 people, it becomes twice as expensive to night light as to bait trap a bird. If the goal is to only capture new birds, it becomes 2.6 times faster to night light (0.5 hours per bird) than bait trap (1.2 hours per bird); however, it is 2.3 times more expensive to use night lighting than it is to bait traps. In the winter months it took 2 hours per bird to bait trap and 0.5 hours per bird to night light. For new birds, it took 2.1 hours to bait trap 1 bird, and 1.2 hours to night light. In the winter months it is 4 times

Table 2. Capture efficiency (hours per bird captured) of bait trapping and night lighting of northern bobwhite in central Missouri, 1994–1996.

	All birds	New birds
Fall trapping season	0.9	1.2 Trapping
(1 Sept. to 15 Nov. 1994, 1995)	0.3	0.4 Night lighting
Winter trapping season	2.0	2.1 Trapping
(Feb. 1994, March 1995)	0.4	1.2 Night lighting

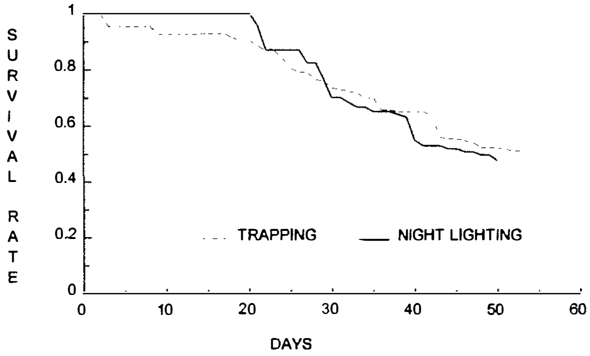
faster to use night lighting to capture birds but 1.5 times more expensive (Table 2).

Distribution of the survival probabilities did not differ between methods for 1993 and 1995 ($X = 1.085$, 1 DF, $P+0.30$, $X = 2.035$, 1 DF, $P = 0.15$, respectively; Figure 1, a and c). In 1994 distribution of the survival probabilities did differ between methods ($X = 5.830$, 1 DF, $P = 0.02$; Figure 1b).

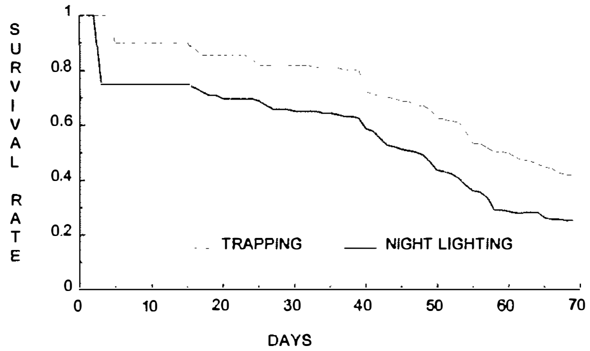
DISCUSSION

The primary objective for the capture phase of any research study is to catch the greatest number of animals for the least cost while incurring the least amount of capture bias, behavioral modifications, and mortality. Given the time constraints we faced during the capture phase in our quail harvest study, we could not have captured our desired sample without using night lighting and bait trapping simultaneously. We captured a similar number of birds by each capture method, although more previously uncaptured birds were captured by bait trapping than by night lighting. Although it was relatively more expensive to capture a bird by night lighting, it was more efficient on an hourly basis. Budgetary constraints may limit the number of night lighting attempts that can be conducted. When planning a study, it may be essential to consider running fewer bait trap lines (to capture the initial bird in each new covey), and spending more time on night lighting.

The most frequently encountered source of mortality was from predators while bobwhites were confined in the bait trap. This could potentially be reduced by covering and "hiding" the traps more thoroughly, by checking the traps more frequently, or by moving traps when predators keyed in on that specific trap or trap line. Theoretically, one should try to avoid recaptures if transmitter replacement or additional data collection is not necessary because of potential mortality associated with handling or stress. If repeated capture increases stress-related mortality, night lighting might be inappropriate because the target covey will always contain marked birds. Our survival probabilities show that there is no difference in survival as a result of different trapping techniques during 2 of the 3 years. The difference in survival during 1994 is probably a result of 1 of 4 night lighted birds dying on the 3rd day of trapping. Other factors which may affect night lighting success are: (1) night lighting is not efficient where vegetation structure at or near roosts is dominated by dense shrubs and vines, and (2) night lighting success might diminish in the winter after potential harassment to coveys from hunters and previous night lighting attempts.



a.



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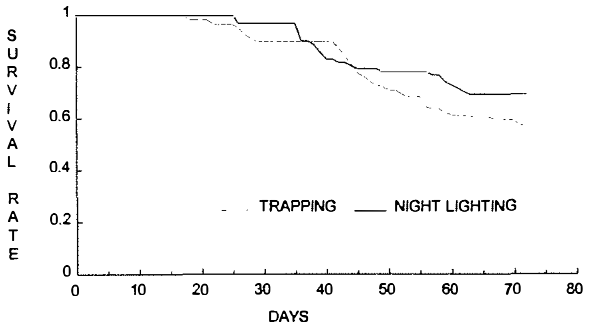

c.

Fig. 1a. Survival probability for northern bobwhites in central Missouri during 15 September–5 November 1993.

Fig. 1b. Survival probability for northern bobwhites in central Missouri during 15 September–15 November 1994.

Fig. 1c. Survival probability for northern bobwhites in central Missouri during 15 September–15 November 1995.

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EFFECTS OF RADIO-TRANSMITTERS ON BODY CONDITION, HARVEST RATE, AND SURVIVAL OF BOBWHITES

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ABSTRACT

Numerous studies of northern bobwhite (*Colinus virginianus*) population and habitat ecology employ use of radio-telemetry techniques to relocate and monitor individuals. Radio-telemetry enables estimation of reproductive success, survival, movements, and home range at levels of resolution not otherwise possible. Unbiased estimation of these parameters via radio-telemetry assumes that survival, reproduction, and behavior of radio-marked individuals are not affected by carrying the radio-transmitter. These assumptions have not been rigorously tested for bobwhites. In 1993, we initiated a study at Divide Section Wildlife Management Area in Mississippi and at Tall Timbers Research Station to test the effects of radio-transmitters on survival, harvest rate, and body condition of bobwhites. From 1993 to 1996 we banded 221 and radio-marked 259 bobwhites on Tall Timbers Research Station. Harvest rate for radio-marked bobwhites was 18.5% and banded birds 12.7%. In 2 of 3 years, radio-marked birds experienced greater mean weight loss between capture and harvest than banded birds. From 1994 to 1995 we radio marked 188 and banded 210 birds on Divide Section Wildlife Management Area. Harvest rate for radio-marked birds was 40% and banded birds 30%. In the 1995–1996 hunting season radio-marked birds had lower mean weight gain from capture to harvest than banded birds. Based on our sample of marked birds, 34% of the fall population on this area was harvested. We have established a captive breeding colony of wild bobwhites at the Blackjack Captive Animal Research Facility at Mississippi State University. During the summer of 1996, genetically wild progeny are being produced to be used in a pen study to evaluate the effects of radio-transmitters on bobwhite body weight and lipid levels under abundant and scarce food resources. This study will provide the first harvest rate estimates for bobwhites on a public hunting area in Mississippi. Additionally, this study will evaluate the effects of radio-transmitters on bobwhite body condition, survival, and harvest rate. It will either validate the assumption of no radio effects and aid interpretation of previous and future radio studies or elucidate critical violations of fundamental assumptions of this methodology. If radio effects are detected, this study will identify the specific mechanisms creating bias in estimation of population parameters. This information will enable researchers to target radio design problems and develop new radio technology with reduced effects. Preliminary results suggest that radio-marking may marginally increase bobwhite vulnerability to harvest and potentially predation.

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EVALUATION OF TWO MARKING METHODS FOR 1-DAY-OLD NORTHERN BOBWHITE CHICKS

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ABSTRACT

We compared survival, weight gain, and mark retention of wing bands ($n = 50$), passive integrated transponders (PITs)($n = 50$), and leg bands proportional to the chicks size (control) ($n = 50$) on 1-day-old northern bobwhite (*Colinus virginianus*) chicks. A repeated measures, generalized complete randomized block ANOVA of the weekly gain in weight showed no difference in the chicks growth ($p >$) 0.05). Survival was similar between marking methods (wing band, PITs, leg band, and control). Retention of bands during the twelve-week pen study were equal but 4% of PITs were destroyed when adult birds were recovered after harvest. We concluded that wing bands may be the most practical method of marking 1-day-old bobwhite chicks.

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COMPARISON OF TWO METHODS FOR QUANTIFYING NORTHERN BOBWHITE HABITAT USE

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ABSTRACT

Habitat use is an important ecological parameter that is used to make informed decisions about quail management and research. Statistical methods for quantifying habitat use are numerous, but few objective criteria are available to support the selection of a particular analytical approach. Therefore, we compared breeding season habitat use by radio-marked northern bobwhites (*Colinus virginianus*) at 2 study sites in Mississippi with 2 widely used statistical methods; Chi-square goodness-of-fit test with Bonferroni confidence intervals, and compositional analysis. These statistical methods produced similar results for both study areas; however, more detailed habitat use information was provided by compositional analysis when performed using the customary hierarchical approach. Therefore, for analysis of radio-marked quail, we recommend this method due to its effective hierarchical approach, improved statistical validity, and ability to incorporate other population parameters (e.g., survival) into statistical models of habitat use by northern bobwhites.

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INTRODUCTION

Habitat use and selection are fundamental concepts in the study of vertebrate ecology and management. Following definitions from Hilden (1965) and others (Johnson 1980, Hutto 1985, Block and Brennan 1994), habitat use is simply an association of an animal with a particular habitat (i.e., collection of physical and biological features supporting life requisites). Habitat selection, however, implies a behavioral process whereby an animal chooses among alternative habitats. The result of most analyses of habitat selection is typically some level of use where one habitat is occupied disproportionate to its availability. Habitat selection can occur at a variety of different spatial and temporal scales (e.g., geographical or within an animal's home range, seasonal). In theory, animals select habitats that optimize their survival and fitness.

Habitat use and selection are important population parameters used as a basis to make informed decisions about northern bobwhite management. Bobwhites most likely select habitats at various spatial and temporal scales; a reflection of specific habitat needs for survival and reproduction. Success of management actions to increase food, cover, and other important resources which affect survival and reproduction can be evaluated with analyses of habitat use.

Following Stoddard's (1931) landmark life history study, perhaps the greatest technological advancement in the study of bobwhite habitat use and selection was development of miniaturized radio transmitters. Although not without liabilities (see Samuel and Fuller [1994] for review), use of radio transmitters to mark individual bobwhites has provided new insight on movements, habitat use, behavior, survival, and breeding biology.

Methods to analyze habitat use data based on ra-

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dio-marked animals, and test for selection, are numerous (see Alldredge and Ratti [1986, 1992] for review). All methods have limitations and advantages. One analytical method proposed by Neu et al. (1974) uses Chi-square goodness-of-fit procedures to test whether observations of habitat use follow the expected pattern of occurrence based on availability. If the Chi-square test detects a significant difference in use versus availability, a Bonferroni *z*-statistic (Miller 1981) is used to determine which habitat types are used more or less frequently than expected. This method is widely applied when use and availability were estimated at the population level and individual animals could not be uniquely marked as to generate individual case histories. As a result, the method must assume equal availability and selection among all individuals. With respect to radio telemetry data, this method forgoes the detailed information derived from individually marked animals and the more complete data structure that is provided. Nonetheless, the Neu et al. (1974) method is widely used for telemetry data (e.g., Killbride et al. 1992, Whiting and Sloan 1993, Dixon et al. 1996), is based on straightforward and easily applied calculations, and is thought to produce satisfactory results when the pooled number of marked individuals and radio locations per individual are sufficiently large (Alldredge and Ratti 1986).

More recently, compositional analysis has been recommended over other methods for assessing habitat selection (Aebischer et al. 1993a, 1993b). Designed for animal-specific paired vectors of use and availability, this method employs multivariate analysis of variance (MANOVA) procedures to first test for a departure from random habitat use. Assuming significant nonrandom use, comparisons of pair-wise differences between matching log-ratios of use and availability produces habitat ranks from most to least used. Compositional analysis is effectively designed to analyze resource selection at multiple spatial levels (i.e., study area versus home range and home range versus individual radio locations), treats the individual animal as the experimental unit, and circumvents statistical assumptions such as equal availability and selection among pooled individuals. Conversely, compositional analysis requires relatively complex calculations, and use of a Geographical Information System to manipulate and produce multilevel-proportion data for marked individuals. Aebisher et al. (1993a) specifically advocates use of compositional analyses for radio-marked individuals as this method more appropriately addresses the following areas of concern: (1) sampling level, (2) data pooling across individuals, (3) non-independence of habitat proportions, (4) differential habitat use by groups (i.e., sex, age class) of animals, and (5) definition of habitat availability.

Since the Chi-square and compositional analysis methods are two of the most widely used techniques for assessing habitat use by bobwhites, our objectives are to compare and contrast the following: (1) results from two different study areas, (2) logistical, statistical, and biological concerns that may affect results, and (3) inferential merits leading to the ensuing habitat management recommendations. Our goal was to provide a qualitative comparison of these two analytical methods for quantifying habitat use of bobwhites. This information will aid researchers and managers in interpretation of past studies and the design of future ones.

METHODS

Study Areas

Our habitat use study was conducted at 2 different sites where bobwhite management had recently been initiated. Copiah County Wildlife Management Area (CCWMA) spans 2900 hectares and is located within the Lower Thin Loess physiographic region of south Mississippi (see Pettry [1977] for description of soil resource areas). The area is dominated by old-field successional pine (*Pinus* spp.) that are 40–70+ years in age, with hardwood drains, and approximately 200 hectares of fields used for hay production prior to 1988. In 1992, disking and burning were employed to promote more suitable bobwhite habitat throughout the area. The second study site, Trim Cane Wildlife Demonstration Area (TCWDA), is located within an alluvial floodplain between the Interior Flatwoods and Blackland Prairie physiographic regions in northeast Mississippi. This 320 hectare study site is composed of old-field and wooded-hedgerow habitats and is surrounded by row-crop agriculture and pasture land. Last farmed in 1986, succession has led to a plant community dominated by broomsedge (*Andropogon* spp.) along with several pioneer tree species (e.g., groundsel tree [*Baccharis* sp.], and ash [*Fraxinus* spp.]). Beginning in 1991, disking and burning were employed on the area which floods regularly during winter and spring. For a more detailed description of study areas see Lee (1994) and Manley (1994).

Data Collection

Bobwhites were captured in collapsible funnel traps at each study area during February–March 1993 and affixed with a 7 g necklace-type transmitter. Bobwhites were located daily throughout the ensuing breeding season (15 April–1 September) via triangulation, radio receivers, directional antennae, and permanent telemetry stations. Triangulation error was assessed by calculating mean distance between point estimates and known locations of test transmitters distributed among all habitat types (White and Garrot 1990:80–90). Geographic Information Systems [PC ARC/INFO (ESRI 1989)] were used to process all telemetry data [TELEBASE (Wynn 1989)], home range data [HOMERANGE (Ackerman et al. 1990)], and study area data required to compare our 2 types of habitat use analyses.

Data Analyses

Addressing each study area separately, we first compared use of habitat types to availability using Chi-square goodness-of-fit tests and Bonferroni simul-

Table 1. Habitat use by northern bobwhites ($n = 16$), as estimated by Chi-square goodness-of-fit test followed by Bonferroni confidence intervals (Neu et al. 1974), on Copiah County Wildlife Management Area, Copiah County, Mississippi, 15 April–1 September, 1993.

		Proportion			
Habitat	Number of locations	Expected use	Actual use	Bonferroni[a] confidence interval	Result
Upland pine woods	607	0.504	0.735	0.692–0.778	Preferred
Hardwoods and drains	2	0.060	0.002	0.000–0.006	Avoided
Mixed pines and hardwoods	102	0.328	0.124	0.092–0.156	Avoided
Clearcut hardwoods	13	0.015	0.016	0.004–0.128	Proportional
Old fields and pastures	102	0.090	0.124	0.092–0.156	Preferred

[a] Confidence interval at $P < 0.05$.

taneous confidence intervals (Neu et al. 1974). Telemetry locations were pooled across animals; we assumed that habitat availability was the same for all individuals. The null hypothesis was: Use of habitat types was proportional to study area availability. Following rejection of this hypothesis, confidence intervals were used to determine which habitat types were used more or less frequently than expected.

Secondly, we considered habitat use by employing the multi-step process of compositional analysis (Aebischer et al. 1993a, 1993b, Carroll et al. 1995). We compared proportions of each habitat in the study area with proportions found in each 95% convex polygon home range (Mohr 1947). We then compared proportions of habitats in each home range with proportion of radio locations for each bird. Using MANOVA procedures (SYSTAT 1992), we tested the null hypothesis: Use of habitat types follows an expected random distribution. Following rejection of this null hypothesis, we used paired *t*-tests to compare relative use of each habitat with all others individually, and then ranked habitats according to relative use. Because of potential nonnormality of these data, we used randomization (Edgington 1980) to construct expected distributions for comparison of observed values. In order to account for missing values we calculated Wilk's lambda values using each habitat as the denominator (Aebischer et al. 1993a). We then calculated a weighted average of the Wilk's lambda values based on the number of missing values in each of the habitats used as the denominator.

RESULTS

Copiah County Wildlife Management Area

Between 15 April and 1 September 1993, 823 radio locations were obtained from 16 bobwhites. Mean number of locations per individual was 51 (range 25–75). Average distance between triangulated estimates and known points of test transmitters was 23.6 meters. Following Neu et al. (1974), habitat use was disproportionate to availability ($\chi^2 = 1478$, df = 4, $P < 0.001$), with upland pine and field habitats being preferred, mixed pine-hardwoods and hardwood drains avoided, and clear-cut habitats used in proportion to availability (Table 1).

Following compositional analysis, proportions of habitats within each home range were different from proportions within the study area ($\Lambda = 0.067$, $P < 0.001$). Analysis of individual habitats demonstrated habitat use trends identical to those of the previous goodness-of-fit tests (Table 2). However, proportions of habitat composed from individual radio locations were not different from habitats within home ranges ($\Lambda = 0.590$, $P = 0.563$). In fact, there were so many missing values in habitat availability at the home range level, we were required to drop the hardwood-drain category to complete the analysis.

Trim Cane Wildlife Demonstration Area

During the 1993 breeding season, 2117 radio locations were obtained from 32 bobwhites. Mean num-

Table 2. Matrix of differences in log-ratios of habitat use by northern bobwhites ($n = 16$), produced by compositional analysis (Aebischer et al. 1993), comparing study area versus home range proportions, Copiah County Wildlife Management Area, Copiah County, Mississippi, 15 April–1 September, 1993.

	Upland pine[a] woods		Hardwoods and drains		Mixed pines and hardwoods		Clearcut hardwoods		Old fields and pastures	
Habitat	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Upland pine woods			−5.834	0.586*	−2.996	0.837*	−4.228	0.515*	−0.268	0.182
Hardwoods and drains	+5.834	0.586*			+2.838	0.905*	+1.606	0.840	+5.566	0.654*
Mixed pines and hardwoods	+2.996	0.837*	−2.838	0.905*			−1.232	0.836	+2.728	0.856*
Clearcut hardwoods	+4.228	0.515*	−1.606	0.840	+1.232	0.836			+3.960	0.440*
Old fields and pastures	+0.268	0.182	−5.566	0.654*	−2.728	0.856*	−3.960	0.440*		
Rank[b]	4		0		2		1		3	

[a] A positive value of log-ratio differences indicates that the column habitat was used more often than row habitat. A negative value indicates the opposite. An asterisk (*) means the difference is significant at $P \leq 0.05$.

[b] Ranks were determined by comparing relative use of each habitat to all other habitats. Largest rank indicates most used habitat(s), and smallest rank indicates the least used habitat.

Table 3. Habitat use by northern bobwhites (n = 31), as estimated by Chi-square goodness-of-fit test followed by Bonferroni confidence intervals (Neu et al. 1974), on Trim Cane Wildlife Demonstration Area, Oktibbeha County, Mississippi, 15 April–1 September, 1993.

Habitat	Number of locations	Proportion: Expected use	Proportion: Actual use	Bonferroni[a] confidence interval	Result
Old field control	274	0.052	0.129	0.109–0.149	Preferred
Old field burn	170	0.116	0.080	0.064–0.096	Avoided
Old field disk	416	0.113	0.197	0.173–0.221	Preferred
Old field burn-disk	254	0.149	0.120	0.101–0.139	Avoided
Pasture	221	0.242	0.104	0.086–0.122	Avoided
Row crop soybeans	121	0.084	0.057	0.043–0.071	Avoided
Hedgerow woodlot	661	0.224	0.312	0.284–0.340	Preferred

[a] Confidence interval at $P \leq 0.05$.

ber of locations per individual was 69 (range 25–86). Average distance between estimated and known points of test transmitters was 62.0 meters. Following Neu et al. (1974), habitat use was disproportionate to availability ($\chi^2 = 685$, df = 6, $P < 0.001$), with hedgerows, strip-disked, and undamaged fields being preferred (Table 3). All other habitats were avoided.

Following compositional analysis, proportions of habitats within each home range were different from proportions within the study area ($\Lambda = 0.86$, $P < 0.001$). Comparisons of individual habitats showed hedgerows and disked fields with the most relative use. Pastures, unmanaged, and burned fields received intermediate use while row crops and burned-disked fields were least used (Table 4). Additionally, habitat proportions composed from individual radio locations were different from proportions within home ranges ($\Lambda = 0.197$, $P < 0.001$). At this level, order of use changed significantly with disked fields receiving the most relative use while hedgerows and pastures were used least. All other habitats received intermediate use (Table 5).

DISCUSSION

Comparisons of the 2 analytical methods demonstrated no difference in final results at CCWMA. Compositional analysis detected no difference in habitat use between bobwhite home ranges and individual radio locations (i.e., no 3rd order selection [Johnson 1980]). However, the 2 methods demonstrated contrasting results at TCWDA. Additionally, within the 2 levels of compositional analysis at TCWDA, significant differences in habitat use occurred between study area versus home range comparisons (i.e., 2nd order selection) and home range versus individual radio locations. Hedgerow-woodlot habitats were very important in determining where bobwhites located home ranges yet contained very few individual radio locations, suggesting a specific need for this habitat (e.g., escape cover, travel corridors). At TCWDA, the Chi-square tests with confidence intervals obscured the different habitat selection processes that occurred at different spatial scales.

Numerous concerns face researchers and managers who design and implement habitat use studies. With regard to the Chi-square-confidence interval method and radio-marked samples, we not only violated statistical assumptions when location data were pooled, but more importantly, we neglected potentially useful information based on variability of individual birds (see Schooley [1994] for review). Methods which do not pool data (e.g., compositional analysis) and have potential to consider individual variation along the year, sex, age, and other effects, provide more information on which to base management recommendations. Moreover, appropriate sampling units for a population are individuals within that population; radio telemetry allows us to estimate the habitat use of such individuals.

There are statistical and logistical constraints to the use of compositional analysis. It is not only desirable to have a large sample size of radio-marked individuals, but it is also essential that the following data be recorded for individual birds: (1) sufficient number of locations to identify the complete home range, (2) area and proportions of all habitats available, and (3) area and proportions of all habitats used. Secondly, larger sample sizes are needed if effects such as year, age, and sex are factored into the overall statistical model. Lastly, it is virtually impossible to collect and process multilevel habitat availability and use data without the aid and proficient use of GIS.

Perhaps the greatest benefit of compositional analysis is that it uses a multiscaled macrohabitat approach. As demonstrated in our comparison of data from TCWDA, this approach yields more information regarding habitat selection than the Chi-square-confidence interval method. Scale is very important in habitat selection, especially by birds, and must have serious consideration in design and interpretation of habitat studies (Wiens 1976, Orians and Wittenberger 1991, Danielson 1992). In fact, scale is likely an important factor at CCWMA, as microhabitat analyses of randomly-located plots versus those used by bobwhites showed significantly less tree basal area and density, and greater forb height in the used areas (Lee 1994). These microhabitat characteristics were missed by our 3rd order compositional analysis because so much of the available habitat proportions were upland pine woods (71% on average), with no differentiation be-

Table 4. Matrix of differences in log-ratios of habitat use by northern bobwhites (n = 31), produced by compositional analysis (Aebischer et al. 1993), comparing study area versus homerange proportions, Trim Cane Wildlife Demonstration Area, Oktibbeha County, Mississippi, 15 April–1 September, 1993.

	Old field[a] control		Old field burn		Old field disk		Old field burn-disk		Pasture		Row crop soybeans		Hedgerow woodlot	
Habitat	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Old field control			−0.563	0.602	+0.217	0.428	−1.245	0.713	−0.566	0.531	−1.881	0.655*	+1.701	0.522*
Old field burn	+0.563	0.602			+0.780	0.363*	−0.682	0.603	−0.003	0.619	−1.318	0.504*	+2.263	0.323*
Old field disk	−0.217	0.428	−0.780	0.363*			−1.462	0.413*	−0.782	0.515	−2.098	0.553*	+1.484	0.286*
Old field burn-disk	+1.245	0.713	+0.682	0.603	+1.462	0.413*			+0.679	0.659	−0.636	0.762	+2.946	0.476*
Pasture	+0.566	0.531	+0.003	0.619	+0.782	0.515	−0.679	0.659			−1.315	0.588*	+2.266	0.479*
Row crop soybeans	+1.881	0.655*	+1.318	0.504*	+2.098	0.553*	+0.636	0.762	±1.315	0.588*			−3.581	0.403*
Hedgerow woodlot	−1.701	0.522*	−2.263	0.323*	−1.484	0.286*	+2.946	0.476*	−2.266	0.479*	−3.581	0.403*		
Rank[b]	4		3		5		1		2		0		6	

[a] A positive value of log-ratio differences indicates that the column habitat was used more often than row habitat. A negative value indicates the opposite. An asterisk (*) means the difference is significant at $P \leq 0.05$.

[b] Ranks were determined by comparing relative use of each habitat to all other habitats. Largest rank indicates most used habitat(s), and smallest rank indicates the least used habitat.

Table 5. Matrix of differences in log-ratios of habitat use by northern bobwhites (n = 31), produced by compositional analysis (Aebischer et al. 1993), comparing home range with individual radio-location proportions, Trim Cane Wildlife Demonstration Area, Oktibbeha County, Mississippi, 15 April–1 September, 1993.

	Old field[a] control		Old field burn		Old field disk		Old field burn-disk		Pasture		Row crop soybeans		Hedgerow woodlot	
Habitat	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Old field control			−1.205	0.469*	+0.059	0.338	−0.054	0.266	−1.516	0.463*	+0.335	0.417	−0.838	0.336*
Old field burn	+1.205	0.469*[a]			+1.407	0.458*	+0.641	0.489	−0.336	0.646	+0.726	0.512	−0.198	0.392
Old field disk	−0.059	0.338	−1.407	0.458*			−0.031	0.370	−1.824	0.508*	−0.839	0.308*	−1.187	0.297*
Old field burn-disk	+0.054	0.266	−0.641	0.489	+0.031	0.370			−1.487	0.467*	−0.331	0.767	−0.879	0.363*
Pasture	+1.516	0.463*	+0.336	0.646	+1.824	0.508*	+1.487	0.467*			+1.430	0.753	+0.672	0.443
Row crop soybeans	−0.335	0.417	−0.726	0.512	+0.839	0.308*	+0.331	0.767	−1.430	0.753			−1.139	0.265*
Hedgerow woodlot	+0.838	0.336*	+0.198	0.392	+1.187	0.297*	+0.879	0.363*	−0.672	0.443	+1.139	0.265*		
Rank[b]	4		2		6		4		0		4		1	

[a] A positive value of log-ratio differences indicates that the column habitat was used more often than row habitat. A negative value indicates the opposite. An asterisk (*) means the difference is significant at $P \leq 0.05$.

[b] Ranks were determined by comparing relative use of each habitat to all other habitats. Largest rank indicates most used habitat(s), and smallest rank indicates the least used habitat.

tween vegetation characteristics within these pine stands.

We recognize our comparison of two methods for analyzing bobwhite habitat use is qualitative and limited to only 2 data sets. Nonetheless, the Neu et al. (1974) approach (i.e., Chi-square goodness-of-fit tests with confidence intervals) provided results similar to Aebischer et al. (1993a) compositional analysis at CCWMA, yet lacked resolution at TCWDA. It is important to remember that the Chi-sqaure method was developed for use on unmarked individuals and is still very applicable for such data. Nonetheless, we recommend that compositional analysis be used for habitat use data derived from radio telemetry due to its improved statistical validity, hierarchical approach, and ability to incorporate other populations parameters (e.g., year, age, sex, survival) into statistical models.

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DEMOGRAPHICS OF QUAIL HUNTERS IN OKLAHOMA

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ABSTRACT

We collected information from Oklahoma hunters during a telephone survey conducted in February 1997, to compare demographics of scaled quail (*Callipepla squamata*) and northern bobwhite quail (*Colinus virginianus*) hunters to other hunters. Eight hundred ninety-two annual, 709 lifetime, and 376 senior citizen hunting license holders, stratified by county of residence, were interviewed. Respondents who hunted quail differed from other hunters by age group, age of first hunting experience, the proportion of their life (≥ 16 years of age) they have owned an Oklahoma hunting license, education level, annual household income, access to a computer at work, access to a computer at home, and access to the Internet at work ($P \leq 0.030$). No difference ($P \geq 0.219$) was found between hunter types by residential location, hunting license type, proportion of life residing in Oklahoma, ethnic origin, and access to the Internet at home. This information can help wildlife managers better understand their quail hunting constituents and tailor agency programs to fit their needs.

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INTRODUCTION

In Oklahoma, as many as 120,500 quail hunters harvest up to 3,242,000 quail annually (Table 1) (Thompson 1988). However, little is known about the average quail hunter in Oklahoma. The most recent demographic information available about quail hunters was reported by Ellis (1972). This information is >25 years old and may not be representative of today's quail hunters.

Understanding constituents is important to wildlife administrators and managers. Knowing the demographics of different user groups allows wildlife agencies to better understand their audience and develop programs to protect the wildlife resources, provide optimum recreational opportunity, and address, where possible, needs of constituents.

This paper reports demographic information about quail hunters in Oklahoma. The data was collected as part of a survey used to estimate the number of hunters and the magnitude of small game harvest in Oklahoma (LaPierre 1997).

METHODS

A sample of 2,945 Oklahoma resident hunting license holders was drawn for the survey. The randomly drawn sample included 1996 hunting and combination (hunting and fishing) license holders for each of the major license types (annual, lifetime, and senior citizen). The sample was stratified by both license type and county of residence.

Non-resident and disabled hunting license holders were not included in the sample. These license categories represented a very small proportion (about 6%) of the total number of valid hunting licenses in Oklahoma. Omission of non-resident and disabled hunting license holders could have biased the data but the impact was probably negligible.

Landowners hunting exclusively on their own property were not required to purchase an Oklahoma hunting license and therefore were not eligible for sampling. The magnitude of bias introduced by exclusion of landowners is unknown. The results of this study should only be generalized to Oklahoma resident hunting license holders.

Two weeks prior to the beginning of the survey, postcards were mailed to approximately 2,500 of the selected license holders. The postcard notified each license holder of their selection for participation in the survey and briefly described the purpose of the interview. License holders that were sent a postcard did not differ in any systematic way from those that were not sent a postcard.

A computer-assisted telephone interview (CATI) system was used to interview 892 annual, 709 lifetime, and 376 senior citizen license holders in Oklahoma. The CATI system provided on-screen prompting of questions to be read by interviewers and direct entry of survey data into the computer. Telephone interviews were conducted during February and March, 1997. Most calls were made on weeknights and Saturday mornings. At least 5 attempts were made to contact each selected license holder at different times of the day and on different days.

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[1] Present address: Texas Parks and Wildlife Department, 4200 Smith School Rd., Austin, TX 78744.

Table 1. Statewide estimates for number of quail hunters, quail harvest, quail hunter success, and percent (%) of hunters who did the majority of quail hunting in their county of residence, Oklahoma, 1986–96.

Year	Sample	Mean bag/ hunter	Mean days hunted	Mean daily bag	No. of hunters	No. of days hunted	Total harvest	95% confidence interval for total harvest	% hunted mostly in own county
1986[a]	537	24.43	7.06	3.46	110,960	783,378	2,711,186	2,352,252–3,070,119	55.26
1987[b]	517	26.90	7.51	3.58	120,517	905,083	3,242,080	2,800,473–3,683,687	63.09
1988[c]	422	20.61	7.08	2.91	97,651	691,369	2,012,172	1,701,565–2,322,779	64.45
1989[d]	415	24.00	7.10	3.30	92,465	656,502	2,179,840	1,805,160–2,554,520	57.70
1990[e]	400	24.26	7.46	3.04	93,026	694,204	2,256,571	1,892,142–2,621,000	64.00
1991[f]	799	32.98	9.85	3.35	98,268	968,171	3,240,764	2,846,242–3,635,286	65.83
1992[g]	668	35.38	8.58	3.86	94,079	806,997	3,238,404	2,861,486–3,795,323	69.76
1993[h]	652	22.19	8.31	2.60	90,733	754,251	2,013,098	1,778,982–2,247,214	63.34
1994[i]	491	27.44	9.35	2.64	84,089	786,088	2,307,057	1,976,583–2,637,532	66.19
1995[j]	569	14.42	6.86	2.15	68,646	471,111	990,118	836,199–1,144,036	52.20
1996[k]	542	18.18	7.14	2.58	72,743	519,133	1,332,260	1,141,940–1,502,580	50.37

[a] Thompson, 1987.
[b] Thompson, 1988.
[c] Thompson, 1989.
[d] Stiver, 1990.
[e] Stiver, 1991.
[f] DeMaso, 1992.
[g] DeMaso, 1993.
[h] DeMaso, 1994.
[i] DeMaso, 1995.
[j] DeMaso, 1996.
[k] LaPierre, 1997.

The Oklahoma upland game harvest survey was conducted using similar telephone survey methodology from 1986–1996. Although the human dimensions questions changed every year, the methods used to collect and analyze harvest data for each species were consistent. Socioeconomic information about respondents was not collected in prior years and therefore was not available for comparative analysis. In 1991, the goal for completed interviews was increased from 1,000 to 2,000. The only major methodological change from 1986–1996 was that in 1994 the CATI system was implemented, replacing pen-and-paper data recording. This change was largely administrative and was not believed to bias the harvest trend data presented in this paper.

Statewide total number of hunters and harvest estimates were determined by calculating the proportion of hunters from the survey who hunted quail and their mean bag for the season. These estimates were extrapolated to the entire population of hunters after adjusting for the fact that not all license holders hunted in 1996. Chi-square tests were used to detect significant differences between categories. All tests were considered significant at $P < 0.05$.

Only active hunters (those survey participants who responded "Yes" to the question, "Did you hunt in Oklahoma during 1996?") were used in the comparison between respondents that hunted quail and those that did not (Table 2). Among active hunters, hunter category was determined by participation in the 1996 quail season. Quail-hunting respondents were defined as active hunters who responded "Yes" to the question, "Did you hunt quail in Oklahoma in 1996?" Non-quail-hunting respondents were active hunters who responded "No" to this question. Quail-hunting respondents did not necessarily hunt exclusively for quail but may have hunted other Oklahoma game species as well.

No information was gathered about participation in past quail seasons. Respondents that hunted quail in a previous year but skipped the 1996 season were not considered quail-hunting respondents. Lacking any evidence to the contrary, it can only be assumed that 1996 was similar to any other year in regard to the number of dedicated or occasional quail hunters dropping out of the sport or new quail hunters joining. Therefore, 1996 season quail-hunting-respondents were thought to be similar to hunters in other years.

Respondents were asked to report the number of years they lived in Oklahoma and the number of years they held an Oklahoma hunting license (Table 2). These variables could not be interpreted without accounting for the respondent's current age. For analysis, both variables were converted to proportions. The proportion of life residing in Oklahoma was calculated as the number of years residing in Oklahoma divided by the respondent's age. The proportion of life owning an Oklahoma hunting license had to be adjusted to account for the fact that a hunting license was not required before 16 years of age. This variable was calculated as the number of years holding an Oklahoma hunting license divided by the respondent's current age, after reducing age by 15 years. Both proportion variables are presented as percentages (0–100%).

Type of residential location was determined by county of residence. Counties considered urban were those with a population density of >100 people per square mile (Oklahoma, Tulsa, Canadian, and Cleveland counties) (Oklahoma Department of Libraries 1995).

Table 2. Questions asked of survey respondents to collect human dimensions information for quail-hunting respondents and non-quail-hunting respondents in Oklahoma, 1996.

Question number	Question
1	Did you hunt in Oklahoma during 1996?
2	*Asked for all upland game species under consideration (American crow, mourning dove, ring-necked pheasant, prairie chicken, quail, cottontail rabbit, jackrabbit, swamp rabbit, fox squirrel, gray squirrel, fall turkey, spring turkey, and American woodcock):* a. Did you hunt [species] in Oklahoma during 1996? b. How many days did you hunt [species] in Oklahoma during 1996? c. How many [species] did you harvest during the 1996 season? d. In which county did you hunt [species] most often during 1996? e. Did you hunt [species] on private land, public land, or both types of land? f. What was the name of the public area on which you hunted [species] most often during 1996? g. How many of the [total number from part b] days that you hunted [species] did you hunt on public land? h. How many of the [total number from part c] [species] that you harvested were harvested on public land?
3	Do you have access to a computer at work? . . . at home?
4	Do you have access to the Internet at work? . . . at home?
5	For how many years have you held a hunting license in Oklahoma?
6	At what age did you start hunting?
7	For how many years have you lived in Oklahoma?
8	What is your county of residence?
9	What is your age, please?
10	What is the highest grade of school you have completed? (Multiple choices)
11	What is your ethnic origin? (Multiple choices)
12	I am going to read a list of income categories for household income from all sources, before taxes, during 1996. Please stop me when I get to yours. (Multiple choices)
13	Respondent's gender. (Not asked, simply noted.)

Near the end of the survey a shortage of time and money caused most of the human dimensions questions to be deleted from the last 510 respondent interviews. The only variables impacted in this quail hunter analysis were those pertaining to access to a computer and the Internet at work and at home (Table 2). Eighteen percent of annual (*n* = 269), 19.3% of lifetime (*n* = 194), and 10.4% of senior citizen (*n* = 47) license holders were not asked these questions. It is possible that the disproportion of senior citizen license holders included in the analysis of the data for these questions biased the results, because senior citizens may be less likely to work and to own a home computer. However, as participation in quail season was not found to differ by hunting license type, this age-related bias was probably equally distributed among both quail-hunting and non-quail-hunting respondents, having little effect on the computer-related variables.

RESULTS

Of the 2,945 attempted surveys, interviews were completed for 1,977 license holders. Eight hundred forty-six attempted surveys could not be completed. Reasons for incomplete surveys included: the license holder moved or was deceased; the phone number was incorrect, disconnected or not in service; no contact was made after five attempts; communication problems (hearing impaired or language barrier), the number was a facsimile machine; or the license holder was not available during the survey period. Only 9 interviews were incomplete because of communication problems. Less than half were senior citizen license holders, which reduced the likelihood that bias against the elderly was introduced as a result of the communication problems. An additional 122 license holders (4%) refused to participate in the survey. Refusals occurred in all license types and in no consistent pattern, and therefore were not likely to bias the data. After removing license holder phone numbers that could not possibly have resulted in complete interviews (deceased license holders, facsimile numbers, and wrong or disconnected numbers) the survey response rate was 78%.

Eighty-five percent (*n* = 1,681) of the Oklahoma hunting license holders surveyed (*n* = 1,977) hunted at least one day during 1996. Survey respondents were asked about their participation in 14 specific hunting seasons: American crow (*Corvus brachyrhynchos*), mourning dove (*Zenaidia macroura*), ring-necked pheasant (*Phasianus colchicus*), prairie chicken (*Tympanuchus cupido* and *T. pallidicinctus*), northern bobwhite (*Colinus virginianus*) and scaled quail (*Callipepla squamata*), cottontail rabbit (*Sylvilagus floridanus*), jackrabbit (*Lepus californicus*), swamp rabbit (*S. aquaticus*), gray squirrel (*Sciurus carolinensis*), fox squirrel (*S. niger*), wild turkey (*Meleagris gallopavo silvestris* and *M. g. intermedia*), American woodcock (*Scolopax minor*), and deer (*Odocoileus virginianus* and *O. hemionus*). The only major hunting season not included in the survey was the waterfowl season.

Quail (scaled quail and/or northern bobwhite) were the most popular small game species hunted by respondents (Figure 1). Of the respondents who hunted in 1996, 32.2% (*n* = 542) hunted quail and 67.7% (*n* = 1,139) did not. For comparison, 28.8% (*n* = 484) of the active hunters hunted mourning dove, 27.7% (*n* = 466) hunted fox squirrel and/or gray squirrel, and 24.5% (*n* = 412) hunted wild turkey. Considering the 14 seasons in question on the survey, 25.3% (*n* = 137) of the quail-hunting respondents hunted exclusively for quail (although participation in waterfowl season was not reported).

Annual, lifetime and senior citizen license holders surveyed were equally likely to hunt quail ($X^2 = 0.06$, df = 2, $P = 0.972$). Statewide harvest estimates and various measures of quail hunting activity from 1986–96 are presented in Table 1. The majority (76.2%, *n* = 413) of 1996 Oklahoma quail-hunting respondents hunted quail exclusively on private land. Respondent

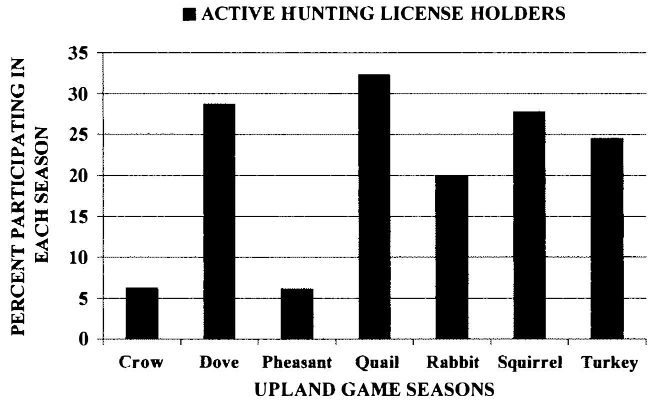

Fig. 1. Distribution of participation in Oklahoma's upland game hunting seasons by respondents that hunted in Oklahoma during 1996 (n = 1680). See Table 2, question 2a for exact wording.

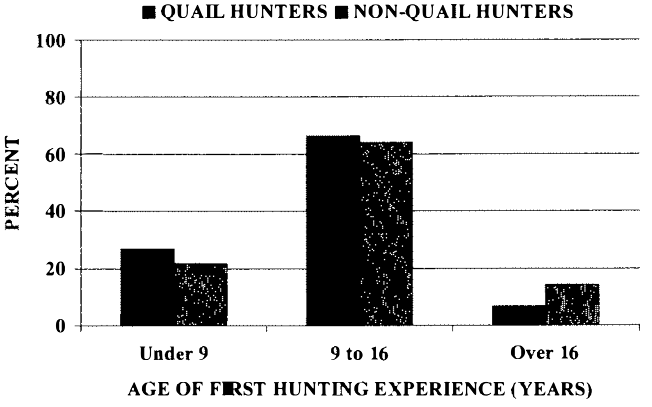

Fig. 3. Distribution of age of first hunting experience (with any species) by hunter category, in Oklahoma, 1996 (X^2 = 21.61, df = 2, P = 0.001, n = 1676). The sample size was reduced by 4 respondents who could not recall the age at which they began hunting. See Table 2, question 6 for exact wording.

use of public land was more common for rabbit, squirrel and turkey hunting (Figure 2).

Half (50.7%, n = 273) of the quail-hunting respondents hunted quail most often in their county of residence (Table 1). Hunters in both categories resided in similar types of locations (X^2 = 1.37, df = 1, P = 0.242). Seventy-three percent (n = 825) of non-quail-hunting respondents and 69.7% (n = 378) of quail-hunting respondents lived in rural counties.

Age of first hunting experience (for any species) varied according to hunter category (X^2 = 21.61, df = 2, P = 0.001). The distribution of age of first hunting experience for quail-hunting respondents was more skewed toward younger age categories than was the distribution of age of first hunting experience for non-quail-hunting respondents (Figure 3). Twenty-six percent (n = 145) of quail-hunting respondents and 21.6% (n = 245) of non-quail-hunting respondents began hunting at $<$9 years of age.

Proportion of life residing in Oklahoma did not vary according to hunter category (X^2 = 2.69, df = 3, P = 0.442). The majority of both quail-hunting respondents (77.9%, n = 422) and non-quail-hunting respondents (74.9%, n = 849) lived in Oklahoma 76–100% of their lives. Proportion of life ($\geq$16 years of age) owning an Oklahoma hunting license varied according to hunter category (X^2 = 28.20, df = 3, P = 0.001) (Figure 4). Seventy-three percent (n = 387) of quail-hunting respondents and 59.2% (n = 661) of non-quail-hunting respondents had an Oklahoma hunting license for 76–100% of the years between 16 years of age and their current age.

Nearly all (98.3%, n = 533) quail hunters surveyed were male, although most non-quail hunters surveyed were also male (95.5%, n = 1,087). Quail-hunting and non-quail-hunting respondents did not significantly differ from one another according to ethnic origin (X^2 = 1.513, df = 1, P = 0.219). The majority of both hunter groups were Caucasian (90.8%, n = 492 and 88.8%, n = 1,007, respectively).

The current age category of quail-hunting respondents and non-quail-hunting respondents differed significantly (X^2 = 20.91, df = 6, P = 0.002) (Figure 5). The age distribution of quail-hunting respondents was

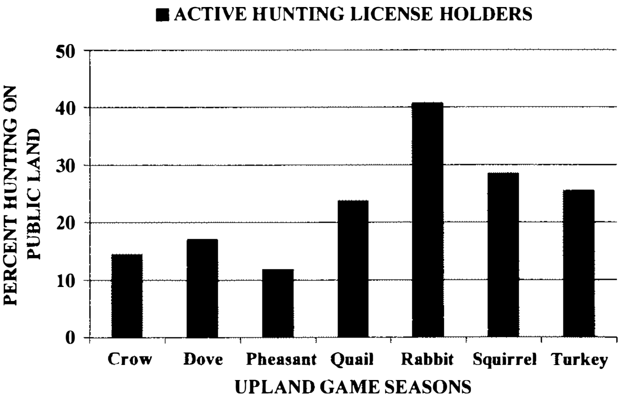

Fig. 2. Distribution of use of public land for Oklahoma's upland game hunting seasons by respondents that hunted each species in 1996. Sample sizes varied by species: crow (n = 104); dove (n = 484); pheasant (n = 102); quail (n = 542); rabbit (n = 333); squirrel (n = 466); and turkey (n = 412). See Table 2, question 2e for exact wording.

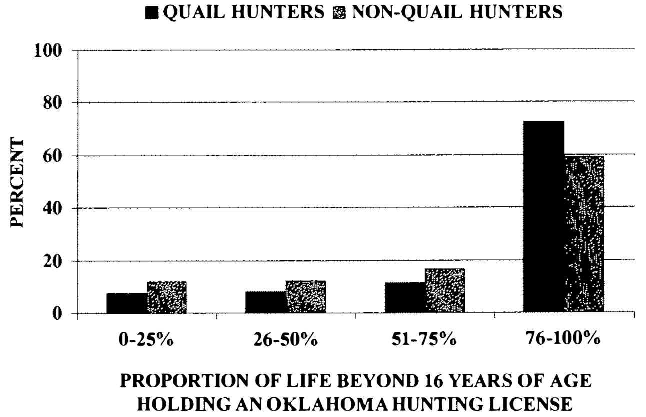

Fig. 4. Distribution of proportion of life ($\geq$16 years of age) that respondents owned an Oklahoma hunting license by hunter category, in Oklahoma, 1996 (X^2 = 28.20, df = 3, P = 0.001, n = 1680). See Table 2, question 5 for exact wording.

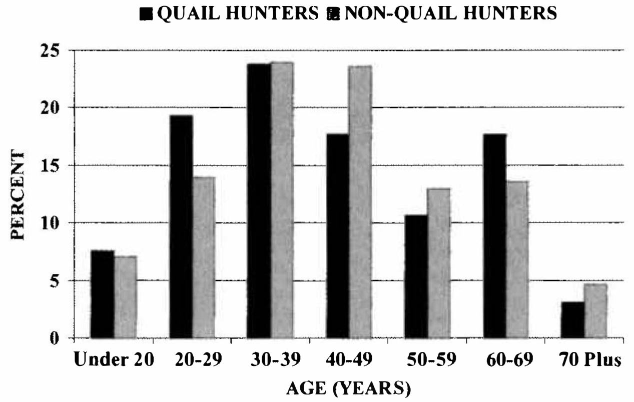

Fig. 5. Distribution of respondent age class by hunter category, in Oklahoma, 1996 (X^2 = 20.91, df = 6, P = 0.002, n = 1680). See Table 2, question 9 for exact wording.

more skewed toward the younger age classes than the age distribution of non-quail-hunting respondents. However, the proportion of quail-hunting respondents in the 60–69 year old age category was larger than the proportion of non-quail hunting-respondents in the same category.

Quail-hunting respondents were more likely to have completed a higher level of education than non-quail-hunting respondents (X^2 = 31.56, df = 7, P = 0.001) (Figure 6). Thirty-eight percent (n = 428) of non-quail-hunting respondents and 48.3% (n = 262) of quail-hunting respondents had at least some college education.

Annual household income differed according to hunter category. Quail-hunting respondents' incomes were more likely to fall within the upper income categories than were incomes of non-quail-hunting respondents (X^2 = 26.66, df = 7, P = 0.001) (Figure 7). Twenty-four percent (n = 250) of non-quail-hunting respondents and 33.2% (n = 170) of quail-hunting respondents reported annual household incomes of at least $50,000; 43.9% ($n$ = 463) of non-quail-hunting respondents and 34.4% (n = 176) of quail-hunting respondents reported annual household incomes under $30,000.

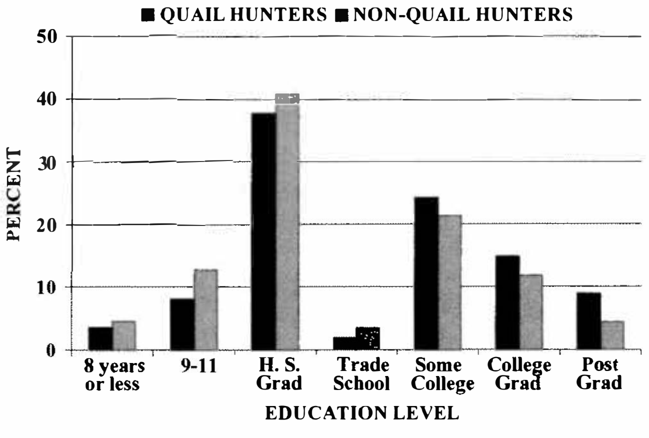

Fig. 6. Distribution of respondent education level by hunter category, in Oklahoma, 1996 (X^2 = 31.56, df = 7, P = 0.001, n = 1675). The sample size was reduced by 5 respondents who refused to answer the education question. See Table 2, question 10 for exact wording.

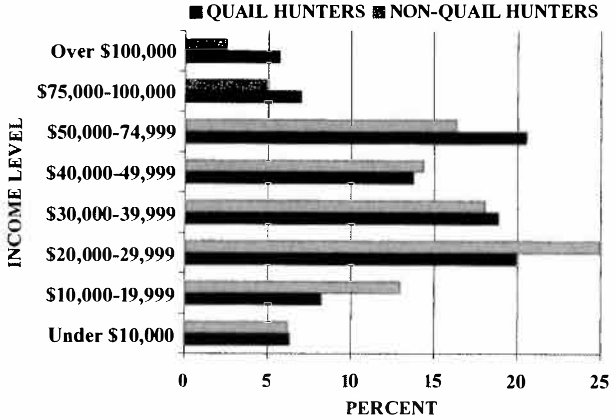

Fig. 7. Distribution of respondent annual household income by hunter category, in Oklahoma, 1996 (X^2 = 27.86, df = 8, P = 0.001, n = 1567). The sample size was reduced by 113 respondents who refused to answer the income question. See Table 2, question 12 for exact wording.

Quail-hunting respondents were more likely than non-quail-hunting respondents to have access to a computer at work (X^2 = 10.02, df = 1, P = 0.002), access to a computer at home (X^2 = 4.71, df = 1, P = 0.030), and access to the Internet at work (X^2 = 9.30, df = 1, P = 0.002) (Figure 8). Hunters in both categories were equally likely to have access to the Internet at home (X^2 = 0.41, df = 1, P = 0.520).

DISCUSSION

Some of the results of this survey can be compared to the results of the 1967 survey conducted by Ellis (1972), although the methodologies differed. Ellis con-

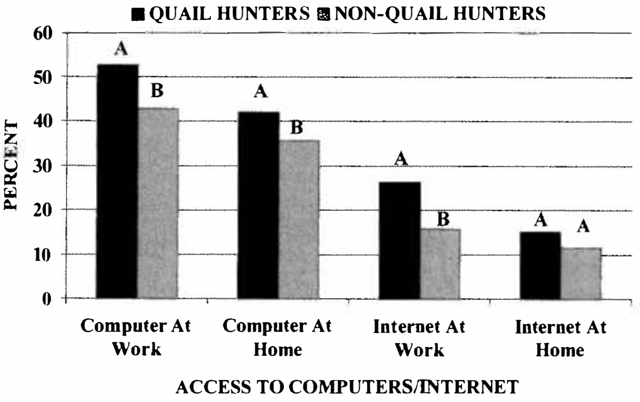

Fig. 8. Distribution of computer and Internet access at work and home by hunter category, in Oklahoma, 1996. Significant differences between adjacent columns indicated by different letters (from left to right: X^2 = 10.02, df = 1, P = 0.002, n = 1172; X^2 = 4.71, df = 1, P = 0.030, n = 1172; X^2 = 9.30, df = 1, P = 0.002, n = 541; X^2 = 0.41, df = 1, P = 0.520, n = 443). The sample size was reduced because the questions were not asked of the last 510 respondents interviewed. Respondents lacking access to a computer at home or at work were not asked about Internet access at that location. See Table 2, questions 3–4 for exact wording.

Table 3. Comparison of Oklahoma quail hunting activity by survey respondents in 1967 and 1996.

Variable	1967[a]	1996
Survey methodology	Mail	Telephone
Response rate (usable/attempted, not adjusted for ineligibles)	51.2%	67.2%
Proportion of respondents that hunted quail	51.7%	32.2%
Quail hunter sample size	2,646	542
Length of quail season	26 days	98 days
Proportion of quail hunting occurring on private land	69.2%	76.2%
Estimated number of quail hunters statewide	167,000	73,318
Mean quail bag/hunter (season)	17.4	18.2
Mean quail bag/hunter (daily)	3.6	2.6
Mean number of days hunted quail	6.2	7.1
Proportion of quail hunters that were male	97.8%	98.3%

[a] Data from Ellis (1972).

ducted his survey by mail rather than by telephone, sending one follow-up mailing of the survey instrument to nonrespondents. Most of his survey questions pertained to quail hunting, probably resulting in a disproportionate number of surveys completed by quail hunters. For example, 51.7% (*n* = 2,646) of all 1967 respondents (active hunters or not) hunted quail (Ellis 1972), while 27.4% (*n* = 542) of all 1996 respondents (active hunters or not) hunted quail.

The proportion of quail hunting that took place on private land in Oklahoma during 1996 (76.2%) was higher than what was reported by Ellis (1972) (69.2%, Table 3), despite an increase in the acreage of public hunting land with suitable quail habitat available. This may partially be explained by an overall increase in hunting pressure on public land and a resulting avoidance of crowded areas. Alternatively, the decrease in public land use by quail hunters can be explained by season conflicts. During the time period in which deer and quail seasons overlap in Oklahoma, public hunting areas are restricted to deer hunting only, prohibiting use by quail hunters. This can eliminate up to the first two weeks of quail hunting on public land. The opening weekend of any season generally is the most popular, helping explain the decrease in public land use for quail hunting in Oklahoma.

The total number of quail hunters reported by Ellis was recalculated in a manner similar to the calculations done in 1996. Using this method, the estimated number of 1996 quail hunters in Oklahoma (72,743) was lower than Ellis's (1972) estimate (143,933) for 1967 (Table 3). The decline in quail hunter numbers may partially result from regional declines in quail populations (Brennan 1991) and the associated decrease in hunter interest.

Estimates of quail hunter success for this study were mean bag per hunter per season and mean daily bag. During 1996, the mean bag per hunter per season was 18.2 quail and the mean daily bag was 2.6 quail. These estimates are similar to what Ellis (1972) reported for Oklahoma quail hunters in 1967 (17.4 and 3.6 quail, respectively). The mean number of days hunted by Oklahoma quail-hunting respondents during 1996 was 7.1 days (Table 3), while Ellis (1972) reported that Oklahoma quail hunters hunted an average of 6.2 days/season. This is surprising, considering that the 1996 Oklahoma quail season was 98 days, compared to the 1967 season of 26 days. This may indicate that the amount of time spent quail hunting is limited by factors other than season length (i.e., vacation time, access to hunting areas, real or perceived availability of quail, expense of the sport, or other).

The 1996 estimates of gender distribution of quail-hunting respondents (98.3% male and 1.7% female) were similar to those in the 1972 study by Ellis (97.8% male and 2.2% female).

Other important findings of this study were not included in the study by Ellis (1972). Quail-hunting respondents reported an age of first hunting experience (for any species) that was often younger than that of non-quail hunters. While the future of all hunting is dependent upon the recruitment of new hunters, it may be especially important for quail hunter recruitment efforts to focus on younger individuals.

Quail-hunting respondents tended to have higher annual household incomes than did non-quail-hunting respondents. Most also lived in rural counties, which is where the majority of wildlife habitat occurs. Having more discretionary income than other hunters may make quail hunters a good market segment to target for programs designed to improve wildlife habitat on private land. Although wildlife management activities (e.g., bulldozing, disking, prescribed burning, etc.) are cost-inhibitive for many rural landowners, this may not be the case for quail hunters. State agencies often lack funds to provide landowners monetary compensation, free materials, or free labor for wildlife management, but free technical assistance may be an adequate incentive for this quail-hunting market segment.

Quail-hunting respondents tended to have more education than non-quail-hunting respondents, although many non-quail hunting respondents were also well educated. This implies that some of the common myths about quail life history and management may be perpetuated *not* because hunters are incapable of understanding the science behind wildlife management, but because there is a breakdown in the transfer of this information from wildlife professionals to our constituents.

In general, computers and the Internet were more accessible for quail hunters than for non-quail hunters, although less than 50% of respondents had Internet access in either hunter category. In all likelihood, the proportion of hunters using the Internet will increase with time and electronic distribution of information will be an ever-increasingly important method by which state agencies communicate with constituents. The use of electronic communication to make information available can help wildlife managers make more efficient use of their time, as one-on-one communication with interested constituents can be time intensive. Web sites with "frequently asked questions" can conveniently provide quick answers to common hunter questions at any hour of the day. Technology can also enable quail hunters and other constituents to e-mail questions, concerns and observations to the agency for a faster reply than by postal mail. Electronic forms of communication should not replace personal contact, but should provide economical methods to supplement traditional forms of communication.

MANAGEMENT IMPLICATIONS

Private industry has used market analysis for years to determine key characteristics and needs of customers. It should not be different for the public sector. State wildlife agencies often know very little about their constituents other than the broad assumptions made about traditional hunters and anglers. Becoming familiar with common characteristics of specific user groups (i.e., quail hunters) allows managers to better understand their clientele and develop programs accordingly. This information can be useful not only for state agencies, but for the private industries supporting hunting and fishing as well (i.e., sportsmen's groups, manufacturers of sporting goods).

ACKNOWLEDGMENTS

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MISSOURI'S QUAIL HUNTER COOPERATOR SURVEY

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ABSTRACT

Since 1938, Missouri has surveyed northern bobwhite *(Colinus virginianus)* hunters to learn of hunter demographics and hunting success. This information is useful for identifying long-term trends in hunting activity and for planning future hunting recreation and regulations. In this paper, I evaluate temporal variation in hunting success within and among hunting seasons. The survey was generated from daily hunting journals of 200 to 600 quail hunters.

On a week-by-week basis, cooperators harvest most quail during the first week of the season. Hunting has consistently been concentrated in a handful of days including the first and last 2 days of the season, Saturdays, Sundays, and holiday weekends. The rate at which quail were found decreased with time during the hunting season. Comparing hunters from metropolitan and rural areas, hunting activity and success have changed with time. During 1938 to 1944, city hunters spent less time in the field and found and bagged quail at a lower rate than did rural hunters. During the 1980's, however, city hunters spent more time in the field and found and bagged quail at a rate almost equal to that of rural hunters. I discuss implications of various trends in hunting activity for management of hunting recreation.

Citation: Dailey, T.V. 2000. Missouri's quail hunter cooperator survey. Page 226 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, Jr., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

THE BOBWHITE BRIGADE: AN INNOVATIVE APPROACH TO WILDLIFE EXTENSION EDUCATION

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ABSTRACT

A pilot program was initiated in 1993 to train high school youth in natural resource management and leadership skills with the goal of training them as "master volunteers." The "Bobwhite Brigade" was formed to educate youth about northern bobwhite (*Colinus virginianus*) biology and management needs. Cadets (high school sophomores and juniors) undergo an intensive curriculum in bobwhite biology, applied ecology, critical thinking skills and leadership development to equip them as spokespersons for wildlife management. Upon graduation from the Brigade, cadets are required to give >3 educational programs to various audiences (youth and adult), and are provided incentives to give additional programs. Through 1996, 145 young people had graduated from the Brigade and presented approximately 1,200 educational programs. These programs have included newspaper and magazine articles, TV stories, public service announcements, and direct contacts through tours and field days. Quail Unlimited recognized the Bobwhite Brigade with its inaugural "Youth in Conservation Award" in 1994, and recognized the Brigade again in 1996 with another award. The Bobwhite Brigade model has served as a springboard for similar programs in >6 other states. The underlying message reinforced throughout the Bobwhite Brigade is one of ecosystem management and how "the whole *is* greater than the sum of the parts." We have found that ecosystem management concepts can be delivered to high school youth in a very tangible manner with a very popular, non-controversial native wildlife species. This same model holds great potential for other youth camps where there is an emphasis on wildlife extension education.

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INTRODUCTION

The Bobwhite Brigade, initiated in 1993, is a 5-day "boot camp" on bobwhite biology and management aimed at educating high school youth in conservation and leadership skills. The Bobwhite Brigade embraces the energy of youth, the charismatic appeal of wildlife (in this case, the northern bobwhite), the importance of natural resource conservation, and the need to educate the public about natural resource issues.

The impetus for the Bobwhite Brigade was the need to develop a corps of trained volunteers for providing nontechnical information on wildlife to a variety of audiences (e.g., school groups, civic clubs). Time, travel, and budget constraints often preclude Extension specialists from addressing all groups with information needs. Urban horticulturists in Texas developed a "Master Gardener" program to provide in-depth training to volunteers, certify them as "Master Gardeners," then empower them to handle the more routine aspects of horticulture. We adapted this concept to empower youth to be ambassadors for conservation. We describe the components of this successful youth education workshop and offer advice about expanding this successful effort to other states.

Cadets undergo extensive training in bobwhite biology, ecology, human dimension aspects of wildlife conservation, public speaking, critical thinking and program development. The Bobwhite Brigade differs from other summer camps in that participants must agree to conduct >3 educational programs upon returning to their communities. Cadets are tested to assess their knowledge about bobwhites before and immediately after the camp.

While the Bobwhite Brigade focuses on quail, the cadets are trained to view quail within the context of the "big picture." Impacts of various quail management strategies on nonhunted species (e.g., neotropical migrant birds) are discussed. Similarly, while the role of hunters in quail conservation is stressed, an appreciation for nonconsumptive recreation like photography and birding are also encouraged and developed.

OBJECTIVES OF THE BRIGADE

1. To provide intense training to a cadre of motivated high school youth on quail biology and manage-

ment, and the ecological processes prerequisite to maintaining quail on the Texas landscape.

2. To improve leadership skills of cadets, especially relative to natural resource management, and subsequently develop young spokespersons to serve as Master Volunteers for conservation.
3. To refine students' critical thinking skills as a method for evaluating management alternatives and differentiating fact from fiction.
4. To assemble a team of resource specialists from various agencies and interested volunteers to plan and execute interdisciplinary conservation education efforts.

DESCRIPTION OF THE PROGRAM

A maximum of 30 in-state, plus 2 out-of-state "cadets" (high school youth 14 to 17 years old) are selected from a pool of applicants by the Steering Committee. The Steering Committee is comprised of representatives of the Texas Agricultural Extension Service (TAEX), Quail Unlimited, Texas Parks & Wildlife Department (TPWD), United States Department of Agriculture Natural Resources Conservation Service (USDA-NRCS), interested volunteers and various sponsors (e.g., local Soil and Water Conservation Districts). The camp is conducted at the Krooked River Lodge located near Abilene, Texas during the last week of June.

Cadets are charged a tuition ($200 in 1997) which covers meals, lodging, and teaching resources. Cadets are grouped into "coveys" of 5 youths each. Each covey is coupled with a "Covey Leader" and an "Assistant Covey Leader" (ACL) (cadets from a previous Battalion who have earned the right to return as counselors). Cadets undergo a rigorous curriculum of biology, conservation and leadership skills. Disciplines covered include morphology, behavior, botany, applied ecology, ornithology, entomology, photography, art, firearms safety, and journalism. Teaching is a blend of lecture and hands-on activities, most of which are conducted in the field. Field projects include plant identification, radio telemetry, nest depredation studies, habitat analysis, dog training, and birding. Pre- and post-testing are conducted to assess information transfer.

Cadets sign a "contract" with the Bobwhite Brigade requiring them to complete >3 educational programs in their home communities upon graduation from the Brigade. Those who complete the most programs are invited back the following year to serve as ACLs. The ACLs are eligible for college scholarships. The scholarship program was implemented at the 2nd Battalion with 1, $500 scholarship awarded. The next year, 1 $750 scholarship was awarded. In 1996, we obtained sufficient funds to award each of the 6 ACLs a scholarship ranging from $1,000 for the top performer, a $750 award for second, and $500 for each of the other 4 ACLs. We hope to sustain (or expand) the scholarship program in the future.

LOGISTICS

Steering Committee

The Steering Committee is composed of 10 to 15 representatives from various sponsoring agencies and organizations. Currently we have representatives from the Texas Agricultural Extension Service (wildlife specialist, communications specialist, 3 county Extension agents), Texas Parks and Wildlife Department (2 biologists), USDA-NRCS (2 district conservationists and 1 soil conservationist), Quail Unlimited (regional director and chairman of state council), vocational agriculture (1 high school teacher), soil and water conservation districts (1 county chairperson) and other private individuals (4 at this time). The committee meets 3 times annually, usually in January, April, and August. The January meeting is to make initial plans and secure funding for the current year's camp. The April meeting is to screen applications, score record books submitted from the previous year's cadets, and make any necessary revisions to the curriculum. The August meeting is used to critique the most recent camp and identify areas within the curriculum that need to be modified.

Recruiting

We seek 32 qualified applicants (high school sophomores and juniors preferred). Applications are solicited through "traditional" clientele (i.e., 4-H and FFA) and by other means (e.g., media). Applicants may also apply via the Internet at *http://texnat.tamu.edu/specpgms.bwbrigad.bwbmain*. Word-of-mouth from past cadets is also an effective recruiting tool. Applications are screened on the basis of demonstrated leadership skills, academic achievements, and an essay stating why the applicant is interested in becoming a member of the Bobwhite Brigade. Those individuals selected are mailed registration forms >6 weeks prior to the camp. Two "alternates" are also selected in the event that any of the chosen cadets withdraw prior to the camp.

Covey Structure

Cadets are assigned to groups of 5 ("coveys") that are led by a Covey Leader (e.g., County Extension Agent, agency biologist) and an ACL. We can accommodate 6 coveys, appropriately named for the 6 species of quail that occur in the U.S. (i.e., Bobwhites, Blues, Gambel's, Mearn's, California, and Mountain). Coveys work, live, and sleep together to "bond" and develop a spirit of teamwork. They compete all week against other coveys for the "Top Covey" award. All members of a particular covey share the same lodging facilities. The addition of the ACLs, beginning with the 2nd Battalion in 1994, has been very worthwhile. The returning cadets know the rigor of the camp and can share ideas that have allowed them to be successful. Additionally, the leadership responsibilities help foster their own abilities in a different role from being a cadet.

Curriculum

The topics covered during the week reflect what a junior-level college student majoring in wildlife science would encounter. In the first exercise, cadets conduct a necropsy on a bobwhite to discuss the form and function of bobwhite anatomy. Various morphological adaptations important to how a bobwhite uses its habitat (i.e., white breast muscle limits long distance flights thus reinforcing the need for interspersion of habitat components) are discussed. Various topics dealing with quail biology include anatomy, behavior, diseases, embryology, plant identification, entomology, and radio telemetry. Each covey of cadets affixes a radio telemeter to "their" bobwhite on the first afternoon. The radio-marked bobwhites are carried to another site about 10 km away and released. On day 3 each covey uses telemetry equipment to locate their quail and record its fate. About one-third of the curriculum deals with leadership development and critical thinking. Basics of communication skills (written and oral) are covered. Other support disciplines like art, photography, and firearm safety are also presented. A detailed description of the week's curriculum is discussed by Rollins (1993).

Field Work

Our curriculum involves 18 to 20 hour work days; basically the only "free time" is between 1 a.m. and 6 a.m. Accordingly, our teaching plans must be action-oriented and fast-paced to keep cadets from falling asleep. A traditional "slide talk" on any subject is likely to be met with inattentive students. Therefore, we concentrate on "hands on" activities like crop analyses, nest depredation transects, plant collections, and others to stimulate the cadets. We use role playing to illustrate various subjects (e.g., roosting behavior) and Project Wild activities like "Habitat Lap Sit" to illustrate ecological principles like community structure and interspersion. An activity dubbed "Run for Your Life" uses hula hoops as loafing coverts to illustrate the relationship between predation and the interspersion of brush cover. In this game, 2 ACLs play the role of hawks (1 buteo and 1 accipiter) whose goal is to capture an errant quail who cannot find refuge in a loafing covert (i.e., hula hoop).

Leadership

All cadets are required to conduct >3 educational programs upon returning to their communities. Leadership is stressed at every opportunity during the camp (Rollins 1996). Each cadet is assigned a "silver bullet" (i.e., inspirational quotation by someone like Aldo Leopold or Will Rogers) which he must recite upon command by a superior any time during the week. We provide training in how to write news releases, conduct slide programs, television interviews, and assemble a static tri-fold display. Each cadet is interviewed on video and their efforts are critiqued by the group the next night. Various exercises stressing teamwork and networking are conducted.

Table 1. Program accomplishments of the Bobwhite Brigade, 1993-1997.

Accomplishment	Measurement	Comments
Battalions mustered	4 in Rolling Plains 1 in East Texas	East Texas Bobwhite Brigade formed in 1996.
Cadets trained	119 in Rolling Plains 24 in East Texas	
Educational programs conducted	Estimated at 1,100	Number of programs conducted by cadets has doubled each year.
Media coverage	7 articles in state or regional periodicals 6 television news stories 3 feature stories in regional newspapers	Periodicals include *Texas Parks and Wildlife Magazine, Texas Wildlife, Texas Farmer-Stockman, Quail Unlimited Magazine, Texas Fish and Game*
Awards received	4	Quail Unlimited's Youth in Conservation Award 1994 and 1996; Texas Section, Society for Range Management's Special Award 1995; Texas Chapter, The Wildlife Society's Excellence in Wildlife Conservation Award (Group Category) 1996
Cadets honored	2	Outstanding Youth Conservationist Award from Sportsmen's Conservationists of Texas 1994; Outstanding Youth Conservationist Award from Georgia Wildlife Federation, 1997

Esprit de corps

Comradery and teamwork are stressed in a quasi boot camp-like atmosphere. One of the main instructors is a former U.S. Marine who strives to keep the cadets motivated. Beginning in 1996, a series of cadences were written (Rollins 1996) and will be included in the curriculum beginning in 1997. Coveys compete all week for points in various exercises for the opportunity to have first selection from a bevy of door prizes donated by various sponsors. Additionally, all cadets and instructors cast 1 ballot for their selection as the "Top Cadet" and this individual receives a special prize.

Sponsors

Initial sponsors in 1993 included the TAEX, TPWD, USDA-NRCS, Lower Clear Fork of the Brazos Soil and Water Conservation District, Krooked Riv-

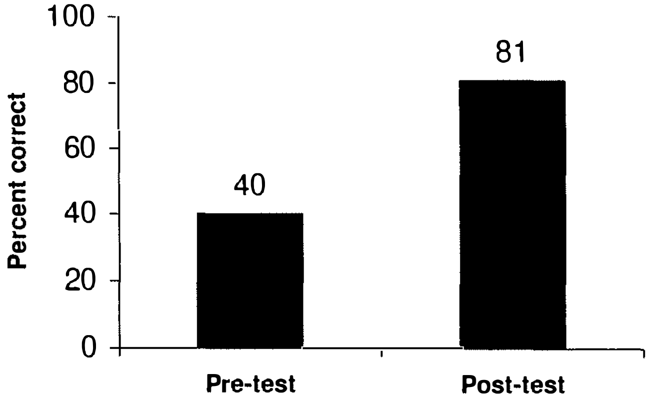

Fig. 1. Pre-test versus post-test scores of Bobwhite Brigade cadets from 1993–1996 (*N* = 119 cadets).

er Ranch Outfitters and the Texas Council of Quail Unlimited. Since 1993, additional sponsors have included the Texas Wildlife Association, Big Country Birdhunters Association, Federal Aid in Wildlife Restoration, U.S. Environmental Protection Agency, Ray and Susan Murski Foundation, Johnny Stewart Wildlife Calls, and an anonymous donor.

Fundraising

Costs for conducting a "typical" Bobwhite Brigade (32 cadets plus about 20 adults) are about $8,000. Food costs account for about 35% of the overall budget. Our lodging costs are donated by Krooked River Lodge. We solicit grants and scholarships from various sponsoring agencies, private individuals, and anonymous donors. The Bobwhite Brigade is a 501(c)(3) charitable nonprofit foundation. Tuition for the camp is $200 per cadet. We assist cadets in locating sponsors at their local level for half of the tuition cost.

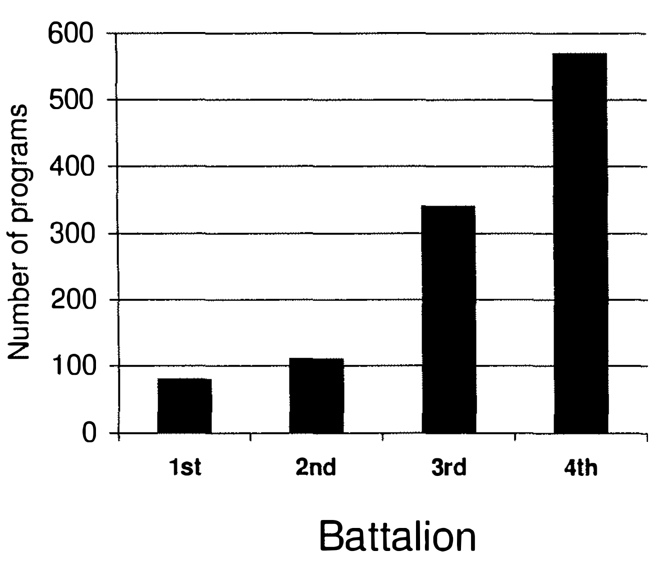

Fig. 2. Number of educational programs conducted during the year following graduation from the Bobwhite Brigade, 1993–1996.

Table 2. Quotes from various media representatives and parents after their exposure to a Bobwhite Brigade camp, 1993–1996.

Source	Author	Quote
Print Media		
Abilene *Reporter News*	J. O'Bryant	*"I don't believe I've ever seen your tax dollars doing a better job."*
Dallas *Morning News*	R. Sasser	*"The Bobwhite Brigade is the MTV of wildlife science."*
Texas Wildlife Magazine	C. McTee	*"We are all winners because of the Bobwhite Brigade."*
Progressive Farmer Magazine	L. Hodge	*"I have seen nothing else that comes close to meriting the recognition this program does."*
Parents		
	C. Taylor	*"I will never forget the excitement and enthusiasm that I saw in my son when my wife and I picked him up at the completion of the camp. It's a day we won't soon forget."*
	T. Dean	*"The Bobwhite Brigade is doing a good job of filling a void in the understanding and appreciation of wildlife resources."*
	E. Brown	*"Thank you for challenging my high school junior. I appreciate the high level of academics and the wide variety of topics presented."*
	L. Clift	*"Our daughter now has a deeper understanding of the delicate balances that exist within our environment, and that resources such as wildlife require careful management."*
	C. Holcombe	*"As parents of two 4-H members that have attended this event, we want you to know that our sons both consider this as one of the most outstanding opportunities they had ever been involved in. Your group does a tremendous job."*
	L. Isenhour	*"Our son attended the recent Bobwhite Brigade and he is still talking about it—it was the best! Thanks for supporting youth."*

RESULTS

Knowledge Transfer

Pre- and post-tests are administered to cadets to assess their knowledge about quail management before and after exposure to the Brigade. Results suggest that quail knowledge is increased an average of 100% across the first 4 Battalions (Figure 1).

Program Highlights

Measurable accomplishments of the Bobwhite Brigade from 1993–1996 are summarized in Table 1. One of the most noteworthy accomplishments is the information transfer by cadets when they conduct educational programs in their local communities. The number of programs conducted by cadets has increased geometrically in the last 3 years (Figure 2).

We believe we get "good" productivity (i.e., > 10 educational programs conducted) from about 20% of the cadets. However, we have not been satisfied with that response rate. In 1995 we raised sufficient funds to award each ACL with a college scholarship ranging from $500 to $1,000 if they earned the most points (by conducting various educational activities). We believe the poor performance among the bottom quartile of cadets is due to a lack of mentors in their local communities, or perhaps in our inability to match up mentors with cadets in a timely manner.

Expanded Efforts

Quail Unlimited adopted the Bobwhite Brigade as its national youth education program in 1995. Since that time camps have been conducted in >6 other states. The East Texas Bobwhite Brigade was initiated in 1996 and graduated 24 cadets during its first year. The first battalion of the South Texas Bobwhite Brigade was conducted in 1998.

Media Response

The Bobwhite Brigade has received excellent publicity by various outdoor, agricultural and "general" press media (Table 2). We often involve various outdoor writers or television reporters to teach various portions of the curriculum dealing with communication skills.

Enthusiasm about the Brigade continues to run high among the cadets, instructors, and sponsors. The Brigade has been a classic example of cooperation among natural resource agencies (e.g., TPWD., USDA-NRCS), private conservation groups (e.g., Quail Unlimited, Texas Wildlife Association), grassroots supporters (e.g., Texas Farm Bureau, local Soil and Water Conservation Districts), private industry (e.g., Johnny Stewart Wildlife Calls, Krooked River Ranch Outfitters), and landowners. The Bobwhite Brigade has been the recipient of several state and national awards, and is the template for Quail Unlimited's "Covey Kids" camps that are now held in >6 states.

We take great pride in observing and working with talented young men and women as they evolve over the course of a very intense week. We often receive feedback from parents who comment that the excitement and level of self confidence are apparent immediately following the Brigade (Table 2). The human capital that is being developed by the Bobwhite Brigade should pay conservation dividends for many future years.

ACKNOWLEDGMENTS

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THE FUTURE OF QUAIL HUNTING IN THE SOUTHEASTERN UNITED STATES

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ABSTRACT

More than 60 years of habitat improvement efforts by state agencies has not prevented the decline of northern bobwhites (*Colinus virginianus*) in southeastern states, nor has ten years of habitat improvement sponsored by Quail Unlimited resulted in their restoration. Therefore, it would appear reasonable to speculate that the cause of the decline might be something other than habitat loss or degradation. Since recent research seems to also absolve most agricultural chemicals, it may be reasonable to consider some other causes. One very likely suspect is predation. This suspicion is confirmed by recent research in Oklahoma and Virginia. Also, reduction of predation on several project areas has resulted in apparent increases in quail populations. We need more research to further test this hypothesis, and the parameters of both mammalian and avian predation should be investigated. If predation is the primary factor responsible for the decline of quail, and assuming that current wildlife policy will not allow wide-scale reduction of predator populations, the future quail hunting opportunities will be limited to areas where predator reduction and control are a major component of northern bobwhite management efforts.

Citation: Barick, F.B. 2000. The future of quail hunting in the southeastern United States. Page 232 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, Jr., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

STRATEGIC PLANNING UPDATE

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> *"As the years roll on, the tribute which we extract from the American landscape to sustain our prodigal society increases. There is an ever-growing demand for more agricultural crops, more livestock and more wood products, while the acres available for production are shrinking from urbanization and other causes."* (Leopold 1978).

ABSTRACT

This paper is a snapshot assessment of what has been achieved in quail management and research since the first national strategic planning workshop was organized at Quail III in 1992. In general, interest in quail remains strong and in many cases is increasing, among a diverse community of managers, researchers, and hunters, despite the continued population declines of several species of quails, and widespread loss of quail hunting opportunities on both public and private lands.

Several regional interest groups who serve as advocates for quail have emerged in both the southeastern and western U.S. Some potentially promising opportunities for broad scale habitat improvement have emerged from Farm Bill legislation (such as subsidies for planting longleaf pine [*Pinus palustris*] in the Southeast). Whether such incentives will serve to reverse the broad scale northern bobwhite decline, remains to be seen. Several states in both the Southeast and Midwest have either reaffirmed or renewed their commitment to quail research and management. They fully realize that reversing declines and local extinctions will be extremely difficult given the incompatibility between most modern agricultural and forestry land use practices and the habitat needs of wild quail. How, and if, wild quail will be able to fit within the ever-tightening constraints of modern land use by our prodigal society is one of the most challenging questions currently facing anyone interested in these birds.

Citation: Brennan, L.A., and J.P. Carroll. 2000. Strategic planning update. Pages 233–235 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, Jr., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium, Tall Timbers Research Station, Tallahassee, FL.

INTRODUCTION

As part of Quail III in 1992, one of us coordinated a workshop (Brennan 1993a, 1993b) that defined the major problems facing wild quail in the United States, and outlined strategies that could be used to solve them. The workshop, and resulting publication was primarily conceptual, and, unlike documents such as the North American Waterfowl Management Plan, did not contain specific population or habitat benchmarks such as "increase northern bobwhite populations in Mississippi 5% per year for the next 20 years." Rather, the workshop leaders chose to outline some basic, concept-driven, practical ideas that could be used on a national scale to benefit the 7 species of wild quail in the United States in terms of issues that related to Agricultural Practices and Pesticides (Capel et al. 1993); Forest Practices (Brennan et al. 1993); Grazing and Range Management (Brown et al. 1993); Releases of Pen-raised Quail (Hurst et al. 1993); and Population Dynamics and Effects of Hunting (Kuvlesky et al. 1993).

In this paper, our objective is to provide a brief synopsis of the major elements of progress that have been achieved with respect to quail management and research since 1992. In addition to keeping up with the scientific and management literature, living and working in the midst of 300,000 acres of private lands managed exclusively for quail hunting, and traveling widely throughout the Southeast, Midwest, and western U.S., we queried the Quail III workshop leaders to send us their insights and perceptions about progress and achievements with respect to quail management and research. Our purpose here is to share those comments and insights.

PROGRESS SINCE 1992

General Issues

One of the most promising developments since 1992 has been the formation of the Southeast Quail Study Group (SEQSG), a consortium of biologists, researchers, and managers who are interested in working cooperatively to solve problems related to the northern bobwhite decline. Other regional efforts in the western states are emerging, but still inchoate.

New bobwhite initiatives have emerged in Virginia, North Carolina, Oklahoma, Tennessee, and Georgia. Major bobwhite programs have continued in Mississippi, and will expand in Texas. Mississippi has spent more than a million dollars on quail research and habitat management during the past decade, and several other states, such as Virginia and Georgia, are developing quail management and research programs with multi-year budgets > several million dollars. A recent study of economics of bobwhite hunting in the Southeast (Burger et al. 1999) needs to be communicated beyond the bounds of the professional wildlife literature.

An area where we have not made much progress is emphasizing the connection between declining quail populations and declining populations of other early successional species. Management to benefit quail and management to benefit other groups, such as early successional and grassland birds, would provide a better and more unified front. Carroll et al. (2000) addressed some of those issues, but mainly documented lack of research in the Southeast.

Agricultural Practices and Pesticides

Although Farm Bill legislation seems to hold promise for encouraging quail-friendly land use practices, it remains to be seen whether this strategy will pay dividends with respect to reversing the bobwhite decline. In addition, research on agricultural issues relative to quail management seems to be on the increase.

Recent work in North Carolina by Palmer et al. (1998) and Puckett et al. (*this volume*) on incorporating bobwhite habitat in modern agricultural landscapes appears promising. By using filter strips, and field borders, it appears that bobwhites can be incorporated in modern agricultural landscapes if about 5% of the total area is allocated for quail. Whether modern farmers will embrace the "5% solution" is not clear. How implementation of precision farming might benefit or hurt these edge areas managed for wildlife is unclear.

New technological advances such as genetically altered crops, "Round-up Ready" soy beans and cotton, and no-till approaches, all remain huge question marks on the agricultural horizon for quail. These technologies potentially allow widespread adoption of alternative cropping systems that might benefit quail. Preliminary data in Georgia (E. Goldberg and J. Carroll, unpublished data) suggest that cotton can be made better for quail brood habitat using strip-tillage systems.

It may be a combination of in-field and field margin approaches used in concert and in creative ways that are acceptable to farmers that will yield the greatest benefit for quail management.

Forest Practices

A huge step forward has been the inclusion of subsidies for planting longleaf pine in the CRP program, along with renewed interest in uneven-aged management of southern pine forests in general. A potential step backward has been the emergence of "total control" southern pine silviculture, whereby all (yes all) competing vegetation in pine plantations is eliminated by herbicides. Basically, the result of this land use is pine trees growing in a substrate of sandy soil and scattered woody debris that remains after site preparation. What this system represents is the final transition of management of southern pines from a silvicultural context to a multi-year agricultural crop. That sort of system creates many of the same challenges already seen in annual row-crop agriculture. However, there are also differences because of the multi-year, growth patterns that accumulate much more standing biomass than row crops.

There needs to be continued progress on understanding how to optimize quail populations and timber resources on the same parcel of land. We know from experience that it is not possible to maximize both quail and timber, but surely, there must be an optimal solution to this dilemma. Approaches to looking at these issues on landscapes containing a shifting mosaic of ephemeral quail habitat might yield more positive results than continued focus only on the stand level.

Grazing and Range Management

Dave Brown reported that "all the issues that existed in 1992 remain with us today."

Releases of Pen-raised Quail

Despite the recent paper by DeVos and Speake (1995), there is little active research in this area. In our opinion, two distinct camps have developed and are evolving: (1) people who do not want anything to do with pen-raised quail, and (2) people who believe that pen-raised quail are the only viable substitute to wild birds for providing hunting opportunities. A third view, based on our observations during a "debate" on the Anchor Covey System at a recent Quail Unlimited Convention, is that there is a contingent of people who believe this method can actually use pen-raised birds to restore wild quail to areas where they did not exist. The difficulty here is that views become quickly entrenched with little scientific evidence to support the notion that distributing pen-raised quail will recover wild populations.

Possibly there is middle ground in approaches adopted by some in Europe. There, the view tends to be that wild bird management is the ideal goal; however, modern land use results in much of the land area providing very little sporting opportunity without large monetary investment. In those situations, compromises on habitat development are made to allow reared birds to survive relatively long periods of time and even reproduce in the wild. However, management of reared birds is looked at as being beneficial only when there is a net conservation benefit in terms of habitat management, not just "dumping and shooting" birds in poor habitat (Tapper 1999).

Population Dynamics and Effects of Hunting

During the past several years, there has been an orchestrated effort to develop a large-scale experiment to assess the effects of hunting on bobwhite populations. However, this project is still in the planning stages.

In general, we see a welcome trend toward more field experiments, including those involving hypotheses related to predation. Investigators working on various field experiments related to predation, as well as other topics, should strive to standardize experimental designs and sampling methods so that effective meta-analyses can be conducted on such data. One project, sanctioned by the SEQSG, and supported by funds from Quail Unlimited, Tall Timbers, and other organizations, is looking at quail productivity relative to indices of mammalian predator abundance on a regional scale by combining the results of a large number of intensive quail studies being undertaken in the Southeast.

CONTINUING PROBLEMS AND CONCLUDING REMARKS

Despite a renewed interest in research, the bobwhite decline continues throughout much of the range of this species. The scaled quail (*Callipepla squamata*) decline also continues, but, in contrast to the bobwhite decline, without the benefit of much research to understand it. The mountain quail (*Oreortyx pictus*) remains largely extirpated from the intermountain regions of its geographic range. Although there is currently an active petition process to list the Columbia-Snake River basin populations as endangered, state and federal resource agencies seem reluctant to embrace a comprehensive solution to this problem.

Despite a heightened interest and activity in both research and in delivering extension products about quail, including a plethora of new videos, myths and misconceptions about quail seem to be more prevalent than ever. This begs the following questions:

- Are we asking the right questions about factors responsible for the declines of quails?
- Are we investing in the right kinds of research to answer those questions?
- Are we framing this work in such a way that all of the competing interests, stakeholders, and constituency groups, understand the level of investment needed to restore quail in the context of tradeoffs relative to other conservation objectives?

We live in a prodigal society (Leopold 1978) where inexorable trends in land use yield less and less habitat space for quail every year. Whether wildlife professionals can devise methods to incorporate quail in modern industrial agriculture and silviculture landscapes, and convince people that it is in their best interest to make some modest concessions, such as the 5% solution developed in North Carolina, remains one of the most challenging wildlife management problems for the next century.

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WORKSHOP SUMMARY: DEVELOPING NORTHERN BOBWHITE MANAGEMENT PLANS—A HABITAT-BASED FRAMEWORK

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ABSTRACT

Successful northern bobwhite (*Colinus virginianus*) management is a complex and often expensive process that requires careful planning and a well-designed habitat management program. Written management plans are often used by landowners who wish to maximize quail populations on their property. Although management plans are as varied as the individuals who write them, a successful plan should: (1) be chronologically based, (2) contain an associated budget, and; (3) combine the objectives of the landowner with the limitations and potential of the individual property. The goal of a management plan is to insure that habitat modifications proceed in a well-designed, cost-effective, and orderly fashion. Although this paper focuses on developing management plans for northern bobwhite, the concepts presented here can be used to develop management plans for other species of quails in the United States.

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INTRODUCTION

The majority of land that is managed intensively for northern bobwhites is owned by private individuals. While the scientific literature is filled with an amazing array of detailed information about northern bobwhite life history and ecology, there is virtually no published information available on the process of quail management plan development. This is because publication of research findings often require that information about habitats and populations be processed as fragments suitable for statistical analysis. Furthermore, the majority of individuals involved with the day-to-day management of quail habitat are not inclined to submit their knowledge for publication in any scientific, or other format.

There is no standardized format for development of a quail management plan. Since the majority of management plans are developed by individuals, the formats used are as varied as the individuals who write them. Regardless of the format used, the goal of a plan is to insure that the complex, and often expensive, process of quail management, takes place according to a well-designed and orderly fashion. There are several key components that should be included in a management plan to provide usable information to a landowner. A properly-designed plan should be site-specific, chronologically based, and have an associated budget. Site specificity is one of the key ingredients in a well-designed plan and one which is often overlooked in broad-based management information. When a private landowner requests assistance with the development of a plan, they are not interested in obtaining general information on the life history and biology of the northern bobwhite. Instead, they are looking for site-specific information that will allow them to achieve specific objectives, given economic limitations, and the potential of the land. For a management plan to be applied, it must discuss habitat modifications in a logical, chronologically based sequence that a landowner can understand. Approximate costs for various management items must be addressed in the plan. While costs vary from site-to-site, to suggest management strategies without discussing the approximate costs for these management items does not provide a landowner with sufficient information to make educated decisions. While a properly-designed plan should provide the basic framework for the successful development of a piece of property, it should also be flexible enough to take into consideration the vagaries of working with systems that are subject to fluctuations in precipitation, and numerous other abiotic and biotic factors that influence quail populations.

MANAGEMENT PLAN COMPONENTS

As mentioned previously, no standard format exists for management plan development. The following sections describe the general format that I have used to develop management plans for private landowners. This format introduces a property, discusses the current limitations to quail production, develops strategies to offset these limitations, analyzes the costs of the proposed management strategies and develops a chronologically based work plan.

The Introductory Section

In the introductory section of the plan, the size and location, along with the past uses of the property should be discussed briefly. The first step in the management plan process is to separate the property into its various habitat components, with the aid of an aerial photograph, and create a map. The information on habitat and forest stand composition (such as number of acres in various habitat patches) should also be presented in tabular format. The current condition of the habitat, in combination with field surveys is then used to: (1) determine factors that could be limiting quail production and; (2) develop general strategies for removing these limitations.

If at all possible, the person developing a management plan should attempt to determine the status of the quail population prior to initiating any proposed habitat modifications. The initial status of the quail population can be used as a baseline to determine the long-term success of a management plan. Hunting records (e.g., covey finds per hour) are often maintained by landowners and can be used in lieu of an absolute population density estimate. If no hunting records are available, a simple covey map combined with a series of stimulated call counts (i.e., number of quail that call in response to a taped bobwhite call) can provide useful information to index current population abundance as a basis for judging future trends.

The objectives of the landowners should also be stated in the introduction. Often, the landowner does not have a precise objective. Typically, a landowner will only have general ideas concerning the future development of this property. It is the responsibility of the consultant to combine the general objectives of the landowner with the limitations and potential of the property and develop a precise, performance-based set of goals and objectives.

Soil and Site Limitations

It is essential to discuss current factors that are limiting quail production in a management plan, because these are the factors that must be overcome using various management strategies. Limitations can be broken into three major categories: soil, site, and financial.

Soil Limitations

The general soil type is one of most fundamental factors that must be considered in the development of a quail management plan. For the most part, soils cannot be changed through the management process. While we can alter soil fertility and acidity on a small scale, we cannot change the hydrological condition of a piece of property. Properties that are excessively wet, or extremely dry, have inherent, non-manageable factors that limit quail production. A realistic appraisal of these problems needs to be addressed in the plan. This is not to say that excessively wet or droughty properties cannot produce huntable populations of quail; however, the cost-to-benefit ratio of quail management is often lower on these areas than it is on sites where soil fertility and drainage is good to excellent.

Habitat-based Limitations

Habitat-based limitations are the inherent habitat factors that suppress populations of native wild quail. These are the principal limitations that we hope to overcome through development of various management strategies. The current condition and distribution of the forest and open-land portions of a property play a critical role in determining the potential of the site to increase numbers of quail and the management costs required to accomplish this objective. A general rule of quail management states that if the property is largely forested, you need to incorporate openings (i.e., fields) and if the property is primarily composed of open ground, you need to incorporate forests. But how the open-land will be broken up and the forested land will be opened up are based in large part on the objectives of the owner, the potential of the property, and the limitations of the land as they relate to factors such as topography and soil fertility.

The current density of quail is one of the most critical habitat-based limitations that must be addressed in the development of a management plan. One of the fundamental questions that should be asked is: Are there a sufficient number of quail on the property that can potentially respond to management within a reasonable (2–4 years) amount of time? If there are not, is there the opportunity to legally relocate quail from other properties owned by the landowner? The capital and lost opportunity costs can be quite high in the initial phases of implementing a quail management plan; therefore, the cost-to-benefit ratio of proposed management practices must be taken into consideration with respect to the current density of quail. On properties that have low initial quail numbers and high hunting desires, pre-season releases of pen-raised quail may be required. The use or non-use of pen-raised birds should be discussed at this phase of plan development. The decision to use or not use releases of pen-raised quail should be left up to the landowner.

Financial Limitations

Financial limitations related to developing habitat that will increase wild quail production must be addressed in any management plan. A general rule of bobwhite management is that everything you do for quail is an economic tradeoff from other land use options. Knowing the comfort level of economic tradeoffs that an individual landowner is willing to accept is an essential part of developing a successful management plan. The level of economic tradeoffs the landowner is willing to accept will dictate the intensity of bobwhite management that can be undertaken.

Habitat Components and Management Practices

The section on Habitat Components and Management Practices is the portion of the plan where management strategies are developed to offset factors that limit wild quail. It is in this section of the management plan that we develop techniques to modify woodland and field conditions. Management strategies for the forested portions of the property should be developed on a stand-by-stand basis. The financial needs of the landowner should be taken into consideration when developing woodland modification techniques. Additionally, future stand regeneration and how it relates to quail management, should be discussed in this section of the plan. Whenever possible, you should stress integration of quail management with economic production from forestry and agricultural operations. Woodland modification techniques such as thinning, clear-cutting, burning, and creation of agricultural openings such as fields should be discussed. Adequate justification should be provided for any proposed timber reduction, or for long term regeneration plans.

The current condition of the open-land portion of the property should be discussed in this section and management strategies should be developed to increase the quail carrying capacity of these areas within the constraints set forth by the landowner. Sod-forming grasses (primarily Bermuda, fescue and bahia grasses) are a serious detriment to quail production throughout the Southeast. When modifying agricultural and fallow-field areas for quail it is absolutely imperative to eradicate these species before initiating any habitat modifications. Large amounts of money can be potentially wasted by not controlling these invasive species prior to incorporating habitat modifications. Open-land modification techniques, such as development of simple and/or complex hedgerows, breaking up large fields into smaller units, planting of pines in fallow-field areas, and incorporation of alternative food sources, should be addressed in this section. The past agricultural history of a property plays an important role in determining the future potential of the area and what management techniques will be used. Properties with a history of intensive farming are often devoid of native, weedy plants that are beneficial to quail. Conversely, non-intensively farmed agricultural fields often have a rich array of native seeds contained within the soil seed bank.

The use of food plots should be discussed in the management plan. Whether food plots are used on a property should be determined by the site-specific limitations of the property. The diversity and structure of a food plot is far more important to the life history of a quail than the actual agricultural plant grown. A diverse food plot should provide a year-round supply of both planted and native foods, areas for quail to forage on insects, summer fruit supplies, and mid-winter escape cover. A well-managed food plot should combine seasonal disking within the planted areas to encourage the production of native plants. Broad statements concerning the use of food plots cannot be made without determining the specific limitations of an individual property, and analyzing the type of food plots that will be utilized.

Cover Management

The key to quail management is "structural diversity," not what you plant or how you plant it, but how the individual components of the habitat are arranged. Therefore, the proper distributions and types of cover are critically important to the development of a management plan. Since most woodland properties are maintained with periodic controlled burning, it is essential to have an adequate distribution of firelines to maintain maximum diversity on the smallest scale that is economically and logistically feasible. If at all possible, a map of current and future firelines should be included in this section of the plan. The season that fire is applied, and how it relates to quail management, should be discussed with the landowner. On the majority of southeastern properties, a combination of cool and warm season fires should be used to maintain the proper landscape for maximum quail production. Alternative methods of maintaining vegetation, such as mowing, chopping and harrowing should also be discussed. The benefits and drawbacks of each of these cover management techniques should be addressed in relationship to the site-specific cover conditions of the property. If chemical (herbicide) control of hardwoods or other brush is required, the justification for this management and a description of the techniques to be used should be included in the plan.

Miscellaneous Practices

In this section of the management plan I cover issues that do not warrant an entire section but are important to include in the plan. Among these are predator control, census techniques, planting techniques (such as what species require inoculations, what type of fertilizer to use, etc.), harvest management and record keeping. Record keeping is essential in the development of a management plan because it allows the consultant and the client to keep track of past success and failures. It also provides, over time, a management history for the property.

Budgetary Considerations

As mentioned earlier, a plan without a budget does not provide the landowner with the information they need to make informed decisions. This is usually the part of a management plan that is most important to a landowner. Therefore cost estimates must be realistic and be as specific as possible. In determining a budget, there is another general rule of quail management that states, "everything takes longer and costs more." Costs should be broken into capital (one time costs) and annual operating expenses. Capital costs include items such as stumping, fireline construction, establishment of pines, herbicides, contract labor, liming and planting of perennials and reseeding annuals. Annual costs include feed, seed, fertilizer, annual herbicide applications and pen-raised quail if they are used. Costs should be presented in a professional and easily understood format.

Chronological Work Plan

The work plan lists specific management activities that need to be completed for landowners to reach their desired objectives. Management activities should be stated in a logical, chronologically based sequence. Work items should be tied to the budget and if at all possible be listed on a monthly basis. If there are non-flexible management practices (such as pines being released via an herbicide application by a certain time or partridge pea being disked in a certain month) then these items should be stressed. All principal, year-round management activities should be listed within the work plan.

Appendices

In this portion of the plan you can include any supplemental information that may be needed by the landowner. The supplemental information may include published articles on census techniques, information on planting techniques, sources for various seeds and seedlings and if possible, local contract labor sources for stumping, pine planting, etc.

Management Map

No management plan is complete until there is a well-developed map or series of maps that show all existing and proposed habitat modifications. The map is important to landowners so that they can visualize the proposed habitat changes discussed in the plan. All maps should include a definitive scale, a north orientation arrow, new and existing food plots, proposed habitat modifications (such as food plots, etc.) and proposed timber harvesting and regeneration areas.

Conclusion

A well-designed quail management plan can be a tremendous aid in the development of a property where the objective is to produce a huntable population of wild bobwhite quail. A properly-designed management plan insures that the complex process of quail management takes place in a logical and orderly fashion. Management plans should be site-specific, chronologically based, have an associated budget, and be flexible enough to deal with the changing objectives of landowners and the vagaries of working with mother nature.

QUAIL MODELING WORKSHOP SUMMARY

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Simulation models may be used to identify deficiencies in empirical databases, develop hypotheses for testing in the field, and examine alternative management scenarios. This modeling workshop dealt with 6 models covering (1) schematic habitat management; (2) the effects of size and density of woody cover patches on usable space; (3) population behavior in stochastic environments; (4) population behavior under alternative hunting scenarios; (5) nesting attempts per hen for nesting seasons with different characteristics; and (6) production under multiple-brooding with nesting seasons of different characteristics.

Simulation modeling provides a valuable tool for understanding and prediction of the behavior of quail individuals and populations. Once an acceptable model for behavior is found, management alternatives may be simulated by altering the value of variables within the model. For example, a population model could be used to evaluate the potential response of a population to management of predation on nests. The modeler would in this case raise the probability of nest success, taking into account competing risks such as trampling, abandonment, flooding, and other loss sources. The modeler might also have to adjust for density-dependent effects on the survival of chicks and adults and the future production of adults. One of the greatest values of modeling comes from thinking through the processes that lead to an outcome or prediction, as the predator example illustrates.

When constructing a model, the modeler usually will want to base the value used for variables in a model on empirical data. In a model of quail demography we would prefer empirical data on daily survival rates for age classes, probability of multiple-brooding, frequency of renesting, and the relation between survival and production and density, among other variables. We also need to know the probability distributions (normal, uniform, Weibull, beta, gamma, and so on) for variables such as daily survival rates if we want to incorporate natural variation in the model. A realistic model usually reveals the existence of weak or nonexistent empirical data. The modeling process, therefore, helps to identify important data gaps, and therefore helps to focus field research efforts.

The purpose of the modeling workshop was to explore a variety of models that may be used for evaluating habitat management alternatives, exploring population behavior of quails with or without hunting, and examining various aspects of production. Two habitat models, PROFILE and GENBUSH, were examined. PROFILE allowed the user to alter the structure and composition of vegetation and to evaluate habitat suitability. The model permits an array of woody cover conditions from open prairie to closed-canopy forest. Likewise, ground cover can be altered from none to tall and dense. GENBUSH is designed to evaluate usable space under various scenarios for size and density of woody cover objects. PROFILE could be used in extension applications (showing clients the nature of bobwhite habitat). GENBUSH would be useful in exploring management options on Conservation Reserve Program fields or abandoned farmland that is deficient in woody cover.

The basic population model evaluated (DD2) let quail populations vary about demographic capacities (something like carrying capacity) during spring and autumn. Density dependence was invoked in population behavior by creating a stochastic tendency for populations to trend toward demographic capacities. The population model could be used to evaluate alternative scenarios for harvest management, population viability, potential response of quail populations to changes in climate (frequency and severity of weather catastrophes), and related applications.

Production models explored included NEST, SUCCESS, and DOUBTRIP. NEST is a simple model that returns nesting attempts per hen under alternative properties of the laying season, i.e., the rate at which hens in a population enter laying condition and the number of days available for laying in a particular season. An estimate of the number of nesting attempts per hen is necessary to obtain probability of nest success given *n* attempts and estimating age ratios. SUCCESS returns properties of the nesting effort under user-defined properties of the nesting season. DOUBTRIP estimates production (percent summer gain, age ratios) in the presence of double- and triple-brooding. This model demonstrates the need for information on empirical variables including the rate at which hens enter laying condition, mean clutch size, probability of success on any nesting attempt, survival rate of adults and chicks, and number of days in the laying season. The model predicts that multiple-brooding has relatively minor effects on total production in comparison with single-brooding, given up to 3 nesting attempts. This outcome of multiple-brooding occurs in part because the probability of a hen laying 3 successful clutches is low. Also, and perhaps more importantly, time limits opportunities for multiple-brooding in any particular nesting season.

In summary, ecological modeling forces one to think through a natural process in considerable detail. This logical process helps to identify gaps in knowledge. The process also improves science and management by providing perspectives and insights not obtainable by pure empiricism.

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WORKSHOP SUMMARY: FEDERAL FARM PROGRAMS—WHAT CAN BE DONE FOR QUAIL?

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Federal Farm programs have had a wide range of impacts on wildlife over the years. Some programs have been extremely harmful to wildlife while others have, intentionally or accidentally, been beneficial to wildlife. Frequently, the same program that is beneficial to wildlife in one part of the country has been less beneficial or even harmful in other parts of the country. This has usually been a result of trying to make one program and set of rules fit all conditions across the U.S.

This workshop examined the tools the 1996 Farm Bill provided to quail managers—the new programs and revised aspects of older programs. Don McKenzie, Wildlife Management Institute, presented the Washington view of the development of the Farm Bill and its conservation provisions.

Agricultural Liaison biologists have a unique opportunity to blend wildlife considerations into the various farm programs. Reggie Thackston, Georgia Department of Natural Resources (DNR), discussed how the Farm Bill programs were developed from the perspective of an Agricultural Liaison biologist.

Some states had very little input into farm programs prior to the 1996 Farm Bill. There was no State Technical Committee operating and only minor input channels were available to them. Breck Carmichael, South Carolina Department of Natural Resources, discussed the opportunities opened by the 1996 Farm Bill.

"Partnerships" is the new buzz word of the 1990's. David Howell of Quail Unlimited in Indiana discussed how their Memorandum Of Understanding with U.S. Department of Agriculture (USDA) works, and how local chapters are impacting and supporting the adoption of quail-friendly practices.

North Carolina made it a high priority to take advantage of the opportunities the Farm Bill presented. Terry Sharpe, North Carolina Wildlife Resources, discussed their progress.

Folks wax nostalgic when discussing the "good old days" of the Soil Bank and its wildlife benefits. Bill Baxter, Nebraska Game and Parks, discussed the progress of Farm Bills on Great Plains wildlife.

An open discussion of other success stories and failures of other states concluded the workshop.

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WORKSHOP SUMMARY: RADIO TELEMETRY APPLICATIONS IN WILDLIFE RESEARCH

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Radio telemetry is a widely accepted tool in the field of wildlife ecology, yet there is little information in the wildlife literature that demonstrates how to incorporate spatiotemporal data from telemetry into spatial databases such as geographic information systems (GIS). Therefore, we designed a workshop that discussed biological applications of radio-tracking data; explained how to obtain radio-tracking data; demonstrated how to process these data using personal computer software; and offered examples of how to incorporate much of this information into a GIS. Demonstrations in the workshop were combined to represent a work-flow which included the following processes: (1) download global positioning system (GPS) point data, differentially correct the data and create point coverages using Trimble Pathfinder™ software; (2) attribute the data with animal ID and habitat information, (3) construct home range polygons from point data and generate polygon coverages in Arc/Info™ or ArcView™ software; (4) estimate habitat use (spatial data from polygon coverages) versus habitat availability (spatial data from an existing GIS) at multiple spatial scales using compositional analysis; (5) determine survival at multiple temporal scales from point telemetry data using Kaplan-Meier method generalized to adjust for staggered entry; and (6) determine cause-specific survival at multiple temporal scales from point telemetry data using methods outlined by Heisey and Fuller. Discussion included radio-location techniques; choosing map coordinate systems and geodetic data; sources of GPS error; considerations and limitations of home range estimators, to include various software packages; levels of habitat use and how to quantify habitat availability; strengths and weaknesses of use vs. availability estimators; and sample size considerations in radio telemetry research.

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CONCLUDING REMARKS: THE RESEARCH PERSPECTIVE

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Attending this symposium was something of a pilgrimage to Mecca for me. I grew up hunting quail and rabbits along railroad tracks and osage orange hedgerows in central Illinois, but every *Field and Stream* story I ever read about quail hunting showed bird dogs on point in a piney woods. Later, when I got to graduate school and told my major professor (the late W.D. Klimstra) that I wanted to work on quail for my research project, he just handed me a copy of Herbert Stoddard's book (Stoddard 1931) and said, "Come back after you have read this and we can talk."

When I asked Lenny Brennan what he wanted me to talk about tonight, he said I should first describe past research-management interactions, then I should assess the current state-of-the-art in quail research, and finally I should discuss how researchers and managers can cooperate to ensure the bobwhite's future—all in 15 minutes. So, I guess I had better get started.

As to how research and management interact, well, I know how they are supposed to interact. Research is supposed to accumulate and synthesize knowledge about a particular subject, and management is supposed to apply this knowledge to achieve certain goals (Bailey 1982). Sounds simple enough, but we all know it is not.

First of all, when the knowledge we seek involves natural systems, the process can be very slow and difficult. One reason is the extreme complexity of these systems. Someone once said that nature is more complex than we think. In fact, it's more complex than we can think. Another problem is lack of direct access to the critters we are studying. We can not confine them to cages and observe them like laboratory rats. In addition, we have no control over the vast array of biotic and abiotic factors that affect these free ranging populations. Consequently, habitat studies are routinely confounded by changes in weather, and vice versa.

Finally, we have to remember that animals live the way they do because natural selection has been molding them into their environment for literally millions of years. Even the most rudimentary understanding of how this "evolutionary wisdom" works is extremely difficult because the time scales involved are almost incomprehensible to us.

Another problem is that all knowledge produced by research is not necessary reliable. Unreliable knowledge can come about in several ways: one is faulty research in which the method of data collection and/or analysis is somehow flawed. Peer review at the proposal or publication stage is supposed to guard against this, but it does not always do a perfect job. A second type of unreliable knowledge was described by H.C. Romesburg in his much-cited 1981 paper (Romesburg 1981). Ideally, research is supposed to follow the scientific method which involves 3 steps: (1) the collection of a set of facts; (2) the development of a hypothesis to explain these facts; and (3) the testing of that hypothesis with another, independent set of facts. Romesburg contended that wildlife research generally stopped after the first 2, and seldom proceeded to the 3rd step. Even worse, he noted that over time, some of the untested hypotheses acquired the status of principles or laws. In other words, they became dogma simply by being repeated often enough. Romesburg was not a quail biologist, but it's interesting that the example he used was Errington's threshold of security concept (Errington 1945) which for years formed the basis of our annual surplus theory of harvesting quail and other upland game.

There is still another type of unreliable knowledge. That is when knowledge obtained under 1 set of circumstances is mistakenly assumed to hold for all circumstances. Back in 1982 at the 2nd Quail Symposium, Klimstra (1982) pointed out that much of what we know, or think we know about quail was derived mainly from thriving, healthy populations occupying large tracts of optimum habitat. He suggested that it might be wise to reexamine some of these so-called truths in light of the fact that many quail populations are now persisting at much lower densities in habitats fragmented by bulldozers and contaminated by chemicals.

This brings me then to the current state-of-the-art in quail research. I think bobwhite research can roughly be divided into 4 periods: The 1st period was the 1920's, 1930's, and 1940's and could rightly be called the Stoddard-Errington-Leopold era. Many of the fundamental principles of quail management derived from their work and writings. The 2nd period spanned the 1950's, 1960's, and 1970's when people like Jack Stanford, W.D. Klimstra, Val Lehmann, Walter Rosene, Bob Robel, Ralph Dimmick and others expanded our knowledge of bobwhite ecology and management. The 3rd period roughly corresponded to the 1980's. As Brennan pointed out at the Quail III Symposium (Brennan 1993), this period represented something of a lull in quail research with a noticeable decline in numbers of papers published, percent of the total literature devoted to quail, and amount of funding for quail projects. Since that time, I think we have entered the 4th era, which is characterized by renewed interest in quail research and management. I am encouraged by the quantity, and especially the quality of bobwhite research being conducted by people like Wes Burger in Mississippi, Fred Guthery and his students at Texas A&M, Tom Dailey and his colleagues in Missouri, and of course here at Tall Timbers and other researchers whom we have heard from over the last couple of days.

I think the people I just mentioned would be the first to tell you that their research has benefitted from the body of knowledge accumulated by workers that preceded them. That is how science is supposed to progress. In all honesty, however, much of the earlier research conducted by us old-timers tended to be mostly descriptive or correlative in nature, often lacked proper experimental controls, and used questionable statistics or none at all. I think that most quail researchers today recognize these problems and are attempting to address them.

As a researcher, I tend to judge the current state-of-the-art of quail research primarily on the basis of its quality and how it contributes to the overall body of scientific knowledge. Managers, understandably, are more concerned with its applicability to their specific goals or objectives. And this brings up the old question of practical versus basic research. There are probably managers here and elsewhere who would disagree, but I do not think this is really an issue with quail research—in my opinion, the vast majority of studies, past and present, have been practical in nature. In fact, I would say that perhaps we have tended to neglect basic research in favor of the practical. Only a very small fraction of the literally thousands of quail studies that have been conducted have focused on such fundamentals as population genetics, sociobiology, and behavioral ecology including optimal foraging strategies, spacing behavior, and the proximate and ultimate factors involved in habitat selection. I would argue that such basic information will ultimately be necessary if we are to ever fully understand what is happening to this bird we are all so concerned about.

Some have suggested that a good deal of the more practical, site-specific types of studies (e.g., optimal burning schedules, disking rotations, or even harvest strategies for that matter) could and should be done as part of management itself. They have even given this a fancy name: Adaptive Resource Management (Walters 1986). The rationale is that because we really do not learn very much from systems at equilibrium, and because management often involves some type of manipulation, we are missing opportunities to obtain new knowledge by not attempting to evaluate the effects of these manipulations in a scientific manner (Macnab 1983). To do this successfully, however, requires the imposition of certain conditions on management operations such as applying only 1 treatment at a time, randomly assigning different levels of this treatment, maintaining untreated or control areas, and collecting data in a statistically sound manner (Sinclair 1991). In the real world, many of these conditions and constraints have proven unacceptable to administrators, managers, and the user public (e.g., Gratson et al. 1993). Still, it is something that we should consider whenever possible.

In closing, I would just like to remind you that as necessary and vital as research is, it is not an absolute cure-all for the current problems faced by quail and other forms of wildlife. The widespread decline in bobwhite abundance over the past 3 or 4 decades did not result from lack of knowledge on the part of biologists and managers. It resulted from fundamental changes in land use and landscape composition and pattern. Given enough time, space, and opportunity, I think we have sufficient knowledge and skill to produce locally abundant quail populations. To be a viable game species, however, it is not sufficient for quail to be only locally abundant. They must be reasonably abundant over relatively large portions of the landscape. The problem, of course, is that quail biologists and managers do not control large portions of the landscape. As Brennan stated a few years ago: "Clearly, the fate of the northern bobwhite hangs in the balance of how we farm our land and manage our forests" (Brennan 1991:553). Finding ways to accommodate the needs of quail in emerging agricultural and forestry programs will be challenging, but absolutely essential. Workshops and discussions here and at the previous quail symposium clearly demonstrate that there is a general appreciation for, and commitment to, this approach.

I thought long and hard about ending my remarks right here—on a reasonably positive note. Instead, I am going to say something that I think most wildlife biologists already know, but for some reason seem reluctant to talk about. In my opinion, the problems we've discussed here tonight and throughout the symposium, important as they are, are still just proximate concerns. There is a more fundamental problem that confronts not only quail, but all other wildlife species as well. I am talking about the continued growth and expansion of the human population, coupled with a land use philosophy that ignores the future in favor of financial priorities and the sanctity of property rights.

I dislike ending on such a pessimistic note—but it is my opinion that in the face of an ever-expanding human presence on the landscape, only a relatively few wildlife species will ultimately thrive, and the bobwhite will probably not be one of them. Hopefully, the expertise and commitment evident at this symposium will be sufficient to prove me wrong.

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CONCLUDING REMARKS: THE MANAGER'S PERSPECTIVE

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JOB DESCRIPTION FOR A QUAIL HUNTING PLANTATION MANAGER

A quail hunting plantation manager must have a broad knowledge of agriculture, timber management and forestry, wildlife management, how to train hunting dogs (both pointing and retrieving), and horsemanship. They must be skilled at direction and supervision of other plantation personnel, know how to be a gracious host to plantation guests, and understand budgeting, accounting, and money management.

During the course of a year, a quail hunting plantation manager will do the following things:

Spring

Conduct prescribed burning. Plan and implement a program for planting various crops. Begin training young hunting dogs. Plan and implement timber sales. Guide spring turkey hunts. Implement flat chopping on "problem" hardwood areas, and conduct general spring cleaning and maintenance.

Summer

Cut grass and maintain lawns. Repair and maintain roads. Continue to monitor agricultural plantings. Plant food patches for quail and turkeys. Maintain and repair buildings. Continue training young dogs. Maintain and manage livestock pastures.

Fall

Harvest agricultural crops. Plant winter crops and plantings. Continue dog training. Get horses and mules in "working shape" for the winter hunting season. Continue yard work and lawn maintenance. Start chopping hunting lanes and "blocks" in the woods. Guide dove hunts.

Winter

Quail, dove, duck and deer seasons are in full swing. This is the busy time of the year. The list of duties and responsibilities for this job goes on and on. I think I should get a raise!

A MANAGEMENT PERSPECTIVE

The job description outlined above is just a rough outline of the major events in a typical yearly cycle of duties for a quail plantation manager. I made this outline because I want people to understand the wide range of duties that managers must perform. The "training" for such a job happened from both spending time in the plantation environment, and from attending school. The successful managers are ones who continue to learn from seminars, publications, and their peers.

Quail plantation managers have to develop a set of plans for an entire year. They must be able to keep spending within a budget. Of course, it also goes without saying that they must also be able to please the landowner(s) for whom they work! Today a manager has to follow many more rules and regulations than they had to in the past. For example, today, we have to be concerned with smoke management from prescribed fires, protecting wetlands, regulations that govern use of pesticides, the endangered species act, and many other environmental issues. The Conservation Reserve Program (CRP) has taken more than 116,000 acres out of "production" for quail in Thomas County, GA. Add the rest of the land that has been planted to other crops and trees, and you will see that the land base available for quail management has decreased greatly in our area.

Money is a much bigger issue today than it was in the past. Also, in the past, the forests were more open around areas planted to agriculture, and there were fewer pine trees. The old "Soil Bank" program was ideal for producing quail, unlike the CRP, which has not been very good for quail.

Cattle used to roam on many parts of the quail plantation woods. They added fertilizer to the soil. Wild hogs roamed freely and applied a natural source of "disking" around plum trees, dogwoods, and grape vines, which in turn, kept them from burning.

A lot of changes have taken place in the past 40 years. Some of these changes have been great. Unfortunately, some land use changes have been detrimental to quail populations. Two of the best things for quail are a box of matches and a harrow. This was how quail management used to be accomplished.

With all the land management and quail research during the past 5 years, we have learned that quail feed patches may not be necessary to produce wild birds for hunting. However, after a slow day when not many birds were found, the first thing the landowner says is, "Where's the feed?"

I believe there is more pressure to use more of the plantation land today than there was in the past. As managers, we want the owners to enjoy and be satisfied with their property, and to have great quail hunting. Since the cost of living has increased, the number of staff on a quail plantation has to be reduced to meet budget constraints. Along with cost of living, is the increased costs of things like insurance, which has skyrocketed. All this leads to fewer dollars that are directly available for producing birds to hunt. These economic changes mean that quail plantation managers are responsible for a "bottom line" and sometimes we, like most anyone else, just have to "do without."

On quail plantations, people need to be out of the woods by June 1st to let the quail nest and hatch. Today, unfortunately, we are in the woods all summer, either working, as in the case of plantation staff, or riding through to study and observe things, as in the case of researchers.

While we understand that work has to be done, and that research on quail and other wildlife is fine, we also need to understand that every new turn around on the side of a plantation road could tear up a nest, which is basically the loss of an entire covey of birds. When people tell me that driving through the woods and turning around does not tear up quail nests, I refer them to that song "*Here's Your Sign!*"

In my opinion, there is nothing new in quail research. We are just rediscovering, and taking a subject that we studied in the past a little farther, or perhaps in a different direction. What we face today is not a dilemma with managers *or* researchers, but *between* managers and researchers. Managers have to run a plantation, and are paid to run a plantation, not find out answers to every issue.

As managers, we understand that the cost of running a quail hunting plantation is high. However, if we would focus on what type of plantation we wanted, then the cost might not be as high, and the end product would be greater. For example, if an owner wants a quail plantation, then the manager needs to focus on quail. If an owner wants a pine plantation, then the manager needs to focus on pines, with quail as a minor, secondary objective. As long as we are trying to manage for both quail and timber, then neither type of plantation will get the greatest output of either birds or planted pines.

Managers are proud of the plantations where they work. Overall, they try to put their utmost into the plantation. Any time a group of plantation managers get together, they inevitably end up comparing plantations, because each manager wants their place to be the best. Then, the stories get deep, and they start talking about how many birds they found. No matter how the conversation started, every story ends up with how many birds "Old Joe" found today.

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