

QUAIL III



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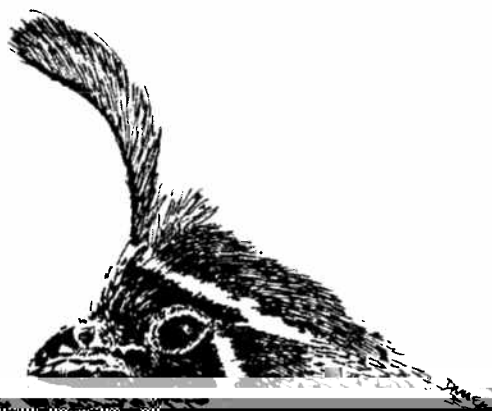
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EDITORS' FOREWORD

This proceedings is the product of Quail III: National Quail Symposium held in Kansas City, Missouri, 14-17 July 1992. Quail III is the third in a series of quail symposia previously held in Stillwater, Oklahoma, 1972 and 1982. Quail III was proposed and originated by the Kansas Department of Wildlife and Parks and the Missouri Department of Conservation. The goal of the conference was to provide a forum for biologists, managers, and conservationists to exchange technical information pertaining to the status, management, research, and future of the 6 species of indigenous quail in the United States.

Quail III was attended by >350 participants representing private individuals, government agencies, and non-governmental organizations from throughout the country. The conference endeavored to address the needs of researchers, managers, and administrators through a combination of formal and informal activities. The plenary, technical, and poster sessions offered state-of-the-art accounts of quail conservation. The strategic planning workshop, organized by Leonard A. Brennan, resulted in a comprehensive document providing direction for management and research well into the 21st century. This unique initiative sets the stage for similar efforts as issues and strategies change in the future. The field trips offered participants the opportunity to view bobwhite habitat and management techniques on a small farm (Hannah Farm), a large power plant site (Jeffrey Energy Center), at Fort Riley, and on Konza Prairie. In addition, a tour was hosted by Sharp Bros. Seed Company to learn about establishing and managing native grasses and forbs. Last, was a special opportunity for participants to acknowledge the valuable contributions of "retired" quail biologists. Recognition was paid during an evening banquet to W.D. Klimstra, Edward L. Kozicky, Robert Pierce Sr., Walter Rosene, and Jack Stanford.

Seventy-two authors provided 29 manuscripts and 11 abstracts for this proceedings, which was sponsored largely by U.S. Fish and Wildlife Service Federal Aid in Wildlife Restoration funds. All manuscripts have been carefully reviewed and subjected to the highest standards of the wildlife profession. As a result of the efforts by authors and reviewers, we believe this proceedings will serve as a valuable reference for students, biologists, managers, and administrators involved in the conservation of quail in the United States. We trust readers will enjoy this proceedings and benefit from the wealth of original information. More importantly, we sincerely hope that Quail III and this proceedings will contribute to the conservation of quail—which is truly the measure of success.



Kevin E. Church



Thomas V. Dailey



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III. We also wish to acknowledge Robert Pierce II (University of Missouri-Extension) who was indispensable as chair of the Arrangements Committee, and DeeCee Darrow for serving as Treasurer.

SYMPOSIUM

We thank the members of the various committees for their invaluable contributions of time and energy in organizing and conducting the conference. Their commitment to providing the best possible symposium, produced not only an informative and enjoyable conference, but established a high standard for future conferences. We also appreciate the fine work of Diana Hallett, Edward Kozicky, Robert Pierce Sr., Randy Rodgers, Walter Rosene, Terry Sharpe, Nova Silvy, and Jack Stanford as technical session chairs; and David Brown, Stephen Capel, William Davidson, John Roseberry, and Walter Rosene as workshop session chairs.

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We are particularly grateful to the authors for their fine written contributions and cooperation during the editing and printing process. Of course, a proceedings is only as good as the reviewers, and we were fortunate to recruit the services of 35 knowledgeable and skilled volunteers. Their work was a much appreciated necessity. Artwork was skillfully developed for the proceedings by David Besenger (cover) and Dana Eastes. A very special note of gratitude is extended to Sandy Clark (redactory editor) and Annette Wiseman for their patience, experience, and skill in developing this proceedings. Without their assistance the final product would have been much less.

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Table 1. Common and scientific names of quail in the 48 contiguous states.

Genus <i>Callipepla</i>
Scaled quail (<i>C. squamata</i>)
California quail (<i>C. californica</i>)
Gambel's quail (<i>C. gambelii</i>)
Genus <i>Colinus</i>
Northern bobwhite (<i>C. virginianus</i>)
Genus <i>Oreortyx</i>
Mountain quail (<i>O. pictus</i>)
Genus <i>Cyrtonyx</i>
Montezuma quail (<i>C. montezumae</i>)

Today the contiguous states harbor 4 genera and 6 species of quail (Table 1). Known hybridization among *Callipepla* species and between *Callipepla* and *Colinus* demonstrates close phylogenetic relationships.

RECENT HISTORY

Available evidence from middens indicates that bobwhite were not commonly used by Indians, probably because of their small size and the difficulty of securing them in large numbers. The wild turkey (*Meleagris gallopavo*) was the upland bird most sought after by Indians (Goslin 1955, van der Schalie and Parmalee 1960, Woolfenden 1965); however, for many Native Americans, the California quail was an important part of the diet, supplementing large mammals, fish, roots, seeds, nuts, and other foods. The birds were so sought after in some areas, especially in the northern half of California, that special devices were developed solely for capturing quail. In the central area of the state there were professional quail hunters, which emphasizes the importance of the birds to Indians in the area (Nissen 1977:228).

In Wisconsin the bobwhite within a period of 10 years, 1845-54, became extraordinarily abundant (Schorger 1946:81-82). It then declined in numbers so rapidly that during the past 75 years the most that can be said for the species is that it has maintained its existence. Taking into consideration all of the known influential factors, Schorger (1946:94-98) concluded that a decade of favorable winter weather seems to have been most important in producing the peak in the population. Unless we assume that weather has continued to be the important factor, the question of why the quail refuses to undergo more than a sporadic increase remains unanswered.

The former periodic irruption or emigration of quail on an extensive scale was an interesting phenomenon (Schorger 1946:87-90). During the movement, which took place usually in September and October, quail behaved abnormally, especially in the north-central states. As late as 1891, Van Dyke (1891:11-13) wrote of the quail in Minnesota:

"In the early part of the fall, ...quail generally have a crazy spell, during which they gather into large flocks, travel quite a distance and even go into town and butt their brains out against houses." Schorger (1946:89) stated, "There is little doubt that the habit of quail to emigrate or irrupt, when a certain density of population was attained, was a powerful factor in producing the huge numbers that existed in Wisconsin in the decade prior to 1854."

There is ample evidence that quail increased greatly simultaneous to a certain stage in the development of agriculture. After the Wisconsin peak quail populations, all stages of land improvement could be found in the southern portion of the state, yet quail never recovered.

Gambel's quail were historically much more abundant in Arizona than at present; extremely high populations were observed from early exploration of the territory until about 1900 (Brown 1988). The earliest explorers (1840's) observed "immense" numbers of quail. Brown (1988:9) quoted from the diary of G. O. Hand based on observations in 1862:

"All along this day's march the quail were astonishing; big flocks of them 200 yards long. I really think there were millions of them in each flock."

High numbers persisted into the late 1880's as "thousands of dozens" were captured and shipped to market. Indeed, Gambel's quail were so numerous as to be considered agricultural pests.

The great drought of 1888-1904 and associated grazing abuses marked the end of high quail abundance in Arizona (Brown 1988:9). Brown (1988:10) speculated, as did Leopold (1977:33-34), that the inherent productivity of the land might have been lowered by the whiteman's land-use practices and the alien plants which he introduced. He also observed that massive flocks of Gambel's quail often were associated with perennial watercourses, scoured each year by floods which deposited nutrient-rich sediment. Daming of the watercourses has thwarted a rejuvenating process of nature.

tween the States, had gone through the early stages of succession and by 1920 offered new challenges to those responsible for the quail crop. Of course, by the late 1920's, quail managers had tried all of the "quick fixes" for quail abundance and were aware that simple answers, such as restrictions on bag limits and seasons, predator control, or restocking were not the solutions. Something more was needed.

The classic study by Herbert Stoddard (1931) in the 1920's was a direct result of the deterioration of hunting quality on existing plantations, and it was financed by unhappy plantation owners. One of the most important principles to emerge from Stoddard's research has to be the concept of a biological approach to management, including fire as a necessary and useful tool. Through private research, southern plantations have had considerable impact on wildlife management as a profession, and quail management in the South in particular. Stoddard's effort, along with Aldo Leopold's classic *Game Management* (1933), were the blueprints of the 1930's for an ecological approach to wildlife management.

WINDS OF CHANGE

We have little reason to be optimistic about the future of wild quail in North America. There are no simple and easy answers. Good quail hunting will become more expensive and require intensive management. Fred Guthery (Caesar Kleberg Wildlife Research Institute, Texas A&I University, pers. commun.) tells me populations of 5-7 bobwhite per ha are possible in Texas in normal years with intensive management. John Olin, with intensive quail management, approached 5 quail per ha on the best bobwhite habitat on his Georgia plantation. It can be done, but the economics are not for the average hunter.

Part of the "winds of change" is the growing use of pen-reared bobwhite for dog training and commercial hunting areas, such as hunting preserves. Unfortunately, we in the wildlife profession have abandoned game-bird propagation and left the effort in the hands of good folks in poultry husbandry, who mostly treat the subject as an unwanted stepchild and do not understand the importance of simulating the sporting aspects of wild birds with their pen-reared counterparts. Their training has been the efficient conversion of feed into pounds of flesh for the meat market. Have those of us in the wildlife management profession forgotten artificial propagation is a tool of wildlife management? Shouldn't we always strive to improve our management tools? When

we do initiate a project with pen-reared game birds, the effort seems to center on what is wrong with pen-reared game birds for hunting purposes instead of how we can improve their field performance. In the meantime pen-reared bobwhite are used to supplement wild populations in many areas and passed off as wild birds in ever increasing numbers (Kozicky 1987:65).

Northern bobwhite is called the king of game birds, but his pen-reared cousins have a serious flaw. They tend to domesticate in captivity rather quickly, and their field performance leaves much to be desired. Quail hunters either on a hunting preserve or commercial hunting area have a right to expect pen-reared game birds to approximate the field behavior of their wild brethren. The birds are expected to flush as a covey and exhibit strong flight characteristics, have the same color and conformation as wild birds, and be fully feathered and not grossly debeaked.

In the beginning of my effort to develop quality bobwhite hunting with pen-reared birds at Nilo, an experimental and demonstrational hunting preserve owned by the Winchester Group, Olin Corporation, I looked for simple answers. But, answers were not simple and required considerable attention to details.

We finally achieved success with the Burnette bobwhite (Kozicky and Madson 1966:138-162). Our greatest critic was John M. Olin, the guiding force behind our efforts at Nilo, and devoted quail hunter. Needless to say, we felt the glow of accomplishment when he stated that we were 90% successful in simulating wild quail hunting with pen-reared bobwhite. But, this brush with success only lasted about 2 years. My source of pen-reared birds from the Burnettes dried up, and we became involved in other projects. The important point is that pen-reared birds can provide quality hunting.

Wildness in any game bird is the sum of heredity and environment. Although the ring-necked pheasant (*Phasianus colchicus*) does not seem to be greatly influenced by environment, the bobwhite is (Kozicky 1987:35-40). The objective on a preserve is to provide consistent, quality hunting of any upland game bird within 30-60 minutes of being released for hunting. The key words are "consistent" and "quality." The 30- to 60-minute time limit is incidental if the loss of released birds can be minimized. As a rule, the longer the period between release of birds and hunting, the lower the return. Released birds are subject to predation and movement after being released.

Consistent means that one can expect the same field performance under the same weather conditions throughout the hunting season. Too often we hear that released birds performed well 1 day but not the next. What happened? In many instances we do not know. But it is a fair assumption that some detail(s) of management for quality quail hunting has (have) been overlooked.

The preserve operator, looking for a simple answer and a scapegoat, is prone to blame the breeder. But, if the birds were good flyers at the time of purchase, the answer lies either in shipping or management of the birds on the preserve.

The game-breeding industry has matured by leaps and bounds on some species of game birds in the last 40 years. Originally, game breeders selected for the domestic strain of game birds. Most game birds were produced for the table. Hence, they selected more docile birds, best egg layers, and largest birds—all traits of domesticity. But, the hunting preserve industry began demanding changes, and great strides have been made, especially with the ring-necked pheasant. Today, game breeders can provide you with a pheasant for the table or a bird as wild as you want. The same is not true for bobwhite.

In the last 40 years the preserve industry has learned the importance of heredity and isolation through trial and error in producing quality bobwhite (Kozicky 1987:36-37). However, there is little valid information on how frequent to back-cross to wild birds. There is no universal understanding of the word "isolation." Some breeders consider isolation of pen-reared bobwhite to be putting their holding pens behind the barn. To me isolation should mean absolutely no contact with dogs and not more than 1 human contact per day, and preferably by the same person wearing the same colored clothing. There are other factors still being evaluated, such as flight pens; rearing on ground or wire; overhead cover; not mixing bobwhite from different holding pens; darkened holding pens; food, water, and dusting; and shipping that influence the performance of pen-reared bobwhite in the field (Kozicky 1987:57-68). Currently, bobwhite breeders advertise that their birds are flight-conditioned. In most cases it is a sales gimmick or buzzword of questionable value. To date, we cannot judge the field performance of pen-reared bobwhite by the most common anatomical or physiological variables—rectal temperature, heart rate, body weight, wing measurements, or toe or leg length (Cain 1974). However, if the birds are docile when you approach

them in a holding pen, it is unlikely they will perform satisfactorily in the field.

We all like simple solutions to complicated problems, but they are seldom valid, which reminds me of a quick fix several years ago. At the Caesar Kleberg Wildlife Research Institute we tried to take average pen-reared bobwhite, inject them with adrenocorticotrophic hormone, and stimulate a docile domesticated bird into simulating a wild bird for at least a few hours. In short, it did not work. What was of interest is that individual birds reacted differently to the drug and external stimuli. This made us realize that bobwhite are also individuals, probably as much as humans. If so, it takes time to unite a group into a covey.

There is considerable tradition associated with bobwhite hunting. The hunter expects to find a covey of birds and have birds flush as a covey and then pursue some of the singles. One problem with pen-reared birds is that they have not had a chance to become a covey, especially when birds for a hunt originate from different holding pens. The birds have not had time to develop a peck order and determine a leader. One of the benefits of the Smith-O'Neal release system (Kozicky 1987:69-70) is that it gives pen-reared birds time to become a covey, and react accordingly when encountered in the field. With good quality pen-reared birds, such as Burnette bobwhite, the birds reacted as a covey unit upon release. But these birds were reared and held together as a unit both by the Burnettes and within the holding pens at Nilo. The normal number of birds in a covey released for hunting at Nilo was 6.

Then, there are folks who want to release pen-reared bobwhite with the thought that they will be accepted by wild coveys. Some have even broadcast pen-reared birds over their hunting areas. It usually is a 1-time affair. The return in harvested bobwhite quickly eliminates this technique. Occasionally a wild covey will accept a pen-reared bird or 2, but such acceptance is more the exception than the rule. Wild coveys have strong social bonds and are not prone to accept recruits.

Besides the rearing and holding of pen-reared bobwhite, there is a series of factors that will affect the field behavior of released pen-reared birds: number of birds in a release, method of release, length of time from release to hunting, type of cover into which the birds are released, weather, traits of the hunting dog(s), and time of day (Kozicky 1987:61-63,116).

Quality quail hunting with pen-reared birds sounds like an impossibility, but many of the problems listed are minor if the birds are of the proper wild stock. *In my opinion there is no substitute for the basic wildness of pen-reared stock, and the efforts made by the game breeder and the hunting preserve operator to retain the basic wildness of the birds.* Mature bobwhite can and have become pets.

As yet no one has developed an environmental influence that will reverse the tendency for bobwhite to domesticate in captivity. All management techniques, with the exception of backcrossing to wild birds, are environmental measures to delay domestication or to influence the field behavior of pen-reared bobwhite. The industry needs the help of universities to solve some of the mysteries of producing quality pen-reared bobwhite for hunting on a consistent basis at a reasonable cost. Personnel at some universities and state wildlife agencies believe that pen-reared bobwhite are a liability in the wild, and the fewer the better. This philosophy reminds me of an ostrich sticking its head in the sand, because thousands of pen-reared bobwhite are released every year for hunting purposes, and the number is growing. Private enterprise in game management has been with us since 1910.

As Aldo Leopold (1933:20) pointed out back in the early 1930's,

"The Crusaders for conservation wrote many volumes on why rather than how wildlife and civilizations could be adjusted to each other. There was 1 periodical, *The Game Breeder*, that pioneered the idea of game production through private initiative, but it leaned toward artificialized game-farming technique, and toward open markets to reinforce the private production incentive. These 2 corollaries, particularly the latter, beclouded the intrinsic merit of the central idea. Its program had the outstanding merit of realism and of constructive discontent with pious phrases."

The Game Breeder magazine eventually went out of business but has been replaced with *Wildlife Harvest*.

The academic challenge is to try and find the best way to produce quality bobwhite at a reasonable price and keep hunting as close to its traditional sporting challenge as possible, including the covey rise. It has been done on a small scale by a Missouri couple devoted to the production of quality birds, but it was more a labor of love than one for profit (Kozicky and Madson 1966). Then, the question remains: will the hunting

preserve client pay for the extra cost of quality bobwhite? We are all aware that the most sensitive nerve in the human body is the one that runs between the heartstrings and the billfold. There are hunters who are quite satisfied with the quality of current pen-reared birds on hunting preserves (Marks 1991:180-181). Also, strange as it may sound, there is a growing number of new hunters who have never experienced the challenge of wild quail hunting and may not know the difference.

SUMMARY

In closing, quail have been a fixture on the American scene for more years than man has recorded history. Their contribution to sport hunting, especially bobwhite and California quail, are legion, and have had a great influence on our social life. Quail have brought out the best in men and dogs, especially the bobwhite. Yet, we need to be concerned about the future of all species of quail.

The future of quail lies in part with the general public, the quail hunter, the economics of the sport, and the academic community. The quail hunter, best described by Charley Dickey (1974:25), "...is a simple and kindly man who asks no more of life than that the birds fly fast, the dogs hold tight, and everything has a sporting chance to live or die," will have to learn to devote more time and money to the future of his sport. The academic community must strive to find ways and means of assuring huntable supplies of bobwhite on an annual basis and help private enterprise produce better and wilder bobwhite in captivity at a reasonable price. The use of pen-reared bobwhite is a fact of life. The challenges are tremendous, but good men and women rise to such challenges, and I have a profound faith that solutions will be found and the sport of quail hunting will continue to epitomize sportsmanship afield.

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to the AOU's committee on nomenclature taxonomic treatment of the odontophorine quail.

TAXONOMY OF NEW WORLD QUAIL

Taxonomy is the study of classifying organisms. Systematics is the study of phylogenetic relationships and evolutionary processes that generate biodiversity. The distinction is important because pure "alpha" level taxonomy may not be sensitive to issues of phylogeny. The most interesting questions in biology are not what an organism's name happens to be, but what are its ecological and evolutionary relationships to other organisms (Brooks and McLennan 1991). Thus most current treatments of taxonomy are really systematic treatments.

Classification of Quail

There have been several taxonomic and systematic treatments of New World quail (Table 1). Until recently most treatments have been based on general morphology (i.e., plumage pattern, color variation, general size) and species integrity (Mayr and Short 1970). Some scientists have based their inferences of relationship on morphology (osteology [Holman 1961]; myology [Hudson et al. 1966]); others have based their inferences on genetic analyses (protein electrophoresis [Gutiérrez et al. 1983]; DNA hybridization [Sibley and Ahlquist 1990]; see also Table 1).

Higher Taxonomic Levels.---All taxonomic treatments of quail place them within the order Galliformes. Sibley and Monroe's (1990) organization (Table 2) is somewhat different than classical approaches because they use a dichotomous classification which requires use of additional taxonomic levels such as "parvorder." This proposed classification is considered to be a working hypothesis by the AOU committee on nomenclature (T. Howell, pers. commun.). Nevertheless, Sibley and Monroe's approach is different from other treatments because they elevate the New World quail to family status (i.e., Odontophoridae). Sibley and Ahlquist (1985, 1990) noted that New World quail were very distinct from other chicken-like birds on the basis of DNA hybridization experiments. The DNA hybridization technique (Sibley and Ahlquist 1990) upon which this classification was based has received widespread criticism among ornithological systematists (e.g., see Lanyon 1992).

Holman (1961) suggested that New World quail should be distinguished as a separate family. He based his suggestion on the significant osteologi-

Table 1. Major taxonomic treatments of New World quail.

Source	Basis for treatment
Peters (1934)	External morphology
AOU (1957)	External morphology
Holman (1961)	Osteology
Brodkorb (1964)	Fossil record
Hudson et al. (1966)	Myology
Mayr and Short (1970)	External morphology
Sibley and Ahlquist (1972)	Egg white protein electrophoresis
Stock and Bunch (1982)	Cytogenetics
Gutiérrez et al. (1983)	Protein electrophoresis
AOU (1983)	Synopsis of literature
Sibley and Ahlquist (1990)	DNA-DNA hybridization (Sibley and Monroe [1990])

cal differentiation exhibited by the New World quail. For example, odontophorine quail are unique among Galliformes by having a serrated mandible. Gutiérrez et al. (1983) also demonstrated that the odontophorine quail were a distinct clade within the Galliformes, but they did not offer a specific recommendation on the family status of the group. Most classification schemes place the New World quail within the subfamily Odontophorinae without substantive comment on the basis for the classification (e.g., Peters 1934, Hudson et al. 1966, AOU 1983), although Delacour (1951) placed them within the subfamily Phasianinae. Despite the large number of studies on species or groups within Galliformes, there is not a comprehensive systematic study of the entire group (see Randi et al. 1991).

Lower Taxonomic Levels.---Many changes in the taxonomy of species and subspecies of quail have occurred in the past 50 years (Table 2). Initially there was a tendency among taxonomists to describe a newly collected specimen as a new species when it has morphologically differentiated from other specimens. As the biology and distribution of these species became known in greater detail, many of the originally named species were relegated to subspecific status. This process continues today as poorly known species in the Neotropics become known (e.g., *Odontophorus*). There also has been a general trend in ornithology to dissolve monotypic genera. The recent merging of the *Lophortyx* quail (AOU 1957) with *Callipepla* is an example of this trend as it affects American quail.

Table 2. Taxonomies of New World quail.^a

	Peters (1934)	Howard and Moore (1991)	Sibley and Monroe (1990)
Parvclass	—	—	Galloanserae
Superorder	—	—	Gallomorphae
Order	Galliformes	Galliformes	Galliformes
Parvorder	—	—	Odontophorida
Superfamily	Phasianioidea	—	—
Family	Phasianidae	Phasianidae	Odontophoridae
Subfamily	Odontophorinae	Odontophorinae	—
Genera			
	<i>Dendrortyx</i> (4,8) ^b	<i>Dendrortyx</i> (3,8)	<i>Dendrortyx</i> (3)
	<i>Oreortyx</i> (1,3)	<i>Oreortyx</i> (1,4)	<i>Oreortyx</i> (1)
	<i>Callipepla</i> (1,3)	<i>Callipepla</i> (1,4)	<i>Callipepla</i> (4)
	<i>Lophortyx</i> (3,10)	<i>Lophortyx</i> (3,16)	—
	<i>Philortyx</i> (1,1)	<i>Philortyx</i> (1,1)	<i>Philortyx</i> (1)
	<i>Colinus</i> (4,33)	<i>Colinus</i> (3,42)	<i>Colinus</i> (3)
	<i>Odontophorus</i> (16,19)	<i>Odontophorus</i> (14,20)	<i>Odontophorus</i> (15)
	<i>Dactylortyx</i> (1,7)	<i>Dactylortyx</i> (1,11)	<i>Dactylortyx</i> (1)
	<i>Cyrtonyx</i> (3,6)	<i>Cyrtonyx</i> (3,5)	<i>Cyrtonyx</i> (2)
	<i>Rhynchortyx</i> (1,4)	<i>Rhynchortyx</i> (1,4)	<i>Rhynchortyx</i> (1)

^aThese are a few examples of New World quail classifications. An extensive chronology of classifications is presented by Sibley and Ahlquist (1990).

^b(Number of species, number of subspecies); no subspecies given by Sibley and Monroe (1990).

The issue of species and subspecies identity and classification is a focal point of debate in ornithology (Barrowclough 1982, Gill 1982, Johnson 1982, Lanyon 1982, Mayr 1982, Monroe 1982, O'Neil 1982, Parkes 1982, Phillips 1982, Storer 1982, Cracraft 1983, McKitrick and Zink 1988). At issue is the species concept itself. Two systematic constructs, among several, at debate are the biological species concept (Mayr 1969) and the phylogenetic species concept (Cracraft 1983, McKitrick and Zink 1988). In the former the species is recognized on the basis of its genetic isolation from other species. In the latter a species is recognized on the basis of its genetic integrity (McKitrick and Zink 1988) and its evolutionary history. Mayr and Short (1970) attempted to demonstrate that few problems in taxonomy occurred when applying the biological species concept to North American birds. However, because quail readily hybridize both in the wild (Henshaw 1885, Peck 1911, Bailey 1928, Aiken 1930) and in captivity (Johnsgard 1971), Mayr and Short (1970) inferred that American quail were extremely similar and some forms could be conspecific (e.g., *Callipepla californica* and *C. gambelii*) or

congeneric (e.g., *Oreortyx pictus* and *C. californica*; Mayr and Short [1970:42]). Although *C. gambelii* x *C. californica* occasionally hybridize there is no widespread introgression. Further, Gutiérrez et al. (1983) demonstrated that *Oreortyx* was distantly related to *Callipepla*. The propensity to hybridize in zones of habitat transitions would not necessarily confuse the taxonomy of the group under the phylogenetic species concept (McKitrick and Zink 1988).

There are currently approximately 128-145 subspecies among the 31 species of extant quail (Johnsgard 1988). In my opinion the validity of many of the subspecies should be questioned. It is clear that some species exhibit a high degree of morphological differentiation (particularly *Colinus*) which facilitates subspecies recognition; but others (e.g., *Callipepla californica*) have many subspecies with relatively little morphological differentiation (Gutiérrez et al. 1983, Zink et al. 1987). Because of these and other problems the trinomial in bird taxonomy has been discussed at length (see Auk 1982:593-615), and proponents of the phylogenetic species concept have suggested abolishing subspecies entirely (Cracraft 1983, McKitrick and Zink 1988).

tophoridae using estimates of genetic divergence, inferred from electrophoretic patterns, among *Colinus*, *Oreortyx*, *Callipepla*, and *Cyrtonyx* (which represented the second monophyletic subgroup within the family), calibration of an electrophoretic clock using fossil specimens, and geologic events coincident with divergence times. Under their scenario, *Oreortyx* separated approximately 12.6 million years ago (MYBP), *Colinus* next diverged about 7 MYBP, *Callipepla squamata* separated at approximately 2.8 MYBP, and finally *C. californica* and *C. gambelii* diverged about 190,000 years ago. These divergence times correspond generally with reconstructed geologic and climatic events (Gutiérrez et al. 1983). Hubbard (1973) proposed another vicariant explanation for the evolution of *Callipepla*. He proposed a trichotomous split in which *C. squamata*, *C. douglasii*, and "pre-*C. californica-gambelii*" diverged first in the Illinoian glacial epoch followed by differentiation of *californica* from *gambelii* during the Wisconsinian glacial period. It is possible that climatic influence of Illinoian epoch on vegetation (Axelrod 1979) may have influenced speciation of *C. californica* and *gambelii* but probably not *squamata*. Nevertheless, it is clear that isolation events probably led to the speciation of New World quail. The current distribution (i.e., sympatry) of these species also suggests dispersal subsequent to speciation (Nelson and Platnick 1981). Nevertheless, these are biogeographic hypotheses which cannot be precisely reconciled with paleobotanical and geologic events. In addition, the remaining taxa within the Odonotophoridae should be examined to derive approximations of their evolutionary histories and as a test of the above hypothesis (Gutiérrez et al. 1983).

RESEARCH AND MANAGEMENT IMPLICATIONS

Systematic and Taxonomic Investigations

It is evident that thorough analysis of the quail would greatly clarify relationships within Odonotophoridae. Genetic assessment techniques now available could be used to clarify not only phylogenetic relationships but also levels of variation within and among species and populations of these fine game birds. A review of the type I envision should include all extant forms of quail in addition to a thorough review of the literature to trace the appropriate nomenclature (sensu Browning 1977). This information could provide

the basis for more informed management of these quail as I suggest below.

Release of Pen-reared Birds

The release of pen-reared quail has occurred for many years as a technique to "augment" natural populations or to increase potential quail harvest (Buechner 1950, Sexson and Norman 1972, Leopold 1977, Roseberry et al. 1987). The artificial propagation and release of quail has been controversial for many years because of its effects on wild populations (Landers et al. 1991) and the low survivorship of pen-reared birds.

Although deleterious genetic effects of cultured salmon on native fish stocks is well known in the fisheries literature (e.g., Waples 1991, Hindar et al. 1991), little is known of genetic effects on native populations of releasing large or small numbers of pen-reared quail despite a long history of such introductions. In fact, few studies have been conducted on any aspect of genetic relationships between pen-reared and wild quail (Ellsworth et al. 1988, Wooten 1991).

Leopold (1977:15) argued that natural selection would soon remove maladapted hybrid California quail produced by interbreeding of native and exotic stock from the population, and thus, any deleterious genetic effects would not be felt in a population. Although this may be true of small local introductions, it is unclear if the effect of continuous large-scale introductions in areas of low native quail population density would be equally benign. The experience of our fisheries colleagues should have stimulated our investigation of the genetic effect of introductions on native populations long ago.

I suggested above that the differentiation observed in quail was probably the result of past isolation. This differentiation appears to be greatest in the northern bobwhite. If this divergence during isolation also resulted in local adaptations to environmental conditions, then widespread, intensive releasing of captive or non-native stock could have potential deleterious genetic effects. Brennan (1991) documented the decline of quail nationally. For example, the northern bobwhite is declining in all areas of its range including those where quail management is a featured land management activity. A comprehensive search for causative factors of this decline must include the effect of genetic mixing of populations. Genetic markers may be identified in wild and introduced birds (Wooten 1991) to trace the introgression of genes into the wild population. Genetic studies should complement

studies of reproductive performance and survival to establish a causal link between changes in demography and changes in genetic structure resulting from introduction of nonnative birds.

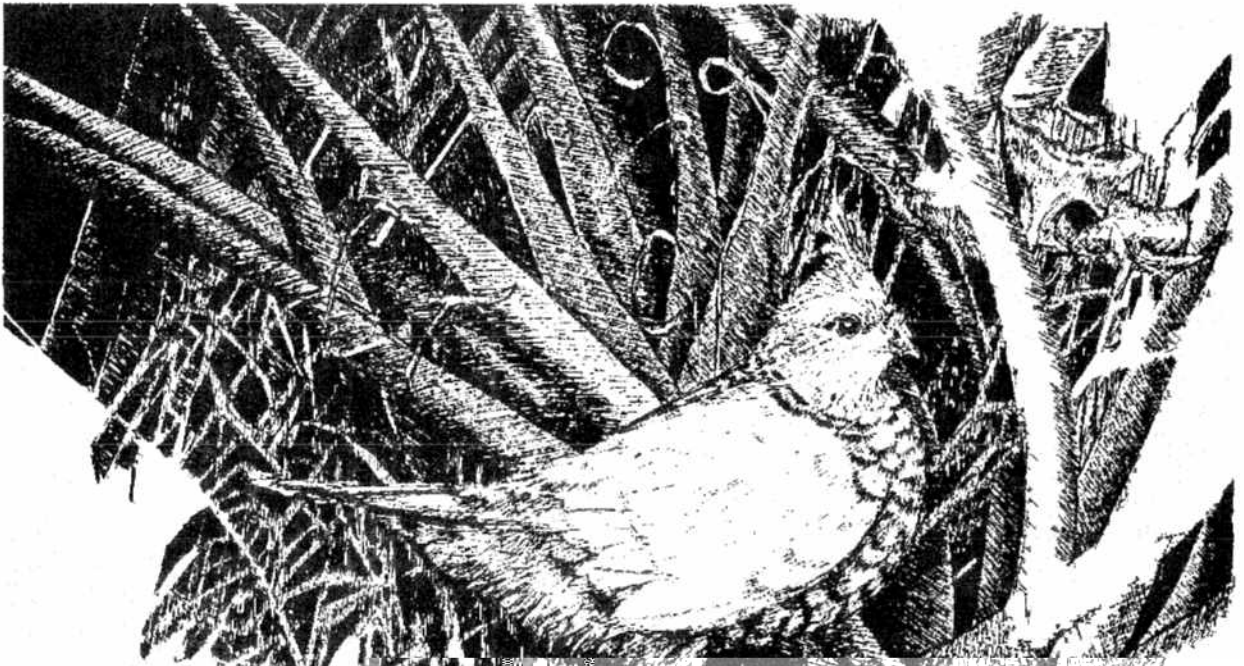
Translocating Quail

Brennan (1991) noted the importance of transferring wild-trapped birds as sources of stock for quail populations extirpated by loss of habitat, stochastic demographic events, or severe weather. If suitable habitat returns or remains following 1 of these events, translocation of quail may be a relatively inexpensive technique for reestablishing a population. However, because of the genetic and behavioral differences between pen-reared and wild birds (Roseberry et al. 1987), only wild caught birds should be used in these endeavors. In addition, populations of the same genetic structure from as close as possible to original populations should be the source of the translocations. Widespread genetic screening of populations is possible with relatively little cost if the objective is to document genetic structure of populations within general geographic areas.

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BOBWHITE AND THE "NEW" BIOLOGY

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Abstract: Phrases and concepts familiar to traditional wildlife managers like carrying capacity, annual surplus, and edge are being replaced in the literature and at conferences by terms such as biodiversity, metapopulations, and fragmentation. I raise the question of whether this new vocabulary merely represents trendy buzzwords of the 1980's, or is it relevant to bobwhite management in the 1990's and beyond? Some aspects of the "new" biology appear to differ from traditional wildlife management primarily with respect to scale, and may therefore be applicable in dealing with relatively isolated populations in dissected habitats. Others, however, reflect more basic differences in philosophies and agendas. Implications for future bobwhite management are discussed.

Key words: conservation biology, landscape ecology, management, northern bobwhite.

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Those of us old enough to remember the First National Bobwhite Quail Symposium in 1972 are familiar with such terms as carrying capacity, edge effect, annual surplus, travel lanes, huntable populations, interspersions, succession, and invertibility. These phrases and concepts have been part of the lexicon of quail biologists since the days of Stoddard, Leopold, and Errington. Nowadays, however, at conferences or in the literature we are more likely to hear about biodiversity, fragmentation, metapopulations, minimum viable populations, population vulnerability analysis, connectivity, heterogeneity, and patch dynamics. This is clearly not the vocabulary of traditional wildlife management, but rather of what might be called the "new" biology, consisting primarily of Landscape Ecology, Restoration Ecology, and Conservation Biology. The question I would pose is: Are these terms and concepts merely trendy buzzwords of the 1980's, or are they relevant to bobwhite management in the 1990's and beyond? At first glance, they may seem to be just fancy new ways of saying the same old thing (e.g., corridors instead of travel lanes, heterogeneity instead of interspersions). On closer inspection, however, certain of the new terms connote a somewhat different perspective related primarily to scale. By scale, I mean the relative size (extent) of the geographic area of concern and the relative detail (resolution) with which information about it is conveyed. Other aspects of the "new" biology appear to reflect more basic differences in general philosophies of wildlife management. The following essay evolved in large measure from stimulating discussions with colleagues R. Gates, W. D. Klimstra, M. McKee, and A. Woolf.

PERSPECTIVE

When habitat was abundant and well distributed, bobwhite research and management often concentrated on site conditions or local situations. Traditional approaches to habitat management (e.g., Ellis et al. 1969, Landers and Mueller 1986) and evaluation (Baskett et al. 1980, Schroeder 1985) generally focused on discrete areas without regard to their orientation in physical space. Population research and management likewise often ignored spatial aspects (e.g., Errington 1945, Kabat and Thompson 1963, Roseberry and Klimstra 1984). However, present-day land use has eliminated or dissected much upland habitat leaving remaining habitats distributed in relatively isolated patches separated by tracts of inhospitable land or other barriers, a phenomenon known as habitat fragmentation (Wilcove et al. 1986:237). This and other associated trends have necessitated a broader perspective in dealing with current management issues and problems.

Habitat fragmentation is a problem most commonly associated with forests and forest communities (Burgess and Sharpe 1981, Harris 1984). However, the increasingly patchy aspect of upland wildlife habitat is a growing concern as well (Roseberry and Klimstra 1984, Kenney 1985, Temple 1992). Earlier, less intensive agriculture, with its small fields, diverse cropping patterns, and network of hedgerows and brushy fencerows provided bobwhite with (in the new vernacular) a fine-grained, heterogeneous landscape characterized by a high degree of connectivity. Such landscapes facilitated exchange of individuals and genetic material between and among neigh-

understand the significance of geographic scale [and] move their consideration from the small scale of a property to the larger scale of ecologically significant geographic areas." This does not mean that quail biologists and quail hunters should not continue to work for and promote the welfare of the bobwhite. Especially as it can be demonstrated that land-use practices conducive to bobwhite abundance also benefit a large community of other species and, indeed, the land itself (Roseberry and Klimstra 1984). We must recognize, however, that certain traditional management prescriptions may not always be appropriate or justified in every situation (e.g., "wildlife" openings in otherwise unbroken old-growth forests). On the other hand, some "new" management initiatives (e.g., restoration of former prairie or savannah areas) offer substantial potential benefit for bobwhite.

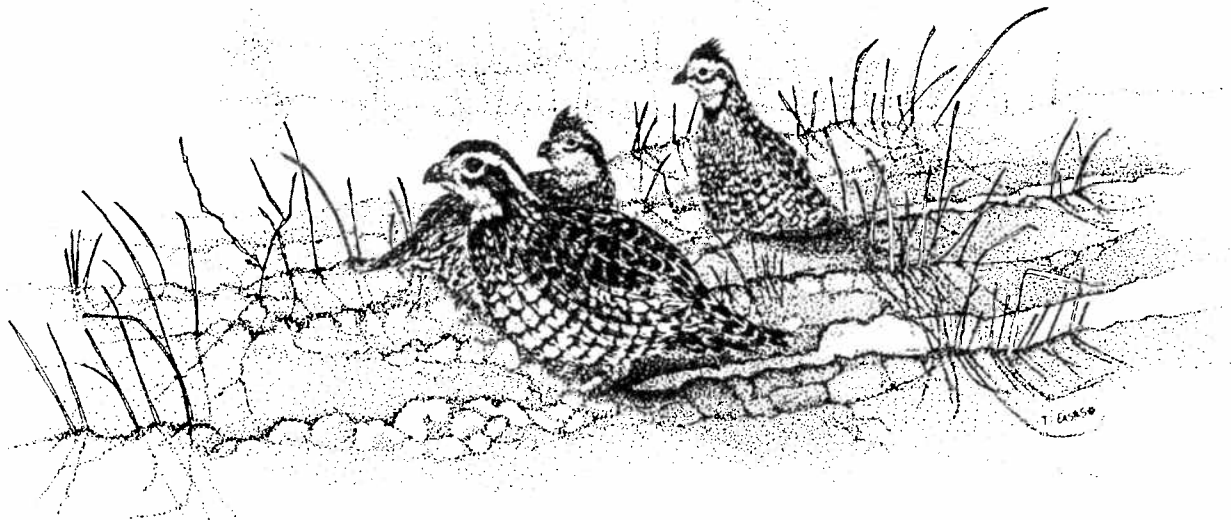
Our country's wildlife resource base—game and nongame alike—is being progressively eroded by an expanding human population and by those who could not care less about conserving it. Therefore, I would tend to agree with Anonymous (1989) and Bolen (1989) that despite some very real and fundamental differences in priorities, there is sufficient commonality of purpose—and that purpose is sufficiently important—to make an alliance of traditional "wildlifers" and "new" biologists essential if we are to salvage at least a portion of what remains of our natural heritage.

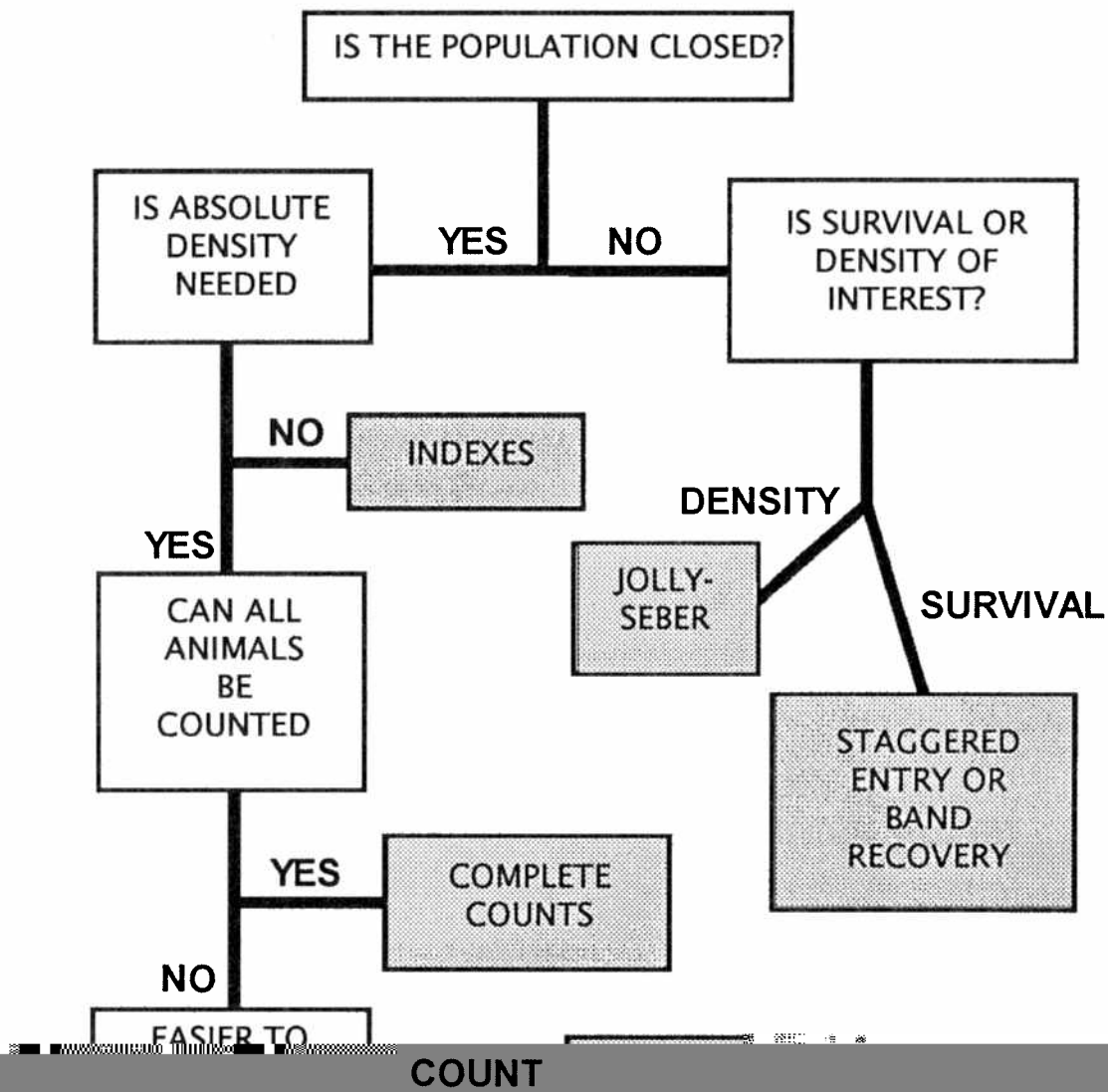
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CAPTURE

Fig. 1. Decision tree indicating the process of determining the appropriate population estimator for quail that will meet assumptions of the techniques and needs of the investigator.

counted, then a drive count would be appropriate. If all the individuals cannot be counted, they need to consider whether it is easier to capture or observe the quail. If it is easier to observe the quail, a line transect estimator would be indicated; a mark-recapture estimate would be appropriate if it is easier to capture individuals.

Open Population Estimates

If the population is open, the relative importance of population estimates vs. survival estimates needs to be considered. If density estimates are of greatest importance, then some form of a Jolly-Seber estimate would be most appropriate. If survival is of interest, then band-

recovery or a staggered entry approach would be suitable (Fig. 1).

Indexes

When an absolute estimate of density is not necessary, various indexes to population levels may be appropriate. Wells and Sexson (1982) provided an overview of indexes to northern bobwhite (*Colinus virginianus*) density.

They felt that rural mail carrier surveys in October provided the best data for predicting fall harvest parameters. Such surveys can provide data over a relatively large area (e.g., a state). If these data can be standardized in terms of how they are recorded and the conditions under which they are taken, they can be used to track population trends.

Measures of hunter success (e.g., birds shot/gun-hour) have been used to track population trends for northern bobwhite (e.g., Wells and Sexson 1982, Fies et al. 1992) and Montezuma quail (*Cyrtonyx montezumae*; Brown 1979). Such data are relatively easy to acquire by state agencies; however, the quality often is questionable. Because the data source is of variable reliability (hunters) and there is a lack of control over data quality (lack of variance estimates, etc.), I believe it is dangerous to give too much credence to this sort of information. These data do not lend themselves well to statistical analysis, and thus it is difficult to identify real differences between areas or years. At best, I believe we are limited to general statements about population trends from hunter data.

The indexing method that has received the most attention is the use of call or whistle counts. One of the first to use whistle counts was Bennitt (1951), who found that spring and early summer counts of bobwhite provided a reasonable index to fall harvest. Rosene (1957) indicated that call counts provided adequate indications of fall harvest for bobwhite. Smith and Gallizioli (1965) reported that whistle counts of Gambel's quail (*Callipepla gambelii*) correlated well (r values >0.94) with the subsequent fall harvest. However, they noted that spring counts will only work well if hatching success and survival of young is constant from year to year. For scaled quail (*C. squamata*), Brown et al. (1978) found that spring whistle counts were correlated with fall harvest, although weather also was an important factor influencing counts.

Although some researchers have successfully used whistle counts to predict fall harvest, this technique has generated substantial disagree-

ment. Norton et al. (1961) critiqued the use of whistle counts to predict fall populations in bobwhite. They reanalyzed data presented by previous workers and noted: "It must be concluded that the case for usefulness of numbers of whistling cocks in summer to estimate autumn populations is weak and that a better method is needed" (Norton et al. 1961:403). They argued that whistle counts may provide a reasonable index of population densities at a particular time and could be used to monitor trends. However, unless data are available for nesting success, recruitment to the population, and survival, we cannot accurately predict fall harvest. Robel et al. (1969) analyzed call counts for bobwhite in Kansas and developed regressions that adjusted counts for effects of time of year, time of day, and weather. Schwartz (1974) noted the problem of spring counts not accounting for production and found August counts worked better to predict fall numbers in Iowa; he suggested that early summer call counts not be used to estimate fall quail numbers. More recently, in a general review, Dimmick (1992) recommended that call counts not be used to estimate populations of bobwhite. In contrast, Curtis et al. (1989) reported a high correlation ($r = 0.94$) of call counts with fall harvest of northern bobwhite on Fort Bragg, North Carolina. They also reported that call counts were correlated well with total number of quail ($r = 0.89$).

So, are call counts good or poor indicators of populations? It appears that more controlled research, of the nature of Curtis et al. (1989), would be appropriate to help us better understand what exactly call counts indicate. In most cases it probably is risky to use call counts to make predictions concerning potential fall harvest, unless such data are supplemented by information on nesting success and survival. However, I believe that it is reasonable to use call counts to derive indexes to population levels. If acquired under standardized conditions (e.g., time of year and day, no or minimal precipitation and wind, trained observers) and replicated spatially or temporally, I believe that call counts can be used to track trends in population levels over time or to compare *relative* densities between different areas (e.g., Cline 1988). Sauer and Droege (1990) provide an excellent practical and theoretical treatment on estimating populations with indexes. In the absence of another easily applied technique used to census relatively large areas in a short time, I expect call counts to continue to be used in the future.

concluded that multiple-recapture models probably are not appropriate for bobwhite, primarily because of heterogeneity in capture probabilities, and that the Lincoln-Peterson estimator is approximately unbiased and is the preferred approach. This approach would be most appropriate when different capture approaches are used for 2 samples; for example, using live-trapping for the first capture period, and shooting for the second.

So . . . Which Technique Is Best?

Each of the estimators discussed will work adequately under certain circumstances, if we meet the assumptions and apply the approach correctly. If we simply want to monitor trends or obtain relative abundance estimates, for example to compare different management strategies, an index such as whistle counts should be adequate. I believe these counts, when conducted under standardized conditions, will provide suitable measures of population abundance. These counts, however, are not likely to be adequate for predicting fall harvest unless they are supplemented by additional information such as survival and hatching success. I do not recommend the use of hunter-success data to indicate quail trends. Drive or walk counts, especially if supplemented by dogs, may provide useful indications of the number of quail on a particular area. This approach, however, will require a greater investment of resources for the area covered relative to indexes. Mark-recapture and transect methodologies provide us with the opportunity to more rigorously estimate populations. These techniques require substantial commitment of resources and may not be appropriate for all needs and situations.

More research is needed on methods to index and estimate quail populations. Some questions, such as what a calling male quail actually represents and what the relationship is between an index or population estimator and the true underlying population have not been adequately answered.

Estimating Survival

It is of considerable interest to know what the survival rates are for quail populations. A common approach to estimating population survival is to use age ratios of quail (e.g., Emlen 1940, Marsden and Baskett 1958, Botsford et al. 1988). Such data can be obtained relatively easily from wings provided by hunters or by surveys in the fall. Although the juvenile:adult ratio can be used

to draw inferences concerning survival of young and reproductive success (i.e., a ratio weighted toward juveniles indicates greater reproductive success and/or survival of young birds), such data seldom can be used to validly estimate survival rates. *Only* when there is a stable population (which rarely occurs in quail populations) can juvenile:adult ratios be used to estimate survival. Concerning the use of ratios in this manner, Caughley has stated "These methods tend to provide answers irrelevant to most practical or theoretical problems" (Caughley 1977:105). Thus, although age ratios determined from hunter bags, etc., may provide useful indications of breeding success, they are not appropriate or suitable for estimating survival rates.

Other more suitable approaches for estimating population survival rates are available, but they require effort beyond that needed for age ratios. If one is able to determine population structure at various times, or can follow marked individuals through time, a life-table approach could be taken. Raitt and Genelly (1964) used life tables successfully on California quail (*Callipepla californica*). Pollock et al. (1989a) have demonstrated the use of band recovery data to estimate survival rates for bobwhite populations, using the approach of Brownie et al. (1985). They also have recently presented the "staggered entry" approach (Pollock et al. 1989b). This approach allows the use of radio-tagging data to estimate survival rates and requires at least 20 (preferably more) birds with radios. These approaches are rigorous and generate survival data that can be compared statistically, e.g., between years, sexes, or sites. Quail workers should plan to use marked birds (bands or radios) if they wish to address questions of survival.

RADIO-TAGGING

Radio-tagging represents a relatively new technology in wildlife research. The use of radio-tagging has opened new doors because of the ability to determine the location and status of individuals without having to flush or disturb the birds. White and Garrott (1990) have provided an excellent review of the use of radio-tagging, and anyone seriously using telemetry should refer to this resource. The primary uses of telemetry data are (1) home range analysis (White and Garrott 1990), (2) analysis of habitat use (e.g., Wiseman and Lewis 1981, Cantu and Everett 1982), and (3) analysis of survival and mortality rates (Pollock et al. 1989a, b).

Home Range Analysis

Three basic approaches have been taken in the estimation of home range sizes. The convex polygon home range has been used since the 1940's. This commonly used method simply estimates the home range as that area created by connecting the outermost locations of the individual being studied. Although easily applied, a potential difficulty with this method is that the home range as defined by the convex polygon may contain large areas where no animal observations were made, over-estimating the home range. Jenrich and Turner (1969) proposed the use of the bivariate normal home range. This estimator assumes that observations are distributed in a bivariate normal fashion and provided more statistical rigor than occurred in the convex polygon. However, this approach is valid only when the observations are in fact bivariate normal, a situation that may not often occur.

More recently, Dixon and Chapman (1980) proposed a nonparametric estimator that is based on the harmonic mean of the areal distribution of observations. This approach is attractive because it does not require assumptions about underlying data distributions and it allows the user to define home range contours that represent the intensity of use. This removes the problem of "holes" within the home range. However, this technique is sensitive to the grid scale that is used underlying the observations; thus results may not be directly comparable among studies if different scales are used. White and Garrott (1990) provide details concerning the computation of these and other home range estimators.

The use of radio-tagging data for survival analysis has been addressed above and the application of these data to habitat analysis will be found in the next section.

Telemetry Error and Its Effects

Radio-tagging represents a "high-tech" approach to wildlife research. It is not uncommon for researchers to have committed tens of thousands of dollars to receiving and transmitting equipment. Given this investment in equipment, and the nature of receiving a signal on expensive and apparently accurate equipment from a radio on a quail that may be several km away, we at times may be too trusting of the data we collect. Unless the investigator is homing (i.e., actually visually locating) on the individual being tracked, the bearings taken on transmitters are subject to error. Some factors that may influence the accuracy of the bearing are (1) signal bounce

as a function of terrain or vegetation, (2) animal movement, (3) weather, (4) equipment failure, and (5) user error.

The traditional approach to accounting for error in telemetry studies is to acquire a number of bearings on transmitters of known location after which standard deviation of these bearings is calculated. The error of all observations is assumed to be normally distributed, and the derived standard deviation is applied to all azimuths obtained. Thus, the intersection of 2 or more azimuths on an individual is calculated as a point, and the error assumed for the azimuths is used to calculate a polygon around the point that represents the uncertainty in the location. The size and shape of the error polygon is a function of the average telemetry error, the distance between the azimuth intersection and receiving point, and the angle of intersection.

Because error associated with an observation is likely to be different for each observation, it is not reasonable to assume a uniform error across all azimuths. Lenth (1981) presented an approach to estimating an error ellipse around each set of azimuths for 1 particular observation. This technique allows determination of the extent of error associated for each observation, and can incorporate factors that may have influenced accuracy at the particular time the observation was taken. When possible, investigators should use the approach of Lenth (1981) to determine error associated with their telemetry observations.

Even though an investigator may indicate that error polygons have been calculated, we seldom know the effect of the error on interpretation of home range or habitat use patterns. In a study on red-shouldered hawks (*Buteo lineatus*), Senchak (1991) found that, when taking 3 simultaneous azimuths (with 3 observers) on a hawk, confidence ellipses ranged from 0.06 to 1600 ha; the average 95% error ellipse ranged from 29 to 213 ha for 5 different hawks. Clearly, if we were to draw conclusions concerning home range size, or habitat affinity, we might not be able to do so with great confidence. I would expect a similar range of error for telemetry observations in typical quail habitat. Such error would be especially disturbing if habitat use is being assessed. For example, if error polygons or ellipses were 10-15 ha in size, and habitat patches were <10 ha, we could not make any solid statements concerning habitat use, because we could not be confident about which habitats were being used. Thus, I believe that we need to be cautious in interpreting telemetry data when triangulation is used. When

data collection and, once the data have been analyzed, may not provide their results in a form suitable for use by managers. For example, a researcher might develop a detailed discriminant analysis or logistic regression model to predict the probability that an area is suitable for quail, but the model might require data of such detail or difficulty to sample that a manager will not use it. Although we may have learned more about how the animal responds to its habitat, we have not gained in our ability to manage it. In such a case, it might be more suitable to construct a model such as a HSI with fewer, more easily measured variables, that will allow relatively rapid assessment of habitat quality. I believe that greater effort needs to be made to draw researchers and managers closer together. Researchers need to make a greater effort to provide results that are directly applicable by those charged with managing our quail resources. At the same time, managers need to work with researchers to let them know their needs and to better understand the intricacies and limitations of research.

METHODOLOGICAL THOUGHTS ON STUDY DESIGN

Recently, substantial thought has been given to the means by which we as wildlife managers and researchers gain knowledge (e.g., Romesburg 1981, 1991, Murphy and Noon 1991, Sinclair 1991). In the field of wildlife science, we could do a considerably better job in design and analysis of our studies. Research dollars are relatively scarce and we need to put forth the best possible effort with the resources available to us. Romesburg (1981) emphasized the need for more rigor in design and execution of wildlife studies and he championed the use of the hypothetico-deductive method to gain reliable knowledge. Although we cannot always meet his suggestions, we should strive to have clearly stated objectives for studies; too often, even now, studies are undertaken with unclear goals that result in expenditure of time and money with little return.

Hurlbert (1984) helped sensitize researchers to the need for true treatment replicates when conducting studies. Without replication of treatments, it is difficult if not impossible, to make unequivocal statements concerning treatment effects. For example, Cantu and Everett (1982) studied effects of grazing practices on northern bobwhite. They studied 4 pastures, each composed of different habitat (open pasture, dense brush, patchy planted habitat, and open savannah) and each with a different grazing intensity.

Because of the lack of replication, no statement can be made concerning grazing effects; any effect noted could just as easily be attributed to site differences associated with habitat. No degree of subsampling within a site can compensate for the lack of treatment replication. More information would be gained from taking only 2 or 3 samples from each of 5 treated and 5 untreated sites than by taking 20 samples each from 1 treated and 1 untreated site. Even if there is no replication, it may be possible to draw some inferences; however, in such cases the investigator needs to acknowledge the tentative nature of the results (e.g., Webb and Guthery 1982).

The use of statistical procedures has become a necessary evil in quail management and research. Although it may at times seem we are simply seeking "statistical sanctification" for results, the appropriate use of statistics in study design and analysis can enhance our understanding of the processes we study. Hanson and Miller (1961:75) stated, "It is becoming a truism that statisticians may prove more helpful before research begins than afterwards." It is critical that researchers and managers have an understanding of basic statistical concepts, or consult with biometricians or statisticians, prior to undertaking research. No amount of statistical data massage can compensate for poor study design. The use of studies that are replicated and stratified should be emphasized. This is not necessarily a new idea; Koziacky et al. (1956) presented an elegant design for stratified sampling of quail for Iowa.

Traditionally, we have relied on parametric statistics (e.g., *t*-tests and *F*-tests) for analyses that make an assumption of a normal data distribution. Seldom, however, do our data actually meet the assumptions of normality. It is important to be aware of the assumptions of the techniques we use, whether for population estimation, radio-tagging, modeling, or statistical analysis. If we do not meet assumptions, then our results may be suspect. Concerning statistical analysis, the assumption of normality may be met by transforming data in some cases. Other alternatives include the use of nonparametric statistics such as Kruskal-Wallis or Wilcoxon Rank Sum tests. More recently, a new family of procedures, based on permutations of the actual data have been developed (Biondini et al. 1988). These techniques make no assumptions concerning underlying data distributions, and I encourage investigators to use such techniques when possible.

One last statistical concept I wish to address is power, which is the probability of detecting a

difference (i.e., reject the null hypothesis) when in fact a difference exists. The concept of power has been known as long as has the idea of Type I error, or alpha, but it has only recently gained much attention (e.g., Toft and Shea 1983). We often work with relatively small sample sizes and may, as a result, fail to detect significance in a test; at such times, it is useful to be aware of what our ability was to in fact detect a difference. For example, in a recent paper, Janvrin et al. (1991) reported that detection rates of radio-tagged northern bobwhite in a study on drive counts did not differ among field seasons ($\chi^2 = 9.71$, 3 df, $P = 0.08$) and data were pooled for further analysis. However, the power of this particular Chi-square test was approximately 15% (from tables in Cohen 1988). Thus, in this case, with only 15% probability of detecting a difference, and with a significance level of 0.08, one might infer that in fact there was a difference among seasons and decide not to pool. (By using this example I in no way mean to detract from the very solid data and useful conclusions presented in this paper; this is solely for illustration.) Cohen (1988) presents approaches for determining power for most common statistical tests. I believe it would benefit us all if we considered the power of our statistical tests along with the significance level when interpreting results, particularly when small sample sizes are involved.

CONCLUSIONS

So, where are we in terms of quail methodology, and where do we need to be? We have available to us a variety of methods for estimating population levels and trends. I believe more effort should be directed to developing statistically sound (e.g., Kozicky et al. 1956) approaches to indexing quail populations across space and time, probably with some form of call-count surveys. Such information should allow us to better track population trends. General data such as that gained from hunter surveys and wings should be treated with caution. When the situation requires more rigorous population estimation, transect and mark-recapture approaches should suffice if the assumptions can be met.

Radio-tagging will continue to be an important tool in our study of quail populations. However, we need to improve our awareness of the assumptions concerning use of this and other methods, and especially to be cautious when triangulation error may affect our results. In many instances, we can do a better study design and should address the need for replication of treatments and a

more rigorous treatment of data. Especially, the assumptions of the techniques being used must be understood and met; otherwise much effort may be expended with little return. In many instances, we should be using nonparametric or permutation-based statistics rather than parametric statistics based upon normal theory. When feasible, we also should determine the power of statistical procedures that are conducted and use this information in our data interpretation.

A gap between researchers (at agencies and universities) and managers (in the field) still exists. If progress is to be made in determining approaches to assessing needs and addressing problems concerning quail, this gap needs to be bridged. It is of utmost importance that we establish a better working relationship and better communication between these 2 groups.

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When our survey began, 1 out of every 18 Illinois residents hunted and 1 in 55 hunted bobwhite; when the survey ended, 1 in 36 Illinois residents hunted and 1 in 134 hunted bobwhite (Preno and Labisky 1971, Anderson et al. 1990).

Hunter Attitudes

Bobwhite Behavior.—Nearly 1/3 of the usable hunter responses mentioned bobwhite behavior. The general perception was that birds were unusually wild or becoming wilder (e.g., flushing ahead of hunters or dogs, running, etc.). References to wildness were somewhat more common in the 1950's and 60's (38.0%) than in the 1970's and 80's (28.4%). Certain cyclic Tetraonids are thought to be wildest during and preceding population lows (Grange 1949:141-142, Keith 1963:96, Bergerud 1972); in contrast, bobwhite may be most wild just prior to peak population phases (Roseberry and Klimstra 1984:49). In the present study, unusual prey wildness was mentioned relatively more often during increasing or high population phases (37.8%) than during declines or lows (27.4%). We compared reported incidence of wildness to population age structure to test the hypothesis that a high proportion of adults in the fall population was a contributing factor. However, there was no correlation between the yearly juvenile:adult ratio and corresponding

percentage of hunters reporting unusual wildness ($r = -0.17$; $P = 0.31$).

Weather.—Hunters often cited weather during the season as affecting dog work, hunting success, etc; however, only comments relating weather to bobwhite abundance are considered here. Of 171 such references, 45% were associated with just 3 periods: the severe late winter of 1960, the successive severe winters of the late 1970's, and the 1988 drought. As noted above, the first 2 weather events caused substantial bobwhite population declines in Illinois, whereas negative effects of the 1988 drought were less severe than originally anticipated (Roseberry 1989).

Predators/predation.—A relatively small proportion (7.8%) of hunter responses referenced predators or predation, and only 1 in 5 of these explicitly called for some type of control. We suspect that these figures would have been higher had the survey contained a specific question regarding predator management. Proportionately more hunters voiced concerns about predation during years of declining or low populations (8.1%) than during upswings or highs (5.2%). Comments about predators were relatively constant (4.5-7.3%) in the 1950's, 60's, and 80's, but peaked in the 1970's at 18.8% (Fig. 2). Two factors may have contributed to this trend. First, the greatest decline in bobwhite abundance occurred

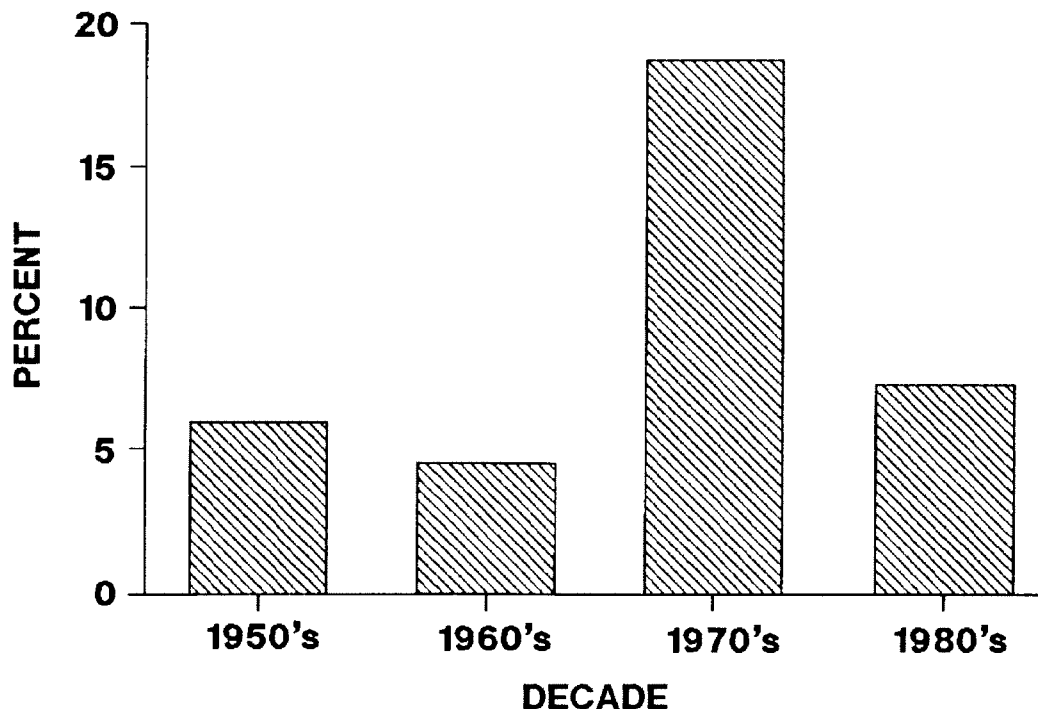


Fig. 2. Percentage of respondents referencing predators or predation by decade, Illinois quail hunter survey, 1954-89.

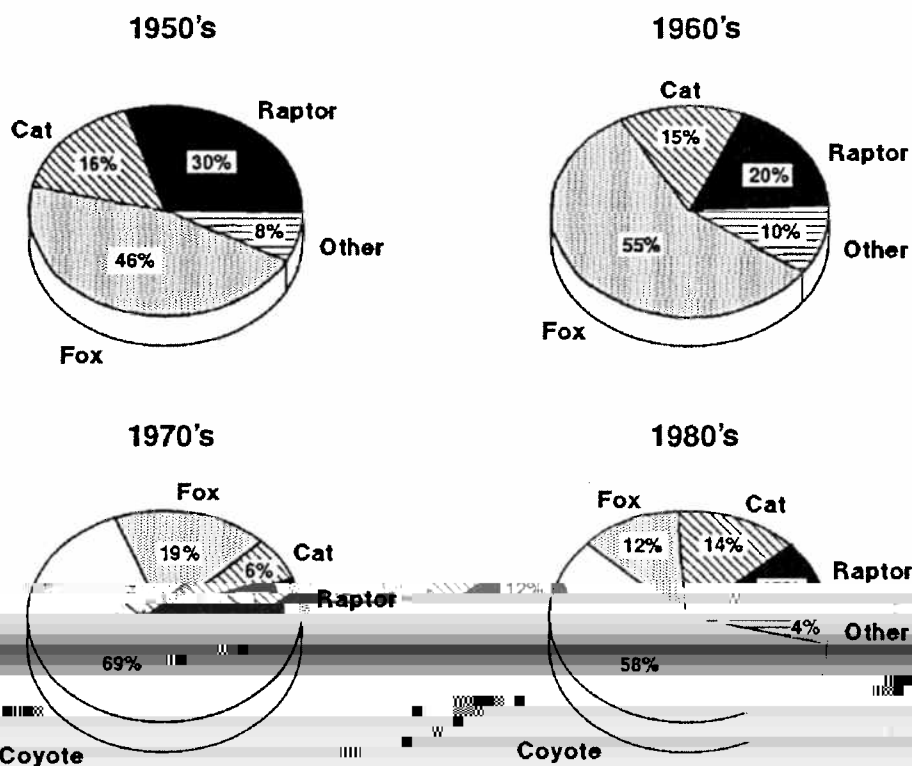


Fig. 3. Types of predators mentioned by decade, Illinois quail hunter survey, 1954-89.

during the 1970's (Fig. 3). In addition, there was a dramatic increase in the distribution and abundance of coyotes in Illinois and throughout the

or gam, needed for habitat improvement, etc.). Of the 1,555 responses we examined, 244 (22.1%)

of 15.6% in the 1960's to only 3.6% in the 1980's (Fig. 4). As with comments about predation, we suspect that these figures would have been higher had the survey contained a specific question on stocking.

Habitat.—This broad response category included any that evinced an awareness of the im-

during years of increasing or high populations (54:46). During the 1950's, 60's, and 70's, hunters wanting more restrictive harvest outnumbered those wanting more liberal harvest by a 2:1 margin. During the 1980's, however, the ratio was approximately 1:1 (Fig. 5). Throughout the study, most hunters who expressed an opinion felt the

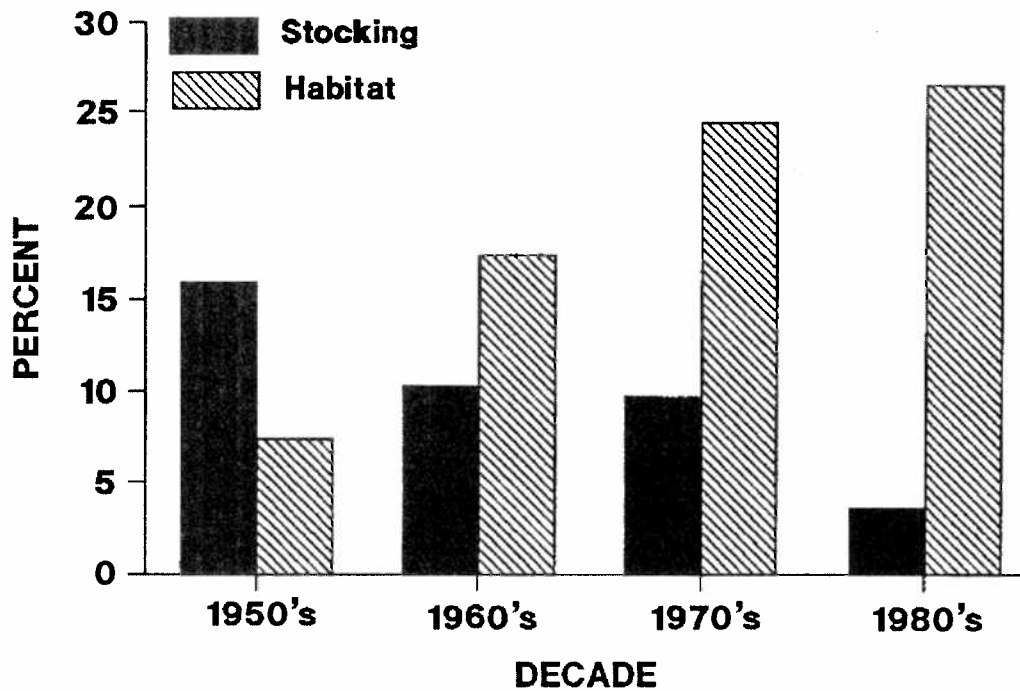


Fig. 4. Percentage of respondents mentioning stocking and/or habitat by decade, Illinois quail hunter survey, 1954-89.

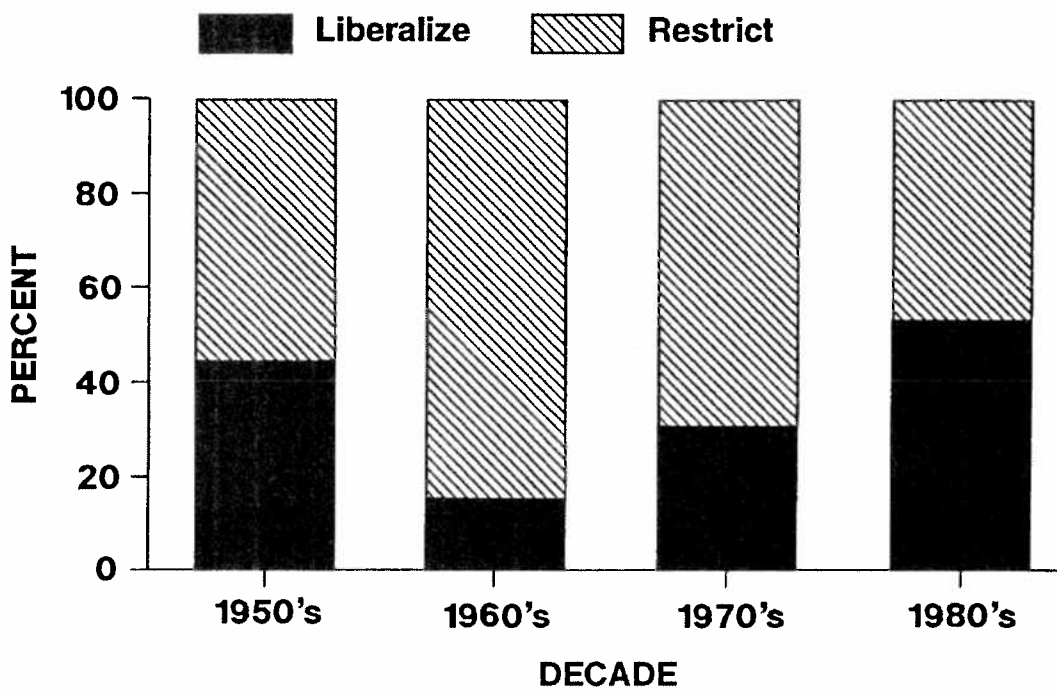


Fig. 5. Percentage of respondents favoring more liberal vs. more conservative harvest regulations by decade, Illinois quail hunter survey, 1954-89.

season started too early. During the first 3 decades, the ratio of hunters wanting a later start as opposed to an earlier one was about 8:2. In the 1980's, 100% of the hunters expressing an opinion felt opening dates were too early. In apparent contrast, only 25% of 850 Illinois quail hunters surveyed by the Illinois Department of Conservation (IDOC) in 1991 considered an opening date of the first Saturday in November too early, whereas 60% thought it about right (Anderson and David 1992). The apparent difference in the 2 surveys probably reflects the tendency for dissatisfied persons to volunteer opinions more readily than satisfied ones (Young 1966:81). Prior to 1980, less than half (45%) of the hunters who mentioned closing dates felt the season should be extended. During the 1980's, however, 80% of such respondents wanted to hunt later in the year. Fifty-six percent of hunters surveyed by IDOC considered an early January closing to be too early (Anderson and David 1992).

DISCUSSION

Attitudes and opinions regarding bobwhite management have evolved substantially among both quail hunters and wildlife professionals over the past 4 decades. For example, stocking was a popular and visible part of the overall upland game-bird management program in Illinois during the 1950's, 60's, and 70's. The IDOC provided day-old chicks to sportsmen's clubs who raised and released the birds at about 8 weeks of age to augment wild populations. In 1981, the agency publicly acknowledged that this 40-year-old program had been a biological and economic failure (Ambrose 1981) and attempted to convert it into a put-and-take operation by first encouraging then requiring participating organizations to release birds just before or during the hunting season. In 1986, the IDOC discontinued propagating bobwhite in state facilities, but continued to purchase chicks from private breeders for distribution to sportsmen's clubs through 1990.

Public and professional attitudes regarding the role of predators in natural communities have also changed significantly over the years. Illinois placed its last previously unprotected raptor, the great-horned owl (*Bubo virginianus*) on the protected list in 1959. Bounties on red and gray foxes (*Vulpes fulva* and *Urocyon cinereoargenteus*) were ended in 1973, although both species are still hunted and trapped. As of 1982, only 2 Illinois counties were still paying bounties on coyotes (*Canis latrans*) although there has been a

year-long open hunting season on the species since 1979.

Coincident with the renunciation of predator control and stocking as viable management options has been increased emphasis on habitat restoration and management by the IDOC and other natural resource agencies (Kenney 1985). In addition, there have emerged new habitat opportunities associated with federal farm programs (Jahn and Schenck 1990). It is therefore not surprising, but nonetheless encouraging, that Illinois quail hunters have demonstrated a progressive level of sophistication over the past 4 decades evinced by increased appreciation of the importance of habitat coupled with correspondingly fewer demands for unproductive practices such as stocking.

On the other hand, present-day hunters tend to demand more recreational use of the resource than did their predecessors despite the fact that the current season length of 60-65 days is about twice as long as in the early 1950's (Fig. 6). We find this attitude somewhat disturbing at a time when the resource base may be shrinking. It is difficult to reconcile a demand for longer and later seasons with the apparent inverse relationship between bobwhite abundance (indexed by total harvest) and season length in Illinois over the past 35 years (Fig. 7), even if no cause and effect is assumed. It is tempting to speculate that hunters in the 1980's merely reflected the prevailing societal attitude of the decade (i.e., "me first"). We must remember, however, that many present-day hunters do not benefit from a long-term perspective such as provided by Fig. 7, either because they are too young or because they do not have access to reliable information. For many, conditions have not deteriorated appreciably during their hunting careers; and may, in fact, have even improved for those who began hunting in the late 70's. Thus, it may not be surprising that some hunters are demanding more consumptive use of the resource than is perhaps biologically justified (Roseberry 1987, 1990).

MANAGEMENT IMPLICATIONS

Wildlife management is increasingly directed by socio-political considerations as well as biological factors. It is expedient, therefore, for agencies to be cognizant of hunter attitudes and concerns when formulating management programs and practices. Unfortunately, the wishes of hunters, and the influence they exert, are not always consistent with sound resource management.

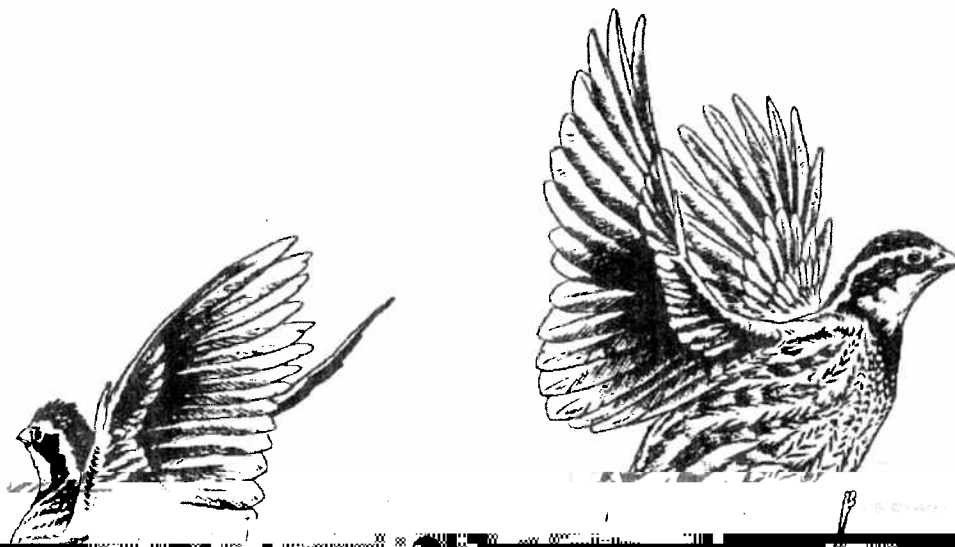
Dahlgren et al. (1977) reported that Iowa hunters scored higher than nonhunters in a test of "wildlife knowledge"; however, Peterle and Scott (1977) found that support for scientific wildlife management declined among Ohio hunters between 1960 and 1974. When hunter opinion is at variance with biological reality, wildlife biologists must address the problem through education. To accomplish this, we must (1) determine prevailing attitudes and perceptions among the various segments of the hunting community, (2) identify the source or basis of these attitudes and perceptions, and (3) select and implement effective modes of information transfer from wildlife professional to hunter.

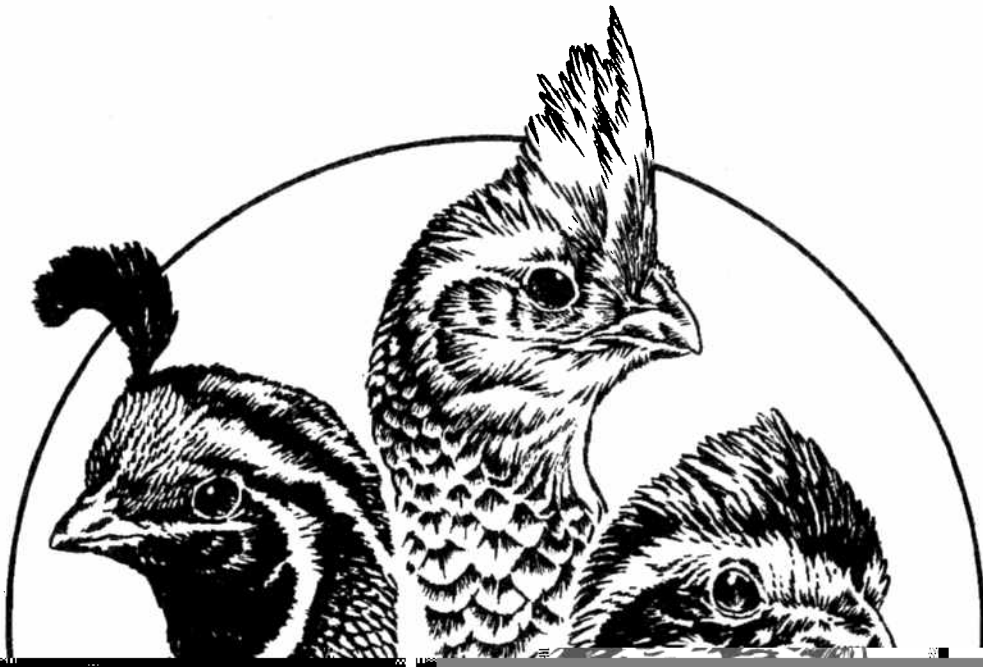
Program support from a well-informed public has always been important to the wildlife profession (Gilbert 1977), but never more so than now. All too frequently, lack of public support (perceived or real) leads to usurpation of policy- and decision-making powers by legislators or lay groups.

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trend estimates <0 in a state was significantly $<50\%$. Similarly, for regions where bobwhite declined, we determined the percentage of physiographic strata in which 9 passerines and 2 predators also had declining populations.

RESULTS

Quail Populations

Northern Bobwhite.—Northern bobwhite are the most widely distributed (39 states and Ontario) and abundant quail in North America (Fig. 1). Highest densities occur in Oklahoma, Missouri, Texas, Kansas, and Georgia. The continental population has declined ($-2.4\%/year$) since the mid-1960's (Table 1). We analyzed long-term trends for 28 states; only in Wisconsin were there increasing populations. Five states observed stable populations, and 22 decreased. Similarly, we analyzed long-term population trends within 28 physiographic strata. Only the Driftless stratum indicated a long-term increasing trend, 6 strata were stable, and 21 populations declined.

The continental population declined over the short-term (1982-91) at a slightly more accelerated rate ($-3.5\%/year$) than that observed for the entire time period (Table 1). Populations in 5 states increased, and 5 were stable. Populations in 16 of 26 states exhibited population declines. Likewise, trends were positive for 3 of 25 strata, 6 were stable, and populations in 16 strata declined.

California Quail.—California quail are the second most widely distributed (5 states and British Columbia) and abundant species of quail in North America (Fig. 2). California has the highest densities. The continental population has been relatively stable since 1966 (Table 2). We analyzed long-term population trends in 3 states and 7 physiographic strata. All states and strata had stable populations. However, since 1982, the continental population has shown a slightly positive trend ($3.2\%/year$), due primarily to increased abundance of quail in the California Foothills stratum.

Scaled Quail.—Scaled quail were observed in 5 states (Fig. 3). The highest densities are found in Texas. The continental population declined ($-3.8\%/year$) since the mid-1960's (Table 2). We analyzed 2 states and 2 physiographic strata. Specifically, long-term populations in New Mexico, Texas, and the Chihuahuan Desert have decreased. Moreover, the rate of decline since 1982 has been twice as rapid ($-8.2\%/year$) as that which has occurred over the long-term.

This short-term change reflects decreasing populations in the Staked Plains stratum.

Gambel's Quail.—Gambel's quail were reported in 5 states (Fig. 4). Arizona has the highest densities. The long-term continental population trend has been stable (Table 2). Likewise, populations in the individual states and the Sonoran Desert showed no change. However, the continental trend during the last 10 years was negative ($-4.6\%/year$).

Mountain Quail.—Mountain quail were observed in 3 states (Fig. 5). The highest densities occur in California. Both the long- (1966-91) and short-term (1982-91) population trends in the U.S. have been stable (Table 2).

Sympatric Species of Northern Bobwhite

In general, long-term population trends of the grassland/shrub guild (13 passerine species) declined where sympatric with northern bobwhite (Table 3). Specifically, $>50\%$ of these species showed declining populations similar to bobwhite in 23 of 26 states. Of these, 6 states reported $>87\%$ of the passerines were declining ($P < 0.10$). In physiographic strata where bobwhite populations were decreasing, each of the 9 sympatric passerines also declined in more strata ($>56\%$) than they increased (Table 4). Declines occurred in $>72\%$ of the strata for 6 species ($P < 0.10$). Conversely, red-tailed hawks and great horned owls increased in $>70\%$ of the strata where bobwhite declined ($P < 0.10$).

DISCUSSION

Population trends indicate marked long-term declines for northern bobwhite and scaled quail. The rate of decline has been greater for both species during the last 10 years. In comparison, long-term trends for more western species appear stable. Although short-term trends of California quail are increasing, those for Gambel's quail are decreasing.

In general, our results concur with independent estimates of population trends by others. Brennan (1991, 1993a) analyzed Audubon Christmas Bird Count data (1960-88) and reported declining populations of northern bobwhite and scaled quail, and stable trends for Gambel's and mountain quail. He also reported declining populations of California quail, and a reduction in the range of mountain quail. Schemnitz (1993) noted scaled quail populations declined 53% in the Oklahoma

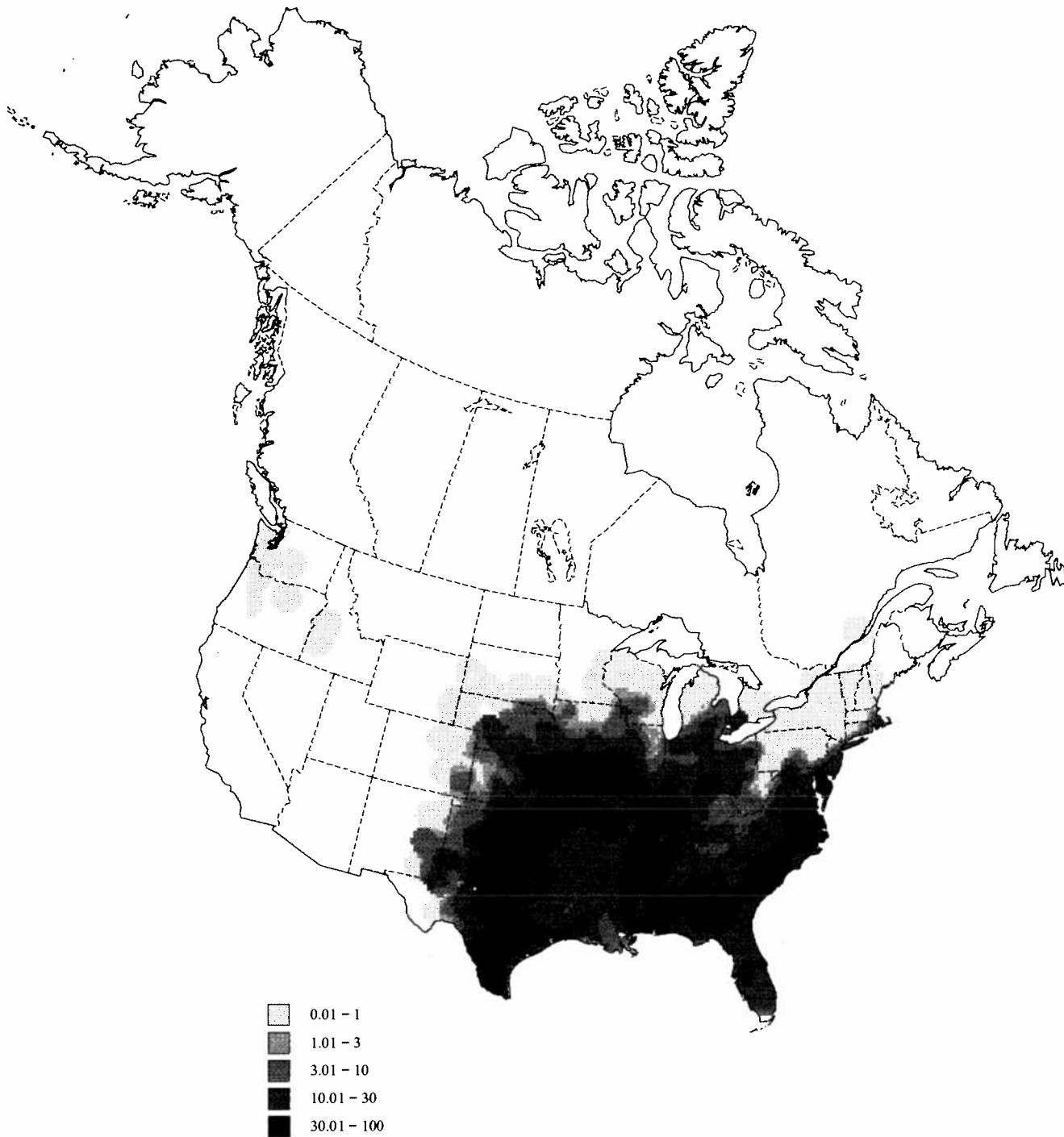


Fig. 1. Distribution and relative abundance (\bar{x} number of birds/Breeding Bird Survey route) of northern bobwhite in North America, 1966-91. Shaded patterns define uniform regions of relative abundance.

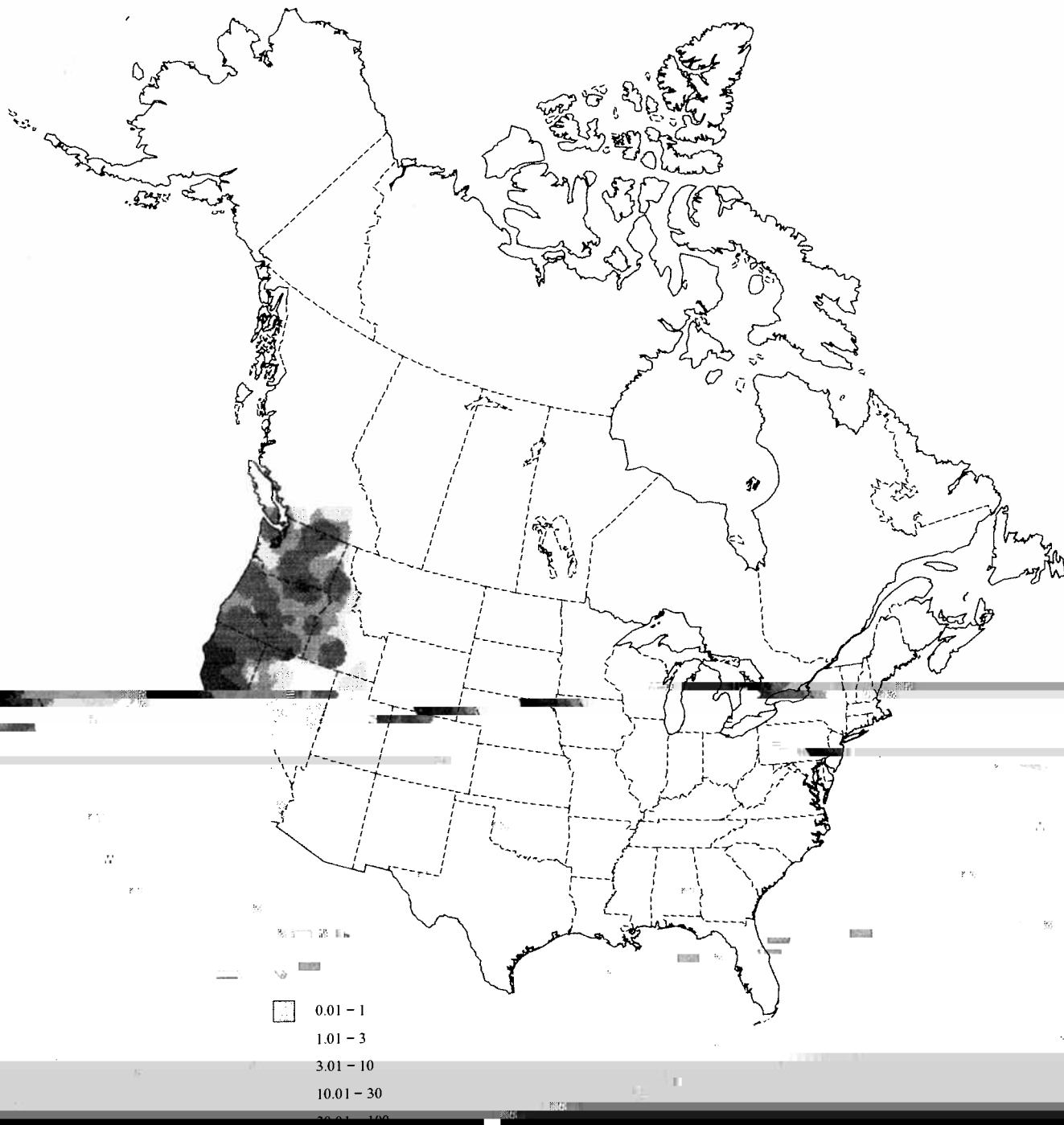


Fig. 2. Distribution and relative abundance (\bar{x} number of birds/Breeding Bird Survey route) of California quail in North America, 1966-91. Shaded patterns define uniform regions of relative abundance.

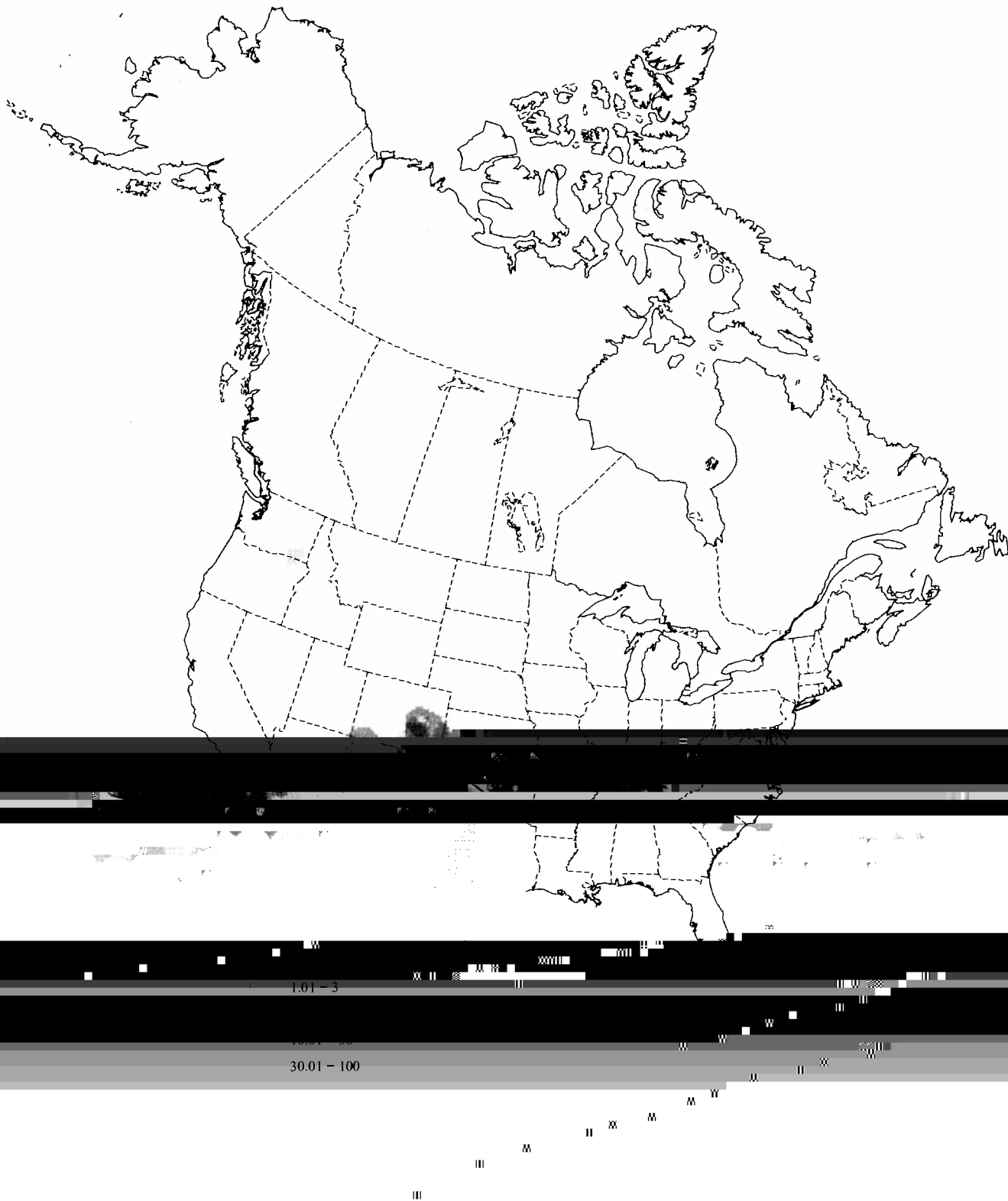


Fig. 3. Distribution and relative abundance (\bar{x} number of birds/Breeding Bird Survey route) of scaled quail in North America, 1966-91. Shaded patterns define uniform regions of relative abundance.



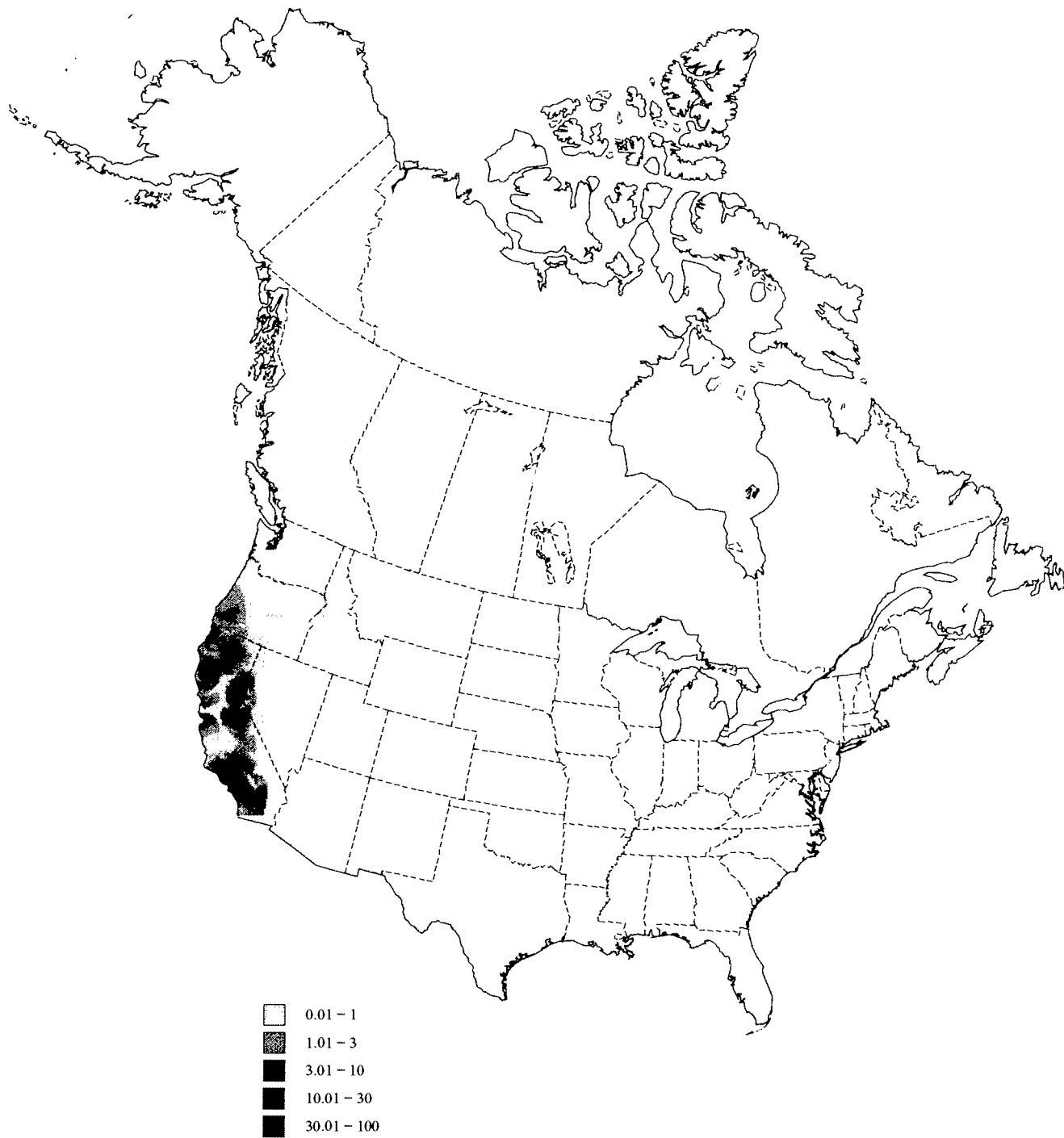


Fig. 5. Distribution and relative abundance (\bar{x} number of birds/Breeding Bird Survey route) of mountain quail in North America, 1966-91. Shaded patterns define uniform regions of relative abundance.

Table 2. Long-term (1966-91) and short-term (1982-91) population trends and relative abundance (\bar{x} -birds/route) of California, scaled, Gambel's, and mountain quail based on the North American Breeding Bird Survey.

State/stratum	Long-term		Short-term	
	Trend	Abundance	Trend	Abundance
<i>California quail</i>				
California	0.1	7.73	1.9	7.96
Oregon	-3.6	4.19	7.2	3.32
Washington	-0.6	2.10	2.8	2.10
Dissected Rockies	2.1	1.66	11.6	1.63
Pitt-Klamath Plateau	2.4	3.90	3.1	4.32
Columbia Plateau	-5.0	4.06	4.1	3.42
Southern California Grasslands	5.3	21.30	-5.7	20.47
Central Valley	2.2	3.79	-6.9	3.07
California Foothills	-0.5	19.65	3.9	19.71
Southern Pacific Rainforests	-0.7	4.41	-0.2	3.63
Continental	0.0	3.00	3.2	3.04
<i>Scaled quail</i>				
New Mexico	-4.0**** ^a	6.73	-11.0***	5.72
Texas	-3.9***	9.17	-7.6*	7.45
Staked Plains	-3.5	8.97	-8.6***	16.64
Chihuahuan Desert	-4.4***	20.99		
Continental	-3.8***	5.91	-8.2***	5.17
<i>Gambel's quail</i>				
Arizona	0.5	17.16	-3.3	25.53
California	1.9	3.09		
New Mexico	0.5	4.63		
Sonoran Desert	0.4	28.21	-0.3	26.22
Continental	0.6	5.87	-4.6***	9.09
<i>Mountain quail</i>				
California	1.3	5.00	-0.6	5.11
Oregon	1.0	0.57		
Sierra Nevada	-0.6	9.75	-0.8	10.89
Pitt-Klamath Plateau	1.9	1.06		
Southern California Grasslands	1.8	5.04	0.2	4.82
Southern Pacific Rainforests	1.0	1.38	0.6	1.26
Continental	1.1	2.81	-0.4	2.86

^a* = $P < 0.10$, *** = $P < 0.01$.

Panhandle based on covey counts in the mid-1950's and early 1990's. Kilbride et al. (1992) indicated California quail populations in Oregon have been stable since the early 1960's.

Our data indicate declining populations of bobwhite may be due to factors affecting all grassland/shrub birds. The factor most often identified as affecting population trends is habitat change. States in the central portion of the bobwhite's range, where forestry and farming practices have greatly altered habitat conditions, show the greatest number of declining species. In addition, the 6 passerines declining in the most regions are, like the bobwhite, relatively intolerant of urban landscapes. Land-use changes like urban sprawl could in part be responsible for

the decline of numerous species over a large geographic area.

Predators have long been recognized as major causes of mortality in bobwhite (Errington 1934, Beasom 1974). Great horned owls and red-tailed hawks are widely distributed predators exhibiting increasing populations where bobwhite are decreasing. Petersen et al. (1988:183) reported similar trends between these predators and pheasant populations. Furthermore, they noted: "Predation on pheasants [by red foxes, great horned owls, and red-tailed hawks] apparently has increased since the 1940's, most notably since 1960" (Petersen et al. 1988:191). Our data are not sufficient to allow us to conclude that declines in bobwhite populations are due to increased avian

Table 3. Proportion of declining populations among 13 passerines sympatric with northern bobwhite, 1966-91.

State	n ^a	n declining (%)	Bobwhite trend (%/year)
Alabama	10	8 (80)	-3.0*** ^b
Arkansas	11	10 (91)	-2.4***
Florida	8	5 (62)	-2.5**
Georgia	11	8 (73)	-3.5***
Illinois	8	7 (88)*	-3.3**
Indiana	8	5 (62)	-2.3**
Iowa	7	6 (86)	-4.1***
Kansas	10	8 (80)	-1.9
Kentucky	10	8 (80)	-2.2***
Louisiana	11	6 (55)	-5.3***
Maryland	8	8 (100)*	-4.0***
Massachusetts	7	3 (43)	-10.9**
Michigan	7	3 (43)	-10.7**
Mississippi	10	8 (80)	-3.9***
Missouri	11	10 (91)*	-0.8
Nebraska	7	4 (57)	-0.6
New Jersey	8	5 (62)	-5.2***
New York	8	5 (62)	-6.4***
North Carolina	9	6 (67)	-3.6***
Ohio	8	5 (62)	-7.1***
Pennsylvania	8	6 (75)	-11.0***
South Carolina	8	6 (75)	-4.4***
Tennessee	10	10 (100)*	-3.1***
Virginia	9	6 (67)	-3.1***
West Virginia	9	8 (89)*	-5.3
Wisconsin	6	3 (50)	5.5**

^aSpecies included in the analysis (field sparrow [*Spizella pusilla*], indigo bunting [*Passerina cyanea*], loggerhead shrike [*Lanius ludovicianus*], brown thrasher [*Toxostoma rufum*], Bewick's wren [*Thryomanes bewickii*], Bachman's sparrow [*Aimophila aestivalis*], gray catbird [*Dumetella carolinensis*], northern cardinal [*Cardinalis cardinalis*], yellow-breasted chat [*Icteria virens*], American goldfinch [*Carduelis tristis*], painted bunting [*Passerina ciris*], prairie warbler [*Dendroica discolor*], and scissor-tailed flycatcher [*Tyrannus forficatus*]) that were observed along the same routes as northern bobwhite.

^b* = proportion different ($P < 0.10$) than expected by chance (50%), ** = $P < 0.05$, *** = $P < 0.01$.

Table 4. Population trends in physiographic strata for passerines and predators sympatric with declining populations of northern bobwhite, 1966-91.

Species	n strata compared	n strata with declining populations (%)
<i>Passerines</i>		
Gray catbird	20	12 (60)
Brown thrasher	23	20 (87)**
Prairie warbler	12	12 (100)*
Yellow-breasted chat	17	14 (82)*
Northern cardinal	25	14 (56)
Field sparrow	21	18 (86)*
Loggerhead shrike	14	12 (86)*
Indigo bunting	22	16 (73)*
American goldfinch	20	13 (65)
<i>Predators</i>		
Red-tailed hawk	23	3 (13)*
Great horned owl	21	6 (29)*

^a* = proportion different ($P < 0.10$) than expected by chance (50%).

predation, but they are consistent with Petersen et al's. hypothesis for pheasant.

CONCLUSIONS

Quail populations in the east and central portions of North America are experiencing long-term declines that have been greater over the past decade. In contrast, quails in the western part of the continent are generally stable. It is noteworthy that there were too few observations of Montezuma quail (*Cyrtonyx montezumae*) along BBS routes for analysis. We encourage potential volunteers (e.g., state biologists) in the range of Montezuma quail to gather BBS data. In addition, we suggest state conservation agencies consider special population monitoring strategies (e.g., harvest surveys) for this species.

Our analysis of a grassland/shrub guild provides an alternative to conventional single-species approaches to habitat analysis. Although

none of these species completely match the life history characteristics of quail, it appears bobwhite may be a good indicator of wildlife-habitat interactions in grassland/shrub ecosystems (Farmer et al. 1988, Hays and Farmer 1990).

Quail are 1 of the most studied and intensively managed taxonomic groups of wildlife (Church and Taylor 1992). As a result, resource managers have assumed that our understanding of quail biology is relatively complete. However, our results indicate there is reason to question the efficacy of current management practices for bobwhite and scaled quail. Thus we support the design and implementation of a comprehensive approach to management and research at a national level such as outlined in Brennan (1993b).

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POTENTIAL POLYGAMOUS BREEDING BEHAVIOR IN NORTHERN BOBWHITE

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Abstract: Breeding behavior of radio-tagged northern bobwhite (*Colinus virginianus*) was observed at Fort Bragg Military Reservation ($n = 19$), North Carolina, in 1985–88, and Tall Timbers Research Station ($n = 27$), Florida, during 1984–86. We observed apparent polygamous breeding behavior in 95% (18 of 19) of the radio-tagged northern bobwhite at Fort Bragg, and 93% (25 of 27) of the birds at Tall Timbers. We documented 5 cases of double-clutching by radio-tagged females. Twenty-seven percent of Fort Bragg clutches ($n = 30$), and 20% of Tall Timbers clutches ($n = 56$) were incubated by radio-tagged males. Northern bobwhite exhibited characteristics of both rapid multiclutch and ambisexual polygamous mating systems. Northern bobwhite are capable of uniparental care, have long breeding seasons, live in an environment with fluctuating resources, suffer high predation pressure during the nesting season, and raise precocial young; all traits that are similar to other bird species which have evolved polygamous mating systems.

Key words: breeding behavior, *Colinus virginianus*, Florida, North Carolina, northern bobwhite, polygamy.

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Despite more than 50 years of research, the breeding biology of the northern bobwhite is poorly understood. Most researchers have assumed bobwhite form monogamous pairs, and will re-nest after the loss or abandonment of a previous nest (Stoddard 1931, Lehmann 1946, 1984, Rosene 1969, Johnsgard 1973, Roseberry and Klimstra 1984). Stettner et al. (1966) examined monogamous behavior by switching mates of several pairs of penned northern bobwhite. The high level of aggression observed when new birds were introduced in a captive environment was thought to be indicative of strong monogamous bonds. Brill (1934) reported polygyny in captive northern bobwhite with a ratio of 1 male:2 females or 2 males:7 females. Baldini et al. (1952) noted that these sex ratios were likely only under laboratory conditions, and stated that northern bobwhite were monogamous in the wild.

Stanford (1953) examined the breeding behavior of captive northern bobwhite, and found that 3 pairs attempted a second nest after the first one was successful. When the first brood reached 13-15 days old, the female started a second nest, leaving the male to assume parental care for the first brood. Kiel (1976) also observed re-nesting attempts by captive northern bobwhite after pairs had successfully hatched initial clutches.

Stoddard (1931) documented that males may take over incubation duties, and either sex may be found at a nest. One sex assumed the primary role of incubating eggs for each nest. Studies in Georgia (Stoddard 1931) and Illinois (Roseberry and Klimstra 1984) indicated that males incubated about 26% of clutches. Male incubation of eggs and subsequent brood-rearing emancipates the female and increases the possibility of her mating again (Emlen and Oring 1977) with either the same or a different male. When uniparental care can meet brood-rearing requirements, desertion by 1 parent may lead to higher reproductive success than staying with the brood (Maynard Smith 1977). However, previous research provides little direct evidence of either monogamy or polygamy for the northern bobwhite.

Recent advances in transmitter design (Shields et al. 1982) have allowed researchers to locate

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individually-marked northern bobwhite throughout the breeding season (Sermons and Speake 1987, Curtis 1990). During 1985, Sermons and Speake (1987) observed that 6 of 16 (38%) females had broods which disappeared when the chicks were 7-35 days of age. These 6 females soon paired with males, and 4 renested. During 1986, 2 of these 6 females again successfully produced second broods. It was not known if juvenile mortality, brood abandonment (Lehmann 1984), surrogate parenting (Stoddard 1931), or some combination of these factors was responsible for brood disappearance. Sermons and Speake (1987) did not say whether radio-tagged females paired with the same males for their second nest attempt. If broods or clutches were left in the care of the male that fertilized the eggs, and females mated with different males for a second nest attempt (i.e., polyandry), then the potential exists for a polygamous mating system in northern bobwhite.

The purpose of this paper is to describe the breeding behavior of radio-tagged northern bobwhite in North Carolina and Florida.

This effort was supported by Tall Timbers Research Station (TTRS), the Department of Defense-Fort Bragg (FB), the International Quail Foundation, the National Rifle Association, the North Carolina State Agricultural Research Service, the North Carolina Wildlife Resources Commission, and Quail Unlimited. We appreciate field assistance by biologists, technicians, and volunteers. J. Walters, L. Brennan, and J. Fleming provided helpful discussion and reviewed a draft of the manuscript.

STUDY AREAS

We observed the breeding behavior of northern bobwhite at TTRS in 1984-86, and at FB during 1985-88. Tall Timbers encompasses nearly 1,300 ha in northern Leon County, Florida. This site lies within the Tallahassee Red Hills subregion of the Coastal Plain, and is characterized by rolling clay hills with gentle to moderate slope (Hendry and Sproul 1966). Approximately 85% of TTRS is woodland, primarily open stands of loblolly (*Pinus taeda*) and shortleaf pine (*P. echinata*) interspersed with live oak (*Quercus virginiana*). Smith (1980) provided a detailed habitat description of the area. Habitat at TTRS supports some of the highest northern bobwhite numbers in the southeastern United States Coastal Plain, and densities greater than 1 bird/0.4 ha have been observed. However, northern bobwhite populations have declined at TTRS since peak numbers were observed in the early 1970's. Based on Peter-

sen estimates from recaptures of banded bobwhite, O'Brien et al. (1985) estimated there were 976 birds occupying TTRS in 1979, compared to 515 bobwhite in 1982.

Fort Bragg lies within the Sandhills region of Cumberland and Hoke counties, North Carolina. Sandhills vegetation has been described by Wells (1932) and Wells and Shunk (1931). The longleaf pine-scrub oak-wiregrass (*Pinus palustris-Quercus laevis, Q. marilandica, Q. incana, Q. margaretta-Aristida stricta*) community is found on undisturbed upland sites. Fort Bragg contains approximately 55,000 ha, of which about 70% are woodland. Long burning rotations (5 years) and infertile soils result in a sparse herbaceous layer with few native legumes. Estimates from covey-mapping, trapping, and following radio-tagged northern bobwhite, indicated fall densities of approximately 1 bird/8.1 ha. Data from controlled check stations at FB indicated bobwhite populations peaked during 1972 (approximately 9,000 birds harvested postwide), and then declined dramatically through 1986 (approximately 650 bobwhite harvested postwide; Curtis et al. 1989).

METHODS

Northern bobwhite were captured primarily in funnel traps similar to those described by Stoddard (1931:443). Peak trapping occurred in January and February at both study areas. Additional bobwhite were captured during May through October at FB, and throughout the year at TTRS. Funnel trap sites were usually prebaited with cracked corn at least 10 days before each capture attempt. At TTRS, traps were placed at a density of 1 per 2-2.5 ha, and covered with vegetation to conceal them from predators. At FB, trap densities were about 1 per 4-4.5 ha, and traps were concealed at problem locations. Additional bobwhite were caught by night-netting at roost sites (Labisky 1968), and males were captured during breeding season in mist nets to which they were attracted by a tape-recorded call (Cink 1975).

Northern bobwhite caught for the first time were sexed and marked with an aluminum leg band. Once a bird was captured and radio-tagged, additional efforts were made to radio-tag at least 1 other covey member. The transmitter used at both study sites was a logic-operated, crystal-controlled oscillator designed by Shields et al. (1982). The 6-8 g collar was worn as a medallion below the crop and concealed under breast feathers. During a field test of this transmitter, no differential mortality was detected between radio-tagged

and banded northern bobwhite (Mueller et al. 1988).

Radio-tagged northern bobwhite were located once daily throughout the breeding season (April through October) to determine breeding status. Nesting behavior was usually detected after incubation commenced, when a radio-tagged bird was found at the same location for 3 consecutive days. Associations with other radio-tagged northern bobwhite, unmarked adults, or broods were recorded in the daily tracking records. Ornithological studies have typically relied on association patterns to evaluate mating systems or individual reproductive success (Gowaty and Mock 1985:11). We realize that apparent mating patterns based on associations, and actual (genetically-effective) mating patterns, may not be the same, and additional electrophoretic exclusion research will be necessary to elucidate the differences. Electrophoretic exclusion techniques have documented multiple maternity and paternity between care-giving adults and putative offspring in apparently monogamous eastern bluebirds (*Sialia sialis*) (Gowaty and Karlin 1984).

Monogamy has been termed a "mating-system-by-default" (Gowaty and Mock 1985:4), and has served as a catch-all, where species are assigned only when they fail to satisfy more easily specified criteria of polygyny or polyandry. Consequently, monogamous mating systems include a diverse array of reproductive strategies that may have little in common.

We defined apparently monogamous breeding behavior based on social organization (1 male-1 female social units; Gowaty and Mock 1985:12). If a radio-tagged bobwhite was associated (flushed or observed) with >1 individual of the opposite sex during a breeding season, we considered this potentially polygamous behavior, even if no nest was found. Radio-tagged bobwhite were associated with both tagged and untagged individuals on many occasions, and it was impossible to determine the actual outcome of these encounters. Our definition based on social observations may result in an overestimate of the actual proportion of genetically-effective matings. However, it was the best estimate of potential polygamy, given that <20% of the bobwhite at both study sites were radio-tagged (based on trapping records and visual observations), and no electrophoretic exclusion work was conducted during this study. Biweekly flush counts of radio-tagged birds or coveys were used to document associations prior to the onset of incubation and

during brood-rearing activities. It was impossible to flush radio-tagged bobwhite more frequently without affecting survivorship, and some associations with untagged birds were likely missed. Nesting bobwhite of either sex were monitored daily during the 23-day incubation period (Rosene 1969) to determine status of the tagged bird. Broods were checked at TTRS by night-lighting to determine chick mortality and parental associations.

RESULTS

It was possible to determine the breeding status of 19 radio-tagged bobwhite at FB. Eighteen (95%) exhibited potentially polygamous breeding behavior, and 1 (5%) tagged male bobwhite apparently stayed with the same tagged female until his death during June (Table 1). This female was subsequently associated with 2 other males, and produced a clutch with another radio-tagged bird during July. The breeding behavior of 41 bobwhite at FB could not be determined because they were observed for only a portion of the breeding season (e.g., males captured and tagged during midsummer), or they were associated with untagged birds on several occasions, and it was impossible to determine if the same untagged bobwhite was involved during each observation. At TTRS, 25 radio-tagged northern bobwhite (93%) exhibited potentially polygamous behavior, and 2 birds (7%) remained with the same mate. The breeding status of 74 radio-tagged bobwhite at TTRS could not be classified.

During 1988 at FB, we documented 3 cases of double-clutching by radio-tagged females. One female successfully raised 2 broods with a tagged male, who cared for her first brood while she incubated a second clutch of eggs. While it is impossible to confirm the paternity of the second brood from observations alone, the same radio-tagged male was repeatedly seen with the female during the month before her second nest was found. The other 2 radio-tagged females raised their first broods until 3-4 weeks of age, then either lost or abandoned the chicks, and were found incubating second nests (it is not known whether they mated with the same male for both nests). Both second nests were lost to predation. We also observed a radio-tagged male incubating 2 different nests during a 5-day period. The following day, this male joined a radio-tagged female and her brood, and he stayed with this group until he was killed by a predator 1 month later.

Table 1. Breeding behavior of radio-tagged northern bobwhite at Fort Bragg Military Reservation (FB), NC, 1985-88; and at Tall Timbers Research Station (TTRS), FL, 1984-86.

		1984	1985	1986	1987	1988	Total
<i>Breeding behavior of radio-tagged bobwhite, n (%)</i>							
Monogamous	FB				1		1 (5)
	TTRS	2					2 (7)
Polygamous	FB		4		7	7	18 (95)
	TTRS	5	15	5			25 (93)
Not classifiable	FB		8	12	11	10	41
	TTRS	7	31	36			74
<i>Number of bobwhite (%) radio-tagged</i>							
Males	FB		5	7	12	8	32 (53)
	TTRS	7	24	18			49 (49)
Females	FB		7	5	7	9	28 (47)
	TTRS	7	22	23			52 (52)
<i>Number of nests (%) incubated</i>							
Males	FB		2	1	2	3	8 (27)
	TTRS	1	8	2			11 (20)
Females	FB		4	4	3	11	22 (73)
	TTRS	3	17	25			45 (80)
<i>Number of bobwhite (%) not associated with a nest or brood</i>							
Males	FB			1	8	2	11 (34)
	TTRS		10	12			22 (45)
Females	FB				4	1	5 (18)
	TTRS		6	1			7 (13)
<i>Number of broods (%) reared</i>							
Pairs	FB		5	5	2	10	22 (71)
	TTRS	2	5	9			16 (50)
Lone females	FB		2	2		3	7 (23)
	TTRS		4	5			9 (28)
Lone males	FB				2		2 (6)
	TTRS	1	3	3			7 (22)

During 1986 at TTRS, we observed 2 cases of double-clutching by radio-tagged females. Both females again raised their first broods to 3 weeks of age, and then either lost or left the chicks to incubate second nests. Both second nests were lost to predation, and the paternity of broods was unknown.

During 1985-88 at FB, 60 radio-tagged northern bobwhite (53% male, 47% female) were observed during the breeding season (Table 1). Radio-tagged bobwhite incubated 30 clutches, and only 1 tagged bird was responsible for incubation duties at each nest. Twenty-seven percent of clutches found were incubated by radio-tagged males; radio-tagged females incubated the remaining 73%. Of the 30 clutches observed, 17 (57%) were the first documented nest of the breeding season for tagged females, and 7 (23%) were first nests for males. Four females (13%) and 1 male (3%) were located at 2 different nests during

the same breeding season, and 1 female (3%) attempted 3 nests in 1 year.

During 1984-86 at TTRS, 101 radio-tagged northern bobwhite (49 males, 52 females) were monitored during the breeding season (Table 1). Radio-tagged bobwhite incubated 56 clutches, and again, only 1 tagged bird was responsible for incubation duties at each nest. Twenty percent of nests were incubated by radio-tagged males, and 80% by tagged females. These proportions were similar between sites ($X^2 = 0.50$, $df = 1$, $0.25 < P < 0.50$). Of 56 clutches observed, 37 (66%) were the first documented nest of the breeding season for tagged females, and 10 (18%) were first nests for males. Seven females (13%) and 1 male (2%) were located at 2 different nests during the same breeding season, and 1 female (2%) attempted 3 nests in 1 year. These proportions were similar between sites for both females ($X^2 = 0.30$, $df = 2$, $P > 0.50$) and males ($X^2 = 0.09$, $df = 1$, $P > 0.50$).

The proportion of broods reared by male and female pairs, lone females, and lone males was similar ($X^2 = 3.90$, $df = 2$, $0.10 < P < 0.25$) between FB and TTRS (Table 1); however, there was a trend for lone males to raise a greater percentage of broods at TTRS. Thirty to 50% of the broods were uniparent (of either sex), and 50-70% were cared for by pairs (usually mixed sexes, but male only pairs were observed).

We describe the following case histories of radio-tagged bobwhite to illustrate potentially polygamous breeding behavior.

Case History 1.—During summer 1984 at TTRS, 5 radio-tagged and 2 untagged bobwhite interacted throughout the breeding season (Fig. 1). Female 748 was associated with 2 males prior to incubation, and both possibly fertilized a portion of the eggs in her nest. Male 749 was observed during the early egg-laying stage of female 748's nest, and eventually assisted with raising her brood. Male 742 was found incubating female 744's nest with 11 eggs. Male 742 hatched 11 eggs, and was then joined by another untagged male which assisted with raising the brood.

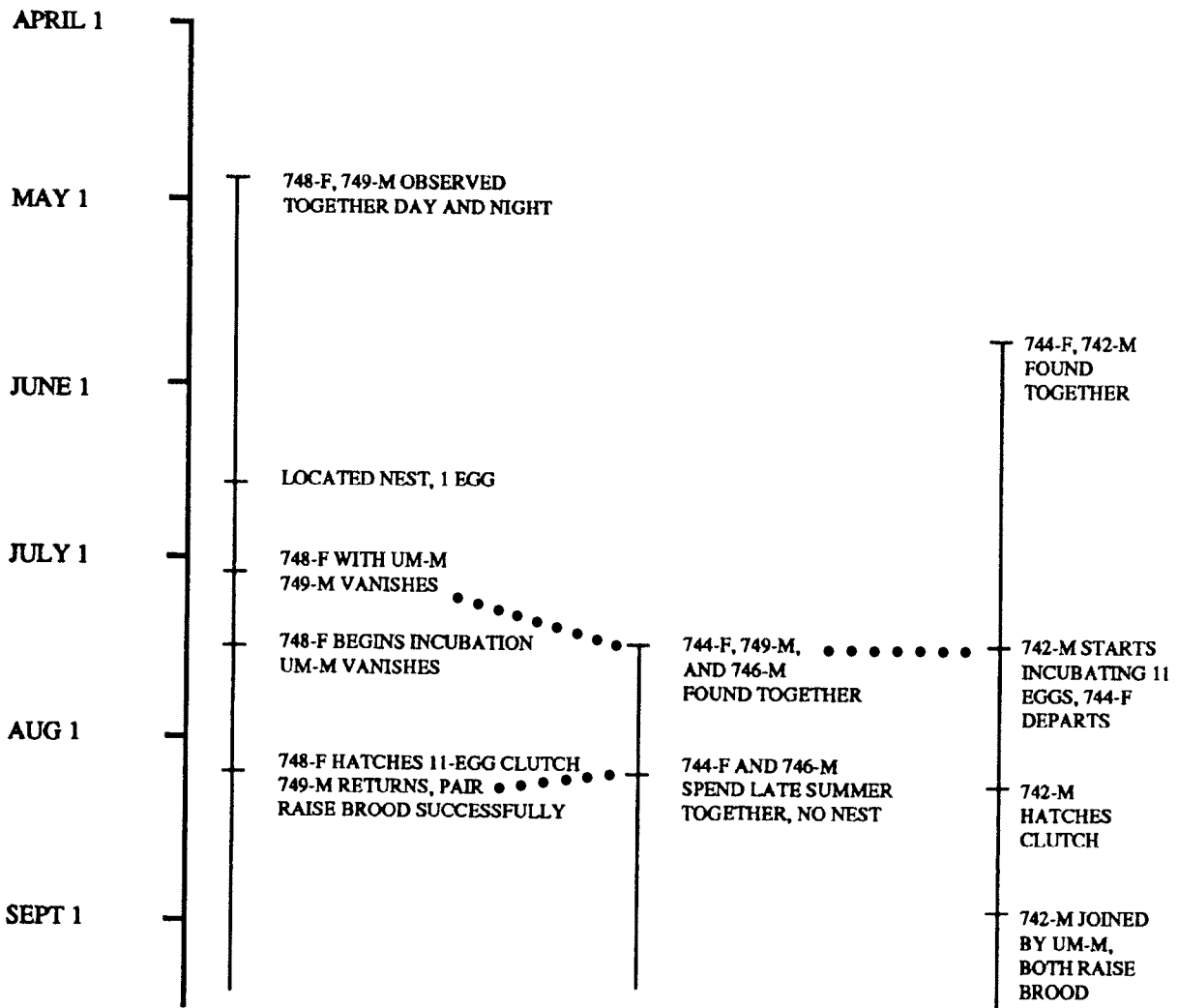


Fig. 1. Case history of the breeding biology of 5 radio-tagged and 2 untagged northern bobwhite from Tall Timbers Research Station FL summer 1984 M = male a • -Dr eā t. • CH

Case History 2.—Double-clutching is described for a radio-tagged female at FB during summer 1988 (Fig. 2). Female 938 and male 941 successfully raised 2 broods, with male 941 caring for the first brood while female 938 incubated and hatched the second clutch. Male 941 was also observed with at least 2 other females while female 938 was incubating her first clutch, and during her first month of brood-rearing as a single parent.

DISCUSSION

Lack (1968) indicated that about 90% of all bird species are monogamous and, although the actual proportion may be less, monogamy is the predominant mating system for most bird species. More recently, it has become clear that several individual breeding strategies may be exhibited by birds classified as apparently monogamous breeders (Gowaty and Mock 1985). It is unclear how many "covert" matings outside the 1 male-1

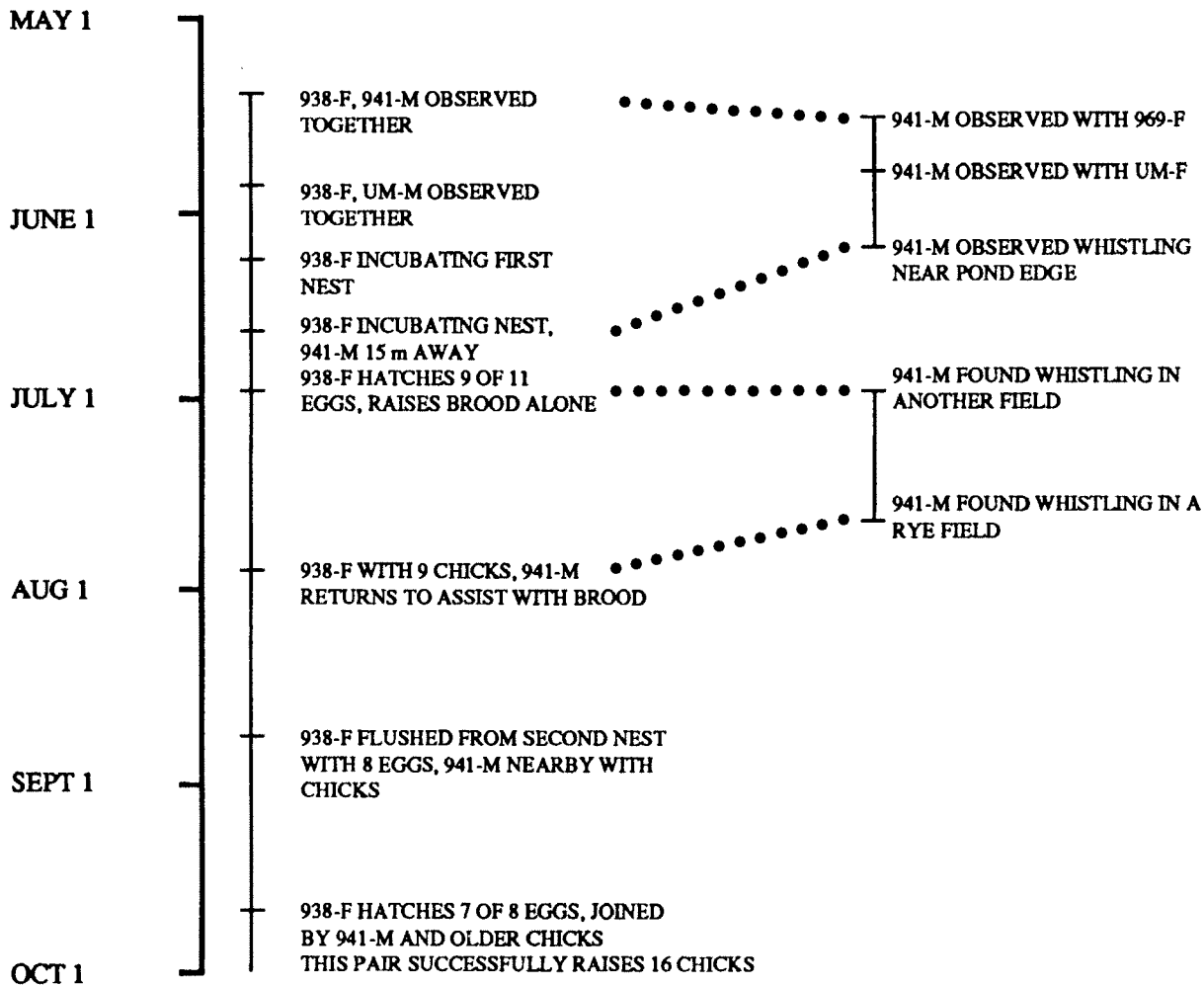


Fig. 2. Case history of the breeding behavior of 3 radio-tagged and 2 untagged northern bobwhite from Fort Bragg, NC, summer 1988 (M = male, F = female, UM = unmarked bobwhite).

female social unit must occur for a monogamous system to be classified as polygynous or polyandrous (Gowaty and Mock 1985), although the 5% benchmark has been used by others (Carey and Nolan 1979). Variations in mating tactics for apparently monogamous birds often confound concepts and definitions of mating systems.

Polygamous mating systems are especially common in precocial birds that do not feed their young (Lack 1968, Orians 1969), presumably because demands on parents are more often insensitive to brood size in such species (Walters 1982). Rapid multiple-clutch mating systems have been defined by Hilden (1975), and first described by Graul (1973). In these systems, the female lays a clutch that is attended by a male. The female then forms a second clutch that she incubates, or gives to a second male (in which case she may incubate a third clutch). This avian social system is not common, and may occur regularly only in a few species of shorebirds and galliformes (Emlen and Oring 1977). When environmental conditions (e.g., unpredictable food supply, variable weather conditions) are favorable, reproductive output can be enhanced with only a slight increase in breeding time.

Rapid multiple-clutch polygamy has been documented for the red-legged partridge (*Alectoris rufa*; Jenkins 1957), sanderling (*Calidris alba*; Parmelee and Payne 1973), mountain plover (*Charadrius montanus*; Graul 1973), and Temminck's stint (*Calidris temminckii*; Hilden 1975). The California quail (*Callipepla californica*), which occasionally practices this mating system (Francis 1965, Leopold 1977:92-93), experiences severe biotic and abiotic environmental fluctuations. All of these ground-nesting species have precocial young that suffer moderate to high predation losses (Emlen and Oring 1977), similar to northern bobwhite.

Northern bobwhite are apparently similar to California quail because females which exhibit double-brooding leave their young when the chicks are about 2 weeks old (Leopold 1977:93). For California quail, double-brooding seems to occur once or twice per decade in years highly favorable for reproduction. Male California quail rarely incubate clutches, and unmated males act as foster parents in years when chicks are abundant.

Persson and Ohrstrom (1989) recently described a new avian mating system, ambisexual polygamy, in which sequential polygyny and polyandry may occur simultaneously. Penduline tits (*Remiz pendulinus*) exhibited

uniparental clutch and brood care; of 140 clutches observed, 48% were attended by females, 18% by males, and 34% were deserted by both parents before incubation. Polyandry was exhibited by 31% of females, and 69% attended their first brood. Thirty percent of males assumed parental responsibilities. It appeared likely that the female made the primary choice to leave a clutch or stay to incubate the eggs (Persson and Ohrstrom 1989). If the female decided to incubate, the male could become polygynous. If the female departed, the male could assume parental care or abandon the clutch. Two females attended both their first and second clutches, and mate-shifting occurred between clutches.

The number of female penduline tits available to breed diminished as the breeding season progressed, and the operational sex ratio (Emlen and Oring 1977) became increasingly male-biased. As males found their chances for successfully breeding reduced, the best way to increase their reproductive output was to assume parental care. Females also may have exploited the skewed sex ratio by becoming polyandrous, as they had a greater probability of finding another mate. By spending less time with each male, a female could mate more often and increase the probability that a male would care for some of her eggs. Persson and Ohrstrom (1989) indicated that all males attempted to practice polygyny, but some were unable to do so because of female choice and behavior. Uniparental care and a long breeding season are necessary for this mating system to develop.

We noted in both case histories, that northern bobwhite females were associated with >1 male during egg laying. Consequently, it is impossible to determine the paternity of a brood without electrophoretic exclusion analyses. In both cases, the male that was present during early laying stages eventually returned to help the female care for the chicks. Schom and Abbott (1974) reported that the fertility of eggs laid by naturally-inseminated, captive bobwhite females dropped from approximately 95 to 68% 4 days following the removal of males. Roseberry and Klimstra (1984) reported that only 3% of 3,249 eggs from 234 wild nests were infertile. Therefore, female bobwhite must be mating frequently to maintain high fertility rates. In cases where a female has associated with 2 males during egg-laying, the paternity of the brood could possibly be shared.

Stoddard (1931) noted the strong adoption tendencies of northern bobwhite. More than 90% of males, females, or pairs not engaged in nesting

readily adopted chicks put with them. Sermons and Speake (1987) suggested that brood abandonment or surrogate parenting may lead to double-clutching. We observed 4 cases of apparent brood abandonment during this study (6% of all broods monitored). Polygamous mating behavior may be more likely to increase reproductive output than brood abandonment and subsequent re-nesting. In fact, pairs helped raise 50% ($n = 32$) of the broods at TTRS and 71% ($n = 31$) of the broods at FB.

Northern bobwhite should potentially be considered polygamous breeders, as mating behavior may shift between variations of polygyny, polyandry, or promiscuity. Northern bobwhite appear to exhibit characteristics of both the rapid multi-clutch and ambisexual polygamous mating systems, although neither system completely describes the breeding associations we observed. Northern bobwhite live in a fluctuating environment, suffer high predation pressure during the nesting season, and raise precocial young, similar to other galliformes and shorebirds that have evolved multi-clutch systems. About 95% of the radio-tagged bobwhite for which we were able to document breeding status exhibited apparently polygamous behavior at FB and TTRS, and our case histories describe several mating and brood-rearing associations.

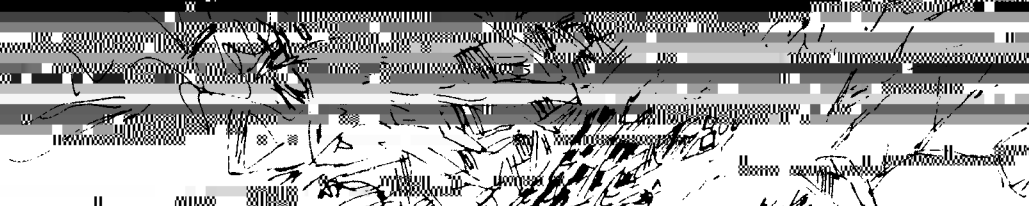
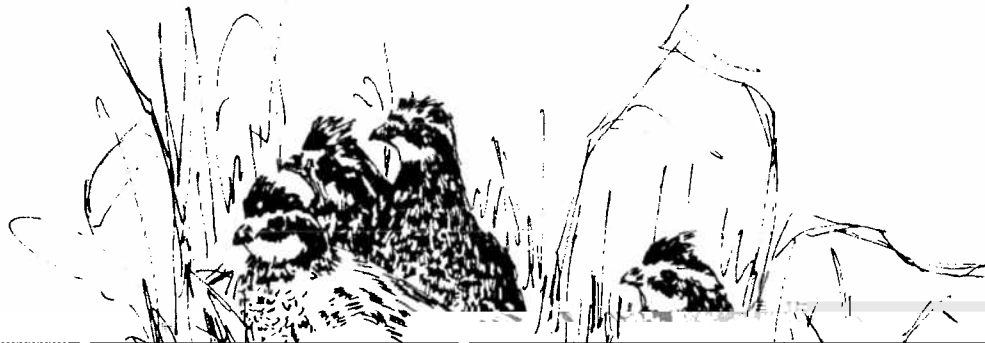
MANAGEMENT IMPLICATIONS

The importance of successful nesting and brood-rearing cannot be overemphasized during development and implementation of northern bobwhite habitat management programs. When environmental conditions are favorable, bobwhite reproductive output may be enhanced with only a slight increase in breeding time due to the flexibility in breeding behavior. Because 70-80% of the fall harvest usually consists of juvenile northern bobwhite (Rosene 1969), the number of birds in the fall population may be influenced by the proportion of bobwhite exhibiting polygamous mating strategies.

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QUAIL AND RAIN: WHAT'S THE RELATIONSHIP?

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Abstract: We used Christmas Bird Count reports in conjunction with precipitation data from 9 locations in Texas, to investigate relationships between rainfall and northern bobwhite (*Colinus virginianus*) and scaled quail (*Callipepla squamata*) abundance. Regional differences in northern bobwhite abundance could not be predicted by precipitation regimes, whereas scaled quail abundance was negatively correlated with fall and winter rainfall. Differences in rainfall patterns were not significantly correlated with year-to-year changes in northern bobwhite and scaled quail abundance.

Key words: distribution, northern bobwhite, population fluctuations, regulating factors, scaled quail.

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Although most research suggests that quail distribution and abundance are regulated primarily by availability and quality of habitat (Johnsgard 1973, Goodwin and Hungerford 1977, Brown 1982, Brennan 1991, Rice 1991), quail populations periodically rise and fall even in areas with high-quality habitat. These fluctuations as well as interregional differences in abundance appear to be due primarily to differences in reproductive success (Lehmann 1953b, Parmalee 1955, Wallmo 1956, Robinson 1957, Speake and Haugen 1960, Schemnitz 1961, 1964, Campbell 1968, Campbell et al. 1973, Roseberry and Klimstra 1975).

Factors such as vitamin (Nestler 1946, Lehmann 1953a), mineral (Cain et al. 1982), and macro-nutrient deficiencies (Wood et al. 1986); increased intake of phytoestrogens (Leopold et al. 1976, Cain et al. 1987, Lien et al. 1987); and water deprivation or drought (Campbell et al. 1973, Kiel 1976, Cain and Lien 1985, Koerth and Guthery 1991) have been suggested as possible explanations for changes in reproductive success. However, only water deprivation, presumably due to annual and regional differences in rainfall expressed as differences in succulent foods and available free water, appears to have potential to induce the dramatic population fluctuations exhibited by quail populations (Koerth and Guthery 1991).

The purpose of this study was to investigate the relationship between rainfall and northern bobwhite and scaled quail abundance, and to compare effects of changing precipitation regimes between these 2 species.

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and Wildlife Research Unit, Department of Range and Wildlife Management, Texas Tech University. This is T-9-649 of the College of Agricultural Sciences, Texas Tech University, Lubbock.

METHODS

We used Christmas Bird Count (CBC) data published in *American Birds* for 1966-91 from 9 locales in Texas to document regional and year-to-year differences in northern bobwhite and scaled quail abundance. For interspecific comparisons, we selected study areas within the area of distributional overlap of northern bobwhite and scaled quail. Location of the study areas roughly corresponds to the western edge of northern bobwhite distribution and the eastern edge of distribution of scaled quail (Johnsgard 1973). Christmas Bird Count locations included Amarillo (Potter County), Anzalduas-Bentsen (Hidalgo County), Big Spring (Howard County), Falcon Dam State Park (Starr County), Lubbock (Lubbock County), Midland (Midland County), Muleshoe National Wildlife Refuge (Bailey County), San Angelo (Tom Green County), and Stanton (Martin County). CBC's were standardized by dividing counts by person hours of observer effort.

We used both uncorrected rainfall data and rainfall corrected for evaporative loss, using Thornwaite's index of precipitation effectiveness (Critchfield 1966) for our analyses. Using simple and multiple regression ($P \leq 0.05$ needed to enter the model) analyses, proportional change in CBC's were compared to precipitation data (U.S. EDS 1966-91) collected at each CBC location, to determine year-to-year relationships between rainfall and proportional change in quail abundance. Precipitation data were grouped by month,

season (winter, spring, summer, fall, breeding, nonbreeding), year, and difference from the long-term (1966-91) mean total annual rainfall for the analyses. Pearson correlation coefficients were calculated to determine correlations among precipitation classes. Christmas Bird Counts were compared to previous year's CBC and year using simple linear regression.

To investigate regional differences in quail abundance in relation to rainfall, for each study area, mean precipitation class values were compared to mean quail abundances (1966-91) using simple linear regression and stepwise multiple regression ($P \leq 0.05$ needed to enter the model). Precipitation classes were the same as those used for year-to-year analyses.

RESULTS

Year-to-year Trends

Relationships between proportional change in quail abundance and rainfall, and change in quail abundance and rainfall corrected for evaporative loss were highly correlated ($r = 0.808, P = 0.000$). For each variable, the corrected rainfall comparisons typically had smaller r and larger P values. For simplicity, the following results and discussion refer to analyses of uncorrected rainfall data (Table 1).

Abundance of both species of quail was shown to be significantly, but weakly, influenced by changing precipitation regimes. However, the factor explaining the most variation in abundance of both species was quail abundance the previous year (northern bobwhite: $r = 0.307, P = 0.000$; scaled quail: $r = 0.322, P = 0.000$). During the past 26 years, bobwhite abundance has not shown a long-term change ($r = 0.017, P = 0.791$), while scaled quail abundance has shown a decline ($r = -0.217, P = 0.001$).

Changes in northern bobwhite populations appear to be most sensitive to changes in precipitation during the previous breeding season (Table

1). Other significant predictors of bobwhite abundance were previous year's total rainfall and precipitation during fall, June, and October (Table 1). Previous year's total and previous year's breeding season rainfall were highly correlated ($r = 0.783$), as were October and fall precipitation ($r = 0.832$).

Changes in scaled quail abundance were most sensitive to variations in precipitation during January and winter (Table 1). January and winter rainfall were highly correlated ($r = 0.652$). Using step-wise multiple regression, no multivariable model was found to be significant ($P > 0.05$) for either species.

Regional Trends

No precipitation class significantly predicted regional differences in northern bobwhite abundance. May precipitation explained the most variation ($r = 0.448, P = 0.227$). Differences in scaled quail abundance among regions were best predicted by winter ($r = -0.654, P = 0.056$) and fall ($r = -0.622, P = 0.074$) rainfall. Using step-wise multiple regression, no multivariable model was found to be significant ($P > 0.05$) for either species.

DISCUSSION

Year-to-year Trends

Year-to-year differences in abundance of many species of quail have been associated with varying precipitation regimes. Research on California quail (*Callipepla californica*; Leopold 1977, Botsford et al. 1988), and Gambel's quail (*Callipepla gambelii*; Swank and Gallizioli 1954, Gallizioli 1960, 1965, Raitt and Ohmart 1968) found significant relationships between the amount and timing of precipitation and reproductive success and survival.

Studies throughout the northern bobwhite range have found significant positive relationships between year-to-year quail abundance and reproductive success, and breeding season rain-

Table 1. Significant ($P \leq 0.05$) relationships between year-to-year rainfall and changes in northern bobwhite and scaled quail abundance based on Christmas Bird Counts in Texas, 1966-91.

Precipitation class	Northern bobwhite			Scaled quail		
	r	r^2	P	r	r^2	P
Winter	-0.059	0.003	0.458	0.163	0.027	0.029
Fall	-0.170	0.030	0.032	-0.029	0.001	0.702
January	-0.099	0.010	0.212	0.283	0.080	0.000
June	0.168	0.028	0.034	-0.078	0.006	0.295
October	-0.159	0.025	0.046	0.015	0.000	0.840
Previous total	0.276	0.076	0.000	-0.040	0.002	0.593
Previous breeding season	0.292	0.085	0.000	0.061	0.004	0.414

BREEDING STRATEGIES OF THE NORTHERN BOBWHITE IN MARGINAL HABITAT

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Abstract: We studied nesting behavior of radio-tagged northern bobwhite (*Colinus virginianus*) in south-central Iowa from 1984 to 1988. Female bobwhite incubated 78% of 81 clutches where incubation was observed and males incubated 22%. On only 1 occasion were both a male and female observed to incubate the same clutch. Incubation was initiated on 73% of the nests by females before 1 July, while incubation was initiated on 56% of the clutches by males after 1 July. Males hatched 16% of all clutches, first nests by females accounted for 69%, renests for 4%, and second clutches by females that had already hatched 1 clutch for 11%. Chicks from 3 of the first broods of females that hatched ≥ 1 brood survived for ≥ 1 week and were not accompanied by other adults. These breeding strategies appear to provide bobwhite populations multiple chances at recruitment in variable environments.

Key words: incubation, nesting, nest success, northern bobwhite.

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Nesting ecology of the northern bobwhite has been extensively studied (e.g., Stoddard 1931, Errington 1933, Klimstra 1950, Simpson 1972, Dimmick 1974, Klimstra and Roseberry 1975, Roseberry and Klimstra 1984). Although these studies have described many aspects of bobwhite population dynamics, many others remain poorly understood. Recent miniaturization of radio electronics allows direct observation of bobwhite nesting, survival, and productivity. Some aspects of bobwhite breeding behavior can only be answered using radio-tagging to follow birds in the wild.

Several studies have documented that males regularly incubate clutches (Stoddard 1931, Klimstra and Roseberry 1975). Usually males appear to incubate nests by themselves. This raises the question about the role males play in overall productivity. Few studies document the relative importance of these activities to overall productivity in wild populations.

Sermons and Speake (1987) observed 2 female bobwhite successfully raise second broods in the wild. Stanford (1972a) observed this phenomenon for pen-reared birds. However, an assessment of the importance of second broods to overall productivity was not addressed by these studies.

This paper deals with part of the results from a larger study on quail population dynamics. The

goal of the larger study was to identify mechanisms that allow quail populations to recover quickly after dramatic declines. Here we will specifically examine what strategies male and female bobwhite use to successfully contribute to productivity.

We thank J. Tellen and many other people who worked long hours collecting data; J. Wooley, B. Rybarczyk, and J. Kienzler for initiating the project; J. Kienzler, P. Curtis, and W. Burger for their helpful comments; and especially B. Fistler, whose dedication made this project a success.

STUDY AREA AND METHODS

Two areas were selected, a 794-ha site in Lucas County and a 938-ha site in Wayne County, in south-central Iowa. This is in the heart of Iowa's best remaining bobwhite habitat. It consists of rolling topography with flat, narrow ridges separated by deeply cut drainages. Almost all of the land (about 90%) is used for agriculture either as rowcrops (primarily corn and soybeans) or as pasture and hay ground. The proportion of land in each cover type varied during the study, ranging from 35-45% rowcrops, 20-30% pasture, and 15-20% hay. Topography, however limits field size in most areas and results in a greater interspersed of cover types. Most woody cover is found in small woodlots of remnant oak-hickory (*Quercus-Carya* spp.) forest or along fencerows and riparian areas. These cover types make up about 12% of the area. Most woodlots were grazed.

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males when making their estimates. But even if we divide the number of nests hatched for all birds by the number of females entering the nesting season, only about 55% produce nests. Nesting effort did not appear lacking, as almost 90% of females still alive on 1 September had at least initiated incubation on 1 nest and 70% had hatched 1 or more nests. Almost 20% of males still alive had also hatched a nest, with 30% having initiated incubation.

Nest success recorded for both males and females was higher than most studies reported (Stoddard 1931, Dimmick 1974, Klimstra and Roseberry 1975). This may be because nest success in those studies was calculated for all nests, whereas we only used nests that reached incubation. If nests have a different rate of loss during the egg-laying and the incubation stage as suggested by Klimstra and Roseberry (1975), then our higher success rates might be expected. The timing of nest establishment had little effect on nest success. Nests established late in the nesting season hatched only slightly less frequently than those established at any other time. Other studies have reported a difference in success rates between nests established during these different periods (Simpson 1972, Klimstra and Roseberry 1975), although the period with the higher success rates differed.

Nesting chronology of our birds closely resembles that reported by Stanford (1972b) in Missouri. Both initiation of incubation and hatching dates were distinctly bimodal, with peaks about 8 weeks apart. First nests by females made up the majority of clutches hatched before 1 July. Clutches hatched after that date were fairly equally divided among first nests by females, second nests by females, and nests by males. Renests by females made up a surprisingly small part of the nesting effort, although this again may reflect our definition of what constitutes a nest attempt. If, as suggested by Klimstra and Roseberry (1975), all nests established after 2 June were renests, then nests where incubation was initiated after 15 June would count as renests. Using this definition, about 18% of all nests hatched by females were renests, 13% were second nests after successful first nests, and 68% were first nests.

We found that a significant number of females did produce second nests after hatching first nests. These females typically raised broods to

approximately 3 weeks of age, left, and became paired with males. The dates of hatch for first nests and timing of brood abandonment are nearly identical to what Sermons and Speake (1987) described. Fortunately we were able to determine the fate of 3 broods abandoned by these females. These broods appeared to do as well as broods accompanied by adult birds. The frequency with which this was observed was surprising but has been suggested by Stanford (1972a). It appears that double broods are an important aspect of bobwhite productivity. The fact that we did not observe this during the last 2 years of the study may be coincidental because only 2 females in 1987 and 5 in 1988 hatched nests prior to 5 July. If we were to view these second nests as if they were random events, then there is about a 10% probability that we would not observe this simply by random chance. Since bobwhite numbers on the study areas were higher during the last 2 years than during the first 3 years, this behavior could be related to population densities.

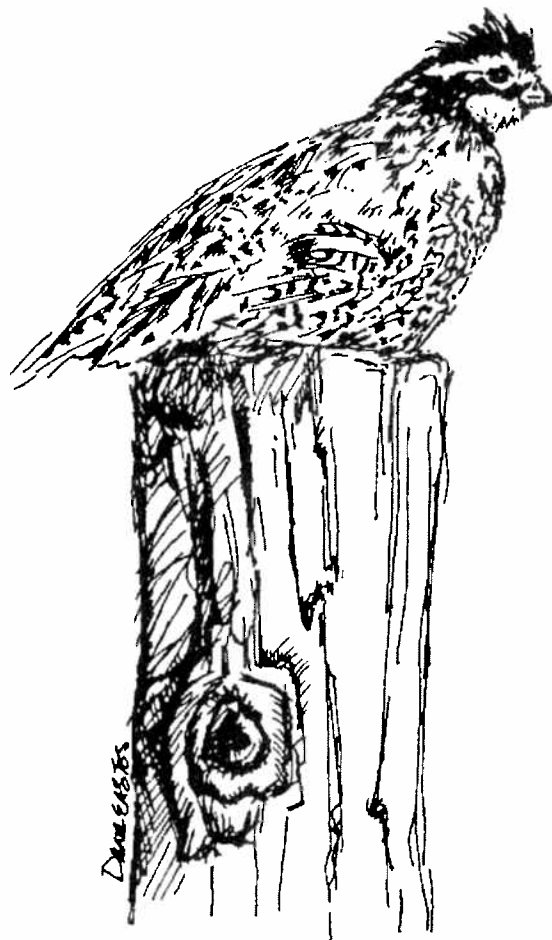
MANAGEMENT IMPLICATIONS

Bobwhite populations appear to recover very quickly from catastrophic weather events such as prolonged cold and heavy snows (Suchy et al. 1991). These events drastically reduce bobwhite numbers in states like Iowa which are on the fringe of their range. We have described several mechanisms that might contribute significantly to these recoveries and we have more clearly defined what roles male and female bobwhite play in recruitment into these populations. Management efforts directed to take advantage of this tremendous reproductive potential may provide real dividends. Efforts to provide undisturbed, quality nesting cover throughout the nesting season might improve the success of these various reproductive strategies.

We believe we raise some interesting questions. Does the breeding behavior observed occur in other areas or are these behaviors the result of natural selection in areas where large voids intermittently occur in the population? How variable are these behaviors from year to year? Are they affected by population density? Whatever the answers, this increased understanding of the breeding behavior of northern bobwhite will allow wildlife professionals to better understand the impacts of management activities on bobwhite.

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SURVIVAL OF NORTHERN BOBWHITE ON HUNTED AND NONHUNTED STUDY AREAS IN THE NORTH CAROLINA SANDHILLS

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Abstract: Radio-tagged northern bobwhite (*Colinus virginianus*) were monitored in the Sandhills region of North Carolina to investigate the influences of hunting on seasonal survival. We used the Kaplan-Meier product limit method with staggered entry design to calculate survival estimates and distributions for 79 radio-tagged bobwhite representing 33 coveys during November-February 1987-89. Estimated winter survival rates for year 1 (59%) and for pooled years (67%) in the nonhunted study areas were greater than in the hunted areas (31 and 45%, respectively; $P < 0.05$). Survival trends for the second winter were again greater in the nonhunted study areas (74%) but not different than hunted study areas (63%; $P > 0.05$). Avian predation was the major proximate cause of mortality, accounting for 66% of the known losses. Summer whistle count surveys indicated that nonhunted study areas contained more ($P < 0.05$) whistling bobwhite per station than hunted areas following winter hunting seasons.

Key words: *Colinus virginianus*, hunting, North Carolina, northern bobwhite, Sandhills region, survival, whistle counts.

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Despite the popularity of northern bobwhite as a game bird, the influence of sport hunting on their numbers is poorly documented (Roseberry 1979, Brennan 1991). It has been assumed that annual harvest would substitute for natural population reductions, based primarily on the works of Errington (1934, 1967). Several studies concluded that hunting appeared to have little effect on standing densities of quail (Mosby and Overton 1950, Gallizioli and Swank 1958, Glading and Saarni 1958, Vance and Ellis 1972). Others have voiced concern for the possible effects of hunting on small game populations (Wagner 1969, Nixon et al. 1974, Destefano and Rusch 1982, Bergerud 1985). Stoddard (1931:226) suggested bobwhite hunting losses could become additive to other forms of mortality. Recent evidence suggests that bobwhite harvest and other natural losses may not be completely compensatory (Curtis et al. 1988, Pollock et al. 1989a). The later in the winter that harvest losses occur, the more likely they will add to natural mortality (Roseberry and Klimstra 1984:140-150).

The northern bobwhite population at Fort Bragg, North Carolina, has declined steadily

during the past decade. Reported bobwhite harvests on the military reservation dropped from about 9,000 birds annually in the mid-1970's to 600 in 1984 (W. M. Hunnicutt, Ft. Bragg Wildlife Branch, unpubl. data). In 1983, a cooperative agreement was established between North Carolina State University and the Department of Defense to investigate the causes of the population reduction and attempt to improve bobwhite management on the reservation. Valuable baseline data were the result of initial phases of the research (Curtis 1990). However, more information was needed upon which to base management decisions. The objectives of our work were (1) to investigate the possible influence of hunting and predation mortality on survival of bobwhite and (2) to examine bobwhite population trends in hunted and nonhunted study areas. If minimal influences were to occur, then we hypothesized that bobwhite survival and population trends on control (hunted) and treatment (nonhunted) areas should be similar.

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STUDY AREA

We studied the northern training portion of Fort Bragg Military Reservation in Cumberland and Hoke counties, North Carolina. The 55,000 ha base is located in the Sandhills physiographic region. Climate was hot and generally humid in summer with a moderately cold, but short winter. Mean annual daily temperature was 16.2 C. Average daily winter temperature was 6.3 C. As reported by Hudson (1984), 60% of the average annual precipitation (115.7 cm) falls between April and September. Mean yearly snowfall total of about 8 cm occurs from December to February.

Predominant overstory species on upland sites were longleaf pine (*Pinus palustris*) and turkey oak (*Quercus laevis*), with a ground cover of primarily wiregrass (*Aristida stricta*). Dense evergreen shrubs (e.g., *Lyonia* and *Ilex* spp.) characterized the mesic habitat. The natural plant communities of the Sandhills region have been described by Wells and Shunk (1931).

The research area was divided into study blocks I and II. Each block contained 2 quail study areas (QSAs) with buffer areas to attenuate impacts of movements between treatment areas. QSAs (approximately 278 ha each) were selected on the assumption that there would be minimal movements between areas. During bobwhite hunting seasons in 1987 and 1988 (November 19-20 to February 28-29), Block I was open to hunting. Hunter trips into this area were controlled by Fort Bragg Hunting and Fishing Center. Block II was used for comparison and was posted and closed to bobwhite hunting.

METHODS

We trapped northern bobwhite during September and October each year with baited funnel traps (Stoddard 1931:443). We placed aluminum leg bands (size 7) on birds and classified them as adults or juveniles according to plumage characteristics and molting stages (Haugen 1957, Rosene 1969). Wing molt and primary feather length were used to estimate date of hatch of juvenile birds (Rosene 1969:44-54). Plumage pattern and coloration were used in sex determination (Stoddard 1931:81).

Birds were fitted with an activity-sensitive chest mounted radio transmitter (7-8 g) (Shields et al. 1982). Efforts were made to distribute radio

transmitters on 2-3 birds per covey. Often, captured birds were too immature to carry the transmitter. Occasionally, a single bird was captured with unsuccessful captures of covey mates. Coveys were monitored once every 1-2 days during the hunting season. Bobwhite that died within 7 days of instrumentation were excluded from survival analyses.

Seasonal and annual bobwhite survival rates were estimated by the Kaplan-Meier or product limit estimator (Kaplan and Meier 1958) with staggered entry design (Pollock et al. 1989b). Survival rates, confidence intervals, and survival distributions were estimated and compared between nonhunted and hunted QSAs by use of normal approximation Z-tests and log-rank tests. Our test is not a direct experimental test of hunted versus nonhunted survival rates, but rather a test of whether bobwhite survival for the 2 hunted areas is different from bobwhite survival for the 2 nonhunted areas.

Characteristic field evidence and postmortem conditions were used to assess the proximate cause of death (after Einarsen 1956). A combination of the evidence was used to classify apparent agent-specific causes of death as follows: (1) small avian predators, (2) large avian predators, (3) mammalian predators, (4) hunting, and (5) other or unknown.

Whistle count surveys were conducted during June 1987-89. A route with 4 listening stations (8 stations per treatment) 1/2 mile apart, was incorporated into each QSA. Surveys began at sunrise on mornings having <50% cloud cover, <19 km/hour winds, and no rainfall. Bobwhite whistles and number of individual birds whistling were recorded at each station for 2 consecutive 5-minute periods. Occasionally disturbance levels due to military activity were high during 1 period, but acceptable during the other period. When this disturbance occurred, the period with the high count was used as the day total for that station. Call-count routes were repeated 5 times each June. Student's *t*-test ($P < 0.05$) was used to detect differences in mean number of whistling bobwhite and mean number of calls heard between nonhunted and hunted QSAs for the 3 years.

RESULTS

Forty-three radio-tagged bobwhite, representing 16 coveys, were at risk during the 1987-88 winter season. Thirty-six bobwhite (17 coveys) were radio-tagged during the 1988-89 winter season. Log-rank tests indicated no differences ($P > 0.05$) in survival functions within hunted and

Table 1. Kaplan-Meier survival estimates of radio-tagged northern bobwhite in the Quail Study Areas (QSAs) at Fort Bragg, NC, winters 1987-89.

Year	QSAs	<i>n</i> ^a	Survival	SE	95% CI ^b
1987-88	Hunted	17	0.308	0.104	0.104-0.512
	Nonhunted	26	0.593 ^c	0.098	0.401-0.785
1988-89	Hunted	15	0.629	0.135	0.364-0.894
	Nonhunted	21	0.737	0.097	0.547-0.927
1987-89	Hunted	32	0.453	0.089	0.278-0.627
	Nonhunted	47	0.670 ^c	0.070	0.533-0.807

^aNumber of bobwhite at risk at least 1 full week during the winter season.

^bCI= Confidence interval.

^cSurvival significantly greater ($P < 0.05$) than the hunted QSAs.

nonhunted QSAs between years, so data were pooled to reduce variation.

During the 1987-88 winter season, estimated survival of bobwhite was greater ($P = 0.023$) in nonhunted QSAs (0.593 ± 0.098) (mean \pm SE) than in hunted QSAs (0.3077 ± 0.104) (Table 1). During 1988-89, bobwhite survival in nonhunted QSAs was again higher (0.737 ± 0.097) than in hunted QSAs (0.629 ± 0.135), but not significantly ($P = 0.258$) (Table 1). For the 2 years combined, winter survival was greater ($P = 0.028$) in nonhunted QSAs (0.670 ± 0.070) than hunted QSAs (0.453 ± 0.089).

Survival schedules for the QSAs were not uniform throughout the hunting season, but appeared to show a sharp decline in midwinter in nonhunted QSAs. For hunted QSAs, survival began to decline with onset of the hunting season (Fig. 1). A difference was detected ($P < 0.05$) in survival distributions between nonhunted and

hunted QSAs for pooled years. Monthly estimates of survival indicated that the probability of dying (1-survival estimate) was highest in December for hunted QSAs and in January for nonhunted QSAs. The greatest number of bird deaths (14) for all QSAs 1987-89 occurred in January. Predation was the major direct cause of bobwhite mortality during winter, with avian predators accounting for 66% of known mortalities. In hunted QSAs, direct hunter-bagged birds amounted to 14% of bobwhite mortality.

We did not detect a difference in the number of whistling bobwhite heard ($P = 0.320$) between designated hunted and nonhunted QSAs in 1987, prior to manipulating hunting seasons. Following establishment of the nonhunted QSAs, whistle count surveys indicated more calling individuals per station for nonhunted than for hunted QSAs in 1988 ($P = 0.022$) and 1989 ($P = 0.015$) (Fig. 2).

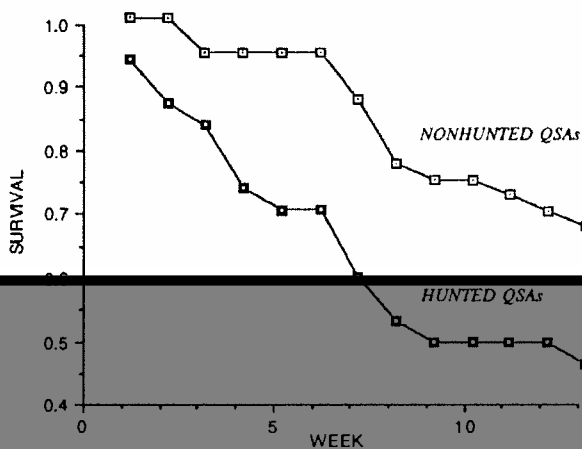


Fig. 1. Northern bobwhite winter survival schedule for hunted and nonhunted Quail Study Areas (QSAs) at Fort Bragg, NC, 1987-89.

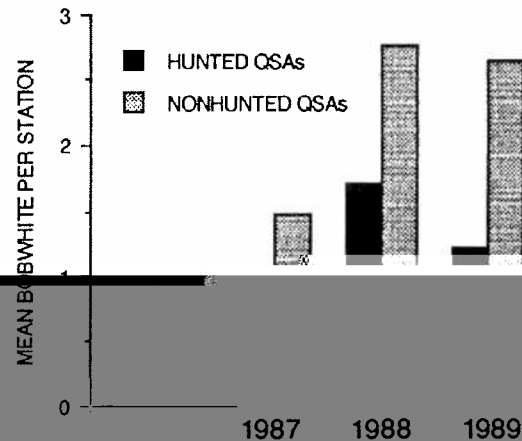


Fig. 2. Frequency distribution of mean number of whistling bobwhite heard per station during June surveys in hunted and nonhunted Quail Study Areas (QSAs) at Fort Bragg, NC, 1987-89.

DISCUSSION

Northern bobwhite naturally exhibit low annual survival. Roseberry and Klimstra (1972, 1984:37-55) and Lehmann (1984:303) suggested that adverse effects could result, depending on when during the winter season losses might occur. Kabat and Thompson (1963) estimated that winter losses for bobwhite were greatest in early winter (mid-November-December) on their Wisconsin study areas. Curtis et al. (1988) observed high natural mortality during January-March in un hunted bobwhite in Florida and hunted birds at Fort Bragg. The lower survival estimates and population trends of bobwhite in our hunted QSAs compared to non hunted QSAs seemed to suggest hunted birds have higher risks for survival to the breeding season than un hunted bobwhite.

Similar to other workers in the southeastern U.S. (Sermons 1987, Curtis et al. 1988), we observed high depredation on bobwhite. Common predation theory (Errington 1934, 1967) may at times inadequately explain predator-bobwhite relationships in the Southeast (Errington and Stoddard 1938, Curtis et al. 1988, Brennan 1991). Thought should be given to the survival of birds based on disturbance leading to indirect mortality from harvesting activities. Field observations in the QSAs found that coveys disturbed by hunters are vociferous in attempting to reassemble, possibly increasing vulnerability to natural predation. This interpretation remains to be thoroughly tested.

One primary approach used to argue that compensatory natural mortality occurs is that hunted populations are commonly the same as un hunted populations when spring counts are taken (Bergerud 1988). Our whistling count surveys provided some evidence of the response of northern bobwhite populations to hunting. We should not consider ourselves obliged to harvest the surplus, as unharvested surplus birds are not wasted. There is a carryover effect from year to year (Roseberry 1979, 1982) and managers should ensure that these carryover populations are not consistently lower than natural carrying capacity. Low bobwhite populations cannot be expected to recover if hunting activities impede reproductive potential by reducing breeding densities.

Currently, the evidence for compensatory mortality is conflicting (Wagner 1969). However, there is mounting evidence that hunting, par-

ticularly late season hunting, and natural mortality are additive. Pollock et al. (1989a) argued that it was hard to devise a compensatory mechanism because hunting season coincided with a time of high natural bobwhite mortality. As bobwhite managers charged with the maintenance of a wildlife resource, we should take a more tenable and scientific approach to managing this harvestable crop.

MANAGEMENT IMPLICATIONS

Our work at Fort Bragg suggested that hunting may be a potential factor depressing bobwhite populations, particularly low populations. We should emphasize that this is what occurred on an area with excellent road access and constant hunter effort throughout the season. While recognizing that factors other than hunting contribute to wildlife population declines, hunting is often the most readily controlled cause of mortality (direct and indirect). An underlying theme in what bobwhite do results from the need to remain inconspicuous to avoid predators. If, at existing low densities, predation mortality is excessive and hunting indirectly influences this mortality, then managers should include practices that improve upon these influences. There is a need to determine acceptable limits of harvest pressure while maintaining optimum numbers of breeding bobwhite. Attention should be given to experimental testing of bobwhite population responses to varying exploitation and disturbance levels.

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SURVIVAL OF NORTHERN BOBWHITE INFECTED WITH AVIAN POX

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Abstract: Avian pox is an enzootic disease among northern bobwhite (*Colinus virginianus*) in the southeastern United States, but occasionally it occurs as local or regional epizootics. Little information exists concerning survival of wild bobwhite infected with this disease. During the winters of 1985 and 1986, we compared survival of radio-tagged bobwhite with and without pox lesions. Pox lesions were considered "wet" or "dry" depending on field evaluations. The incidence of pox was greater in 1985 ($X^2 = 16.536$, $df = 1$, $P < 0.005$) than in 1986. Bobwhite with wet pox lesions weighed less than those with dry pox ($t = 2.550$, $P = 0.014$) or no pox ($t = 2.393$, $P = 0.018$). In 1985 6-week survivorship of bobwhite showing signs of wet pox was different compared to those with dry pox ($Z = 1.7498$, $P = 0.0402$) and no pox ($Z = 2.9992$, $P = 0.0014$). Survivorship of birds with dry pox and no pox was not different ($Z = 0.6460$, $P = 0.2611$). Bobwhite with wet pox in 1985 had 45.6 and 53.3% overall lower 6-week survival rates than birds with dry and no pox, respectively. No difference in survivorship existed between bobwhite with dry pox and those with no pox in 1986 ($Z = 1.1727$, $P = 0.1210$). No difference in predatory agents responsible for mortalities between birds with or without pox occurred ($X^2 = 0.8851$, $df = 2$, $P > 0.05$). All mortality of infected birds appeared to be caused by predation and not the disease itself. Implications of these data for inter- and intraspecific disease transmission are discussed.

Key words: avian pox, *Colinus virginianus*, mortality, northern bobwhite, radio-tagging.

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Northern bobwhite are susceptible to numerous diseases and are hosts to a variety of parasites (Kellog and Doster 1972). Avian pox virus is prevalent worldwide, and a diverse array of birds are susceptible to this disease (Karstad 1971, Cunningham 1978). Several strains of avian pox viruses exist, many of which are host-specific to certain species of birds, while others may infect a variety of species (Davidson et al. 1982).

Avian pox is characterized by discrete proliferative lesions on the skin and/or mucous membranes of the mouth and upper respiratory tract (Karstad 1971), and can occur in 2 forms. Dry pox (or the cutaneous form) is characterized by lesions that develop primarily on unfeathered skin, such as the legs and feet. Wet pox involves lesions on the mucous membranes of the mouth, nasal passages, and upper respiratory tract (Davidson et al. 1982). In some cases both dry and wet pox may occur on the same bird.

Avian pox is spread by direct mechanical transmission of the virus (i.e., pecking at lesions; Cunningham 1978). In addition, the disease can be caused by inhalation of viral particles in dust or by blood-feeding insects, particularly mosquitoes (Davidson et al. 1982).

Reports of avian pox in wild bobwhite are infrequent (Stoddard 1931, Davidson et al. 1982, Hansen 1987). However, this disease is known to exist in pen-raised bobwhite, with occasional severe outbreaks (Shillinger and Morley 1937, Poonacha and Wilson 1981). Avian pox is endemic in southeastern bobwhite populations and normally occurs at low levels (Davidson et al. 1982); however, local or regional epizootics may occur. Davidson et al. (1980) described an outbreak of pox in southwestern Georgia and northcentral Florida that resulted in an estimated 12-fold increase in the incidence of infection among wild bobwhite and a mortality rate between 0.6 and 1.2%.

Survival rates of wild free-ranging bobwhite infected with a disease are difficult to determine due to the rapid removal of dead birds by predators and scavengers and to the species' cryptic coloration and secretive nature (Rosene and Lay 1963). To more accurately assess the effect of

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avian pox on bobwhite, we compared survival of wild radio-tagged birds with and without pox lesions. Implications of these data for inter- and intraspecific disease transmission are discussed. Additionally, effects of an increased use of pen-raised bobwhite and their potential to spread this disease are addressed.

STUDY AREA

We studied 2 sites on Dekle Plantation in Grady County, Georgia. Site A encompassed approximately 190 ha forested primarily with mature longleaf (*Pinus palustris*), with loblolly (*P. taeda*), and shortleaf pine (*P. echinata*) interspersed in old-field areas. Dominant understory plants were bracken fern (*Pteridium aquilinum*) and wiregrass (*Aristida stricta*). Agricultural fields (primarily corn), ranging from 0.5 to 7.0 ha, occupied about 15% of this site. Area B contained about 100 ha and had an overstory of naturally regenerated loblolly and shortleaf pine and a grass-forb understory characteristic of southeastern old-field communities. Small (0.5-3.0 ha) corn fields comprised 30% of the area.

METHODS

Bobwhite were captured with baited funnel traps (Stoddard 1931) and with nets at roost sites. Trapping periods were 3-16 January 1985 and 28 December 1985-5 January 1986. Individuals from 25 different coveys were trapped, and radio-transmitters were distributed based on the number of captured bobwhite in a given covey. Number of radio-tagged individuals within a given covey ranged from 2 to 11, ($\bar{x} = 6$). Birds were aged (Rosene 1969), banded, sexed, weighed, radio-tagged (Shields et al. 1982), and checked for lesions of pox.

We monitored 73 radio-tagged bobwhite in 1985 and 76 in 1986. The 6-week monitoring periods were 17 January-27 February 1985 and 6 January-16 February 1986. Bobwhite were monitored daily and attempts were made to confirm mortality within 24 hours.

We determined depredation from field signs, postpredation condition of the transmitter, direct observations, and remains in hawk nests. The predatory agents were categorized as mammal, avian, or unknown.

Survival was estimated with the staggered entry design (Pollock et al. 1989). A Z-test was used for comparing survival curves (Pollock et al. 1989). A 6-week survival time frame was used because it approximates the average length of a

pox occurrence (Karstad 1971, Cunningham 1978). Because of our short trapping periods, the survival time frame began immediately after the first capture and ended 6 weeks after the last bird was trapped.

Laboratory confirmation of pox could not be made on location and utilize the radio-tagged bird in the field; therefore, field determination of pox was accomplished by visual inspection using 2 trained observers. Additionally, 5 cases of pox within the total capture sample were confirmed by laboratory analysis consisting of histopathologic examination conducted by the Southeastern Cooperative Wildlife Disease Study.

RESULTS

One hundred and forty-nine wild northern bobwhite were captured, examined for pox infection, radio-tagged, and monitored during the winters of 1985 and 1986. Of this total, 103 (69.1%) had no evidence of avian pox infection, whereas 46 (30.9%) had pox-like lesions. Of the 46 suspected cases of pox, 27 (58.7%) were represented by lesions on the legs or around the nares ("dry pox"), and 19 (41.3%) had lesions on the eyelids, in the mouth, or inside the nasal cavity ("wet pox").

Survivorship

A difference existed in the prevalence of pox between 1985 and 1986 ($X^2 = 8.815$, $df = 1$, $P = 0.003$) and in the survivorship of birds showing pox-like lesions ($\hat{S}_{1985} = 0.4514$, 95% confidence interval [CI] = 0.2822-0.6206; $\hat{S}_{1986} = 0.8264$, 95% CI = 0.6015-1.0514; $Z = 2.1845$, $P = 0.0146$). Therefore, survivorship data were analyzed by year. No differences in survivorship ($Z = 0.4610$, $P = 0.3228$) or prevalence of pox ($X^2 = 0.905$, $df = 1$, $P = 0.342$) were noted between sites A ($\hat{S} = 0.7968$, 95% CI = 0.7166-0.8770), and B ($\hat{S} = 0.7642$, 95% CI = 0.6519-0.8764); therefore study sites were combined for analysis of data.

1985.—Of the 73 bobwhite monitored, 39 were free of pox lesions, and 34 had lesions. Of the 34 birds, 18 had lesions typical of wet pox and 16 showed signs of dry pox. Bobwhite with wet pox had a lower survival ($\hat{S} = 0.3277$, 95% CI = 0.1287-0.5268) than birds with dry pox, ($\hat{S} = 0.6027$, 95% CI = 0.3394-0.8695; $Z = 1.7498$, $P = 0.0402$) or those with no pox, ($\hat{S} = 0.7011$, 95% CI = 0.5591-0.8437; $Z = 2.9992$, $P = 0.0014$). No difference existed between bobwhite with dry pox and those

with no pox ($Z = 0.6460$, $P = 0.2611$). Bobwhite with wet pox had a 45.6 and 53.3% overall lower 6-week survival rate than dry and no-pox birds, respectively.

1986.—Of 76 bobwhite monitored, 64 were free of pox. Of the infected birds, 1 had lesions typical of wet pox and 11 showed signs of dry pox. The 1 bird with wet pox died 2 weeks after capture; with only 1 wet-pox bird in 1986, no significance can be placed on this survivorship. No difference existed between survivorship of bobwhite with dry pox ($\hat{S} = 0.9091$, 95% CI = 0.7300-1.0882) and those without pox ($\hat{S} = 0.7828$, 95% CI = 0.6698-0.8959; $Z = 1.1727$, $P = 0.1210$).

Weights

Body weight of bobwhite did not differ between study sites ($t = 1.667$, $SE = 2.162$, $P = 0.097$) or between years ($t = 0.689$, $SE = 2.151$, $P = 0.492$). Therefore, study sites and years were combined for analysis of weight data.

Bobwhite with wet pox weighed less ($\bar{x} = 151.3$ g, $SE = 8.872$) than birds with dry pox ($\bar{x} = 162.5$ g, $SE = 16.663$; $t = 2.550$, $SE = 4.399$, $P = 0.014$) or no pox ($t = 2.393$, $SE = 3.057$, $P = 0.018$). There was no difference in body weight between birds with dry pox and those with no pox ($\bar{x} = 158.6$ g, $SE = 12.069$; $t = 1.381$, $SE = 2.830$, $P = 0.170$).

Predation

Of the 59 mortalities that occurred over the 2 years, we were able to determine the predatory agent responsible for 40 deaths. Twenty-nine were caused by avian predators and 11 by mammals. The remaining 19 deaths could not be assigned to a specific group with confidence; therefore, the deaths were listed as caused by an unknown predator. No difference existed among the predatory agent responsible for a given kill and the disease condition of the bird (dry, wet, or no pox) ($X^2 = 0.8851$, $df = 2$, $P > 0.05$).

DISCUSSION

While region-wide outbreaks of avian pox are known to occur (Davidson et al. 1980), most epizootics of this disease are probably localized (Davidson et al. 1982). A variety of factors can contribute to the large variations in year-to-year incidence of avian pox (Karstad 1971, Davidson et al. 1980). The incidence of pox we observed (30.9%) falls within the range of prevalence for occurrence in localized areas (Davidson et al. 1980).

Low mortality of bobwhite infected with dry pox in our study agrees with observations of other researchers (Davidson et al. 1982, L. J. Landers, L. P. Simoneaux and C. D. Sisson, pers. commun., Tall Timbers, Inc. and Southeastern Cooperative Wildlife Disease Study, Tallahassee, FL.). Wet pox, however, is a virulent disease that appeared to greatly increase the probability of mortality, albeit through increased vulnerability to predation. Domesticated birds infected with wet pox usually die of starvation or suffocation due to the proliferative nature of this virus in the moist portions of the esophagus or respiratory tract (Cunningham 1978). However, our data suggest the major cause of death for wild bobwhite infected with wet pox is an increased susceptibility to predation caused by an overall weakened condition.

We attribute differences in body weights between wet-pox and dry- or no-pox birds to reduced food intake. This is reported to be caused by impairment of vision, respiration, or swallowing (esophageal occlusion; Cunningham 1978). In domestic fowl infected with avian pox, weight loss is principally an economic consideration (Cunningham 1978); however, among wild bobwhite this apparent loss of fitness has lethal consequences.

Wet-pox birds suffered higher predation, and consequently lower survival. The ratio of avian to mammalian kills in our project appears to be similar to previous studies (Curtis et al. 1989), suggesting that wet pox infection increased vulnerability to both avian and mammalian predators approximately equally.

MANAGEMENT IMPLICATIONS

Avian pox is an endemic disease, with an historically low prevalence in the southeastern U.S. (Stoddard 1931, Davidson et al. 1980, Hansen 1987, Landers et al., pers. commun.). Background levels of avian pox are normally not a management consideration; however, during pox outbreaks a tremendous potential for intraspecific transmission of this disease can occur. This transmission can be mechanical (by pecking of lesions) or through arthropod vectors. The potential for interspecific disease transmission of pox viruses infecting bobwhite is less well known. Currently there are no known methods to prevent or control epizootics originating in the wild.

The potential for released pen-raised bobwhite to elevate the incidence of pox in wild bobwhite populations also is of concern. Pen-raised birds



REPRODUCTIVE ECOLOGY OF NORTHERN BOBWHITE IN NORTH FLORIDA

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Abstract: Brood habitat use and summer mortality of northern bobwhite (*Colinus virginianus*) chicks and adults were studied from 1984 to 1986 at Tall Timbers Research Station near Tallahassee, Florida. Adult bobwhite ($n = 134$) were radio-tagged and monitored throughout the breeding season. Fifty-four nests were located and 227 bobwhite chicks were monitored to determine reproductive output and brood status. Counting chicks on the roost at night provided reliable estimates of brood size reduction. Chick loss rates were 62% to 2 weeks and 71% to 1 month posthatch. Adult mortality from 15 May to 15 October for combined years was 31%. Seventy-one percent of females surviving to 15 October produced a brood (defined as >1 chick surviving to 2 weeks of age). Fourteen percent of males which survived the summer incubated a nest and produced a brood. Brood locations were analyzed for vegetative structure, composition, and insect abundance and compared to random plots. An inverse correlation ($P < 0.05$) existed between insect abundance and brood home ranges at 2 weeks. However, there was no correlation between insect density and chick mortality ($P > 0.05$). Brood locations had a greater ($P < 0.05$) occurrence of *Compositae*, *Gramineae*, *Leguminosae*, *Rosaceae*, and shrubs than random locations. Preferred brood areas were old (>5 years), fallow fields with a scattering of shrubby thickets and a relatively open tree canopy. Two cases of double clutching occurred in which females successfully raised a brood to 1 month of age and subsequently were found incubating a second nest.

Key words: brood, *Colinus virginianus*, habitat, mortality, northern bobwhite, north Florida.

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Over 50 years of research has generated nearly 2,800 papers on the life history and management of northern bobwhite (Scott 1985). Many studies have concentrated on fall/winter habitat management, food habits, and population biology. Traditional bobwhite management is fairly well understood (Kellogg et al. 1972); however, knowledge of breeding season ecology and summer habitat use is limited. The ability of researchers to observe adults and broods in lush summer vegetation is one of the principal problems encountered in breeding-season research. Several studies have addressed nesting/brood chronology, nesting habitat, and adult mortality and attempts have been made to estimate recruitment of chicks into the fall population (Stoddard 1931, Lehmann 1946, Klimstra 1950, Speake and Haugen 1960, Dimmick 1972, Simpson 1972, Dimmick 1974, Roseberry and Klimstra 1984). Much of these data were gathered through intensive searches in nesting habitat, vegetative sampling of nest sites, brood observations throughout the summer, banding, and harvest data.

Hurst (1972) and Jackson et al. (1987) studied preferences of chicks for various insects and insect densities in various vegetation types thought to be good brood habitat. They emphasized the importance of insect abundance to survival of growing chicks.

Survival of juvenile bobwhite immediately posthatch is 1 of the most important but least documented aspects of quail biology (Roseberry and Klimstra 1984). The cryptic coloration and freezing behavior of young chicks make observation difficult. Group rearing, brood switching, double clutching, and adoption also appear to be more common than previously believed, thereby increasing variability in survival estimates (Curtis et al. 1993). It is generally agreed that the first 2 weeks of life are the most critical to survival of chicks due to flightlessness, lack of protective feathering, and high protein requirements (Stoddard 1931, Klimstra 1950, Fatora et al. 1966, Hurst 1972). Current estimates have been derived from brood surveys and based on average size of broods sighted of a given age throughout the breeding season. Estimated losses are highly variable but are commonly around 50% to 5 months of age.

In addition to the lack of brood/chick information, little data exist on survival and timing of

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Because of the difficulty in counting flightless chicks, we believe that true estimates of brood size could only be obtained by radio-locating the roosted parent at night. Once visual contact was made on the roost, the adult was gently, physically moved off the brooded chicks. Chick counts with this technique were quite successful; however, some adults, particularly males, did not allow close approach and accurate estimates were not attainable until chicks reached flight stage at approximately 2 weeks of age. Weekly flush counts were made of broods older than 2 weeks. Two observers were present on most chick counts to ensure consistency. Other problems encountered in brood counts included adults with chicks other than their own and brooding behavior exhibited by chicks 1 month old and older. Brood size reduction was assumed to be a direct indicator of brood mortality, and although some brood switching was apparent it occurred primarily in the more advanced aged broods (i.e., >2 weeks old).

Brood and adult home ranges were analyzed using Mohr's minimum range technique (Mohr 1947). Adult bobwhite with >20 locations were used in home range estimation. Differences in brood ranges between years were tested by analysis of variance.

All brood locations were sampled for vegetative composition and structure as soon as broods reached 15 days of age. Brood locations were assumed as plot center of a 0.04 ha plot. Flags were tied 10 m from center in the 4 cardinal directions. Insects were collected with 40 sweeps of a sweep net on the compass lines of each brood plot. All vegetation and insects collected in nets were put in 3.8 L glass jars with a 50/50 mixture of alcohol and water. Insects were later separated to orders, and volume displacement for each order was recorded. Chi-square analysis was used to detect differences between brood ranges and ran-

dom locations. We related 2-week brood home ranges to insect abundance within brood ranges by regression analysis.

Vegetative parameters measured for plots included percent overstory (>2 m) canopy cover by ocular estimate, distance of plot center to ecotone, and number of vegetative intercepts at 1.5 m. A 0.5-m² grid was placed 4 times, at equal spacing, on both compass lines; percent chick cover at 15 cm, percent bare ground, species composition, and percent species coverage were recorded in each grid. In 1986, 6 broods used a relatively small area, referred to as the "Gay field" (18 ha), and were analyzed separately. Random plots were sampled identically to brood locations. Chi-square analysis was used to detect differences between brood locations and random plots.

RESULTS

Adult Survival

One hundred and thirty-four adult northern bobwhite were captured and radio-tagged during the 1984-86 field seasons. One hundred and fourteen bobwhite surviving > 2 weeks post release in 1985-86 ($n = 60$ males and 54 females) were used in mortality analyses (Table 1).

There was no difference in adult summer survival between 1985 (0.664) and 1986 (0.729) ($X^2 = 2.689$, $P > 0.10$). Female survival from 24 June to 25 August 1985 (0.548) was less ($X^2 = 4.069$, $P < 0.05$) than that of females surviving the same time period in 1986 (0.819). Survival of females was lower ($X^2 = 4.296$, $P < 0.05$) than that of males in both years combined. Predation was implicated in all bobwhite deaths; of the 29 total mortalities which occurred over both years, we were able to determine the predatory agent responsible for 27 (93%) of the deaths. Of these, 16 (59%) were caused by avian predators and 11 (41%) were mammalian predation. The proportion of deaths

Table 1. Kaplan-Meier survival estimates (\hat{S}) for male and female northern bobwhite radio-tagged at Tall Timbers Research Station, Tallahassee, FL 1985-86.

	Females			Males			Total		
	<i>n</i>	\hat{S}	SE	<i>n</i>	\hat{S}	SE	<i>n</i>	\hat{S}	SE
15 May -11 Jun	54	0.9773	0.0225	51	1.0000	0.0000	105	0.9881	0.0118
12 Jun - 9 Jul	53	0.7921	0.0633	53	0.9219	0.0387	106	0.8559	0.0372
10 Jul - 6 Aug	42	0.8715	0.0574	50	0.9120	0.0442	92	0.8935	0.0347
7 Aug - 3 Sep	32	0.9310	0.0517	39	0.9688	0.0317	71	0.9508	0.0294
4 Sep - 1 Oct	23	1.0000	0.0000	28	1.0000	0.0000	51	1.0000	0.0000
2 Oct -15 Oct	15	1.0000	0.0000	18	0.9444	0.1323	33	0.9697	0.0700

volumes in brood locations were higher in 1986 compared to 1985 ($X^2 = 108.293$, $P < 0.001$). No differences in insect volumes were noted between 1985 and 1986 random locations ($X^2 = 108.293$, $P = 0.157$). Insect volumes in Gay field brood locations were greater than in the remaining brood ranges in 1986 ($X^2 = 13.219$, $P = 0.013$). However, non-Gay brood ranges in 1986 had less insect volume than 1985 ranges ($X^2 = 33.172$, $P < 0.001$).

An inverse correlation existed between brood home range size and insect densities within brood ranges in 1985 and 1986 (1985, $r^2 = 0.521$, $P = 0.008$; 1986, $r^2 = 0.479$, $P = 0.013$). Although areas selected by brood-rearing adults had relatively higher insect densities, no correlation between

insect densities and 2-week chick loss rates was detected (1985, $r^2 = 0.029$, $P = 0.716$; 1986, $r^2 = 0.056$, $P = 0.511$; Gay broods, $r^2 = 0.415$, $P = 0.229$).

DISCUSSION

Successful reproduction is paramount to hunt-able fall densities of bobwhite. Little can be done to offset inherently high mortality rates of adult bobwhite in the winter/spring; therefore, providing quality brood rearing habitat is essential. Although reproduction is broadly regulated by uncontrollable climatic conditions (Lehmann 1946, Speake and Haugen 1960, Rosene 1969, Klimstra and Roseberry 1975), efforts should be made to provide quality escape cover for adults, patchy nesting sites, and high insect density areas for brood production.

Our summer adult mortality estimates (30%) were somewhat lower than those reported by other researchers. Roseberry and Klimstra (1984) estimated average summer mortality to be nearly 40% over a 16-year period, while Rosene's (1969) estimate was a range of 52-63%. Speake and Sermons (1987) reported summer female mortality in a radio-tagged sample at 64%, with avian predators responsible for 54% of known bobwhite deaths. Cantu and Everett (1982) reported breeding season mortality in radio-tagged females to be 44% in 1980 and 57% in 1981. Our female mortality estimates (45 and 30% in 1985 and 1986, respectively) are similar to the preceding 2 researchers' estimates of radio-tagged female mortality.

Early spring mortality associated with migrating hawks may contribute to seasonal variation in productivity if losses are not compensated for in the breeding season. Losses in early- and mid-summer, such as found in our study in 1985, can have substantial impacts on overall production (Stoddard 1931, Roseberry and Klimstra 1984, Simpson 1972, Speake and Sermons 1987) by removal of reproductively active adults. Stoddard (1931), Simpson (1976), Speake and Sermons (1987), and Curtis et al. (1988) noted that mortality rates of females during summer are higher than those of males and speculated that reproductive stress associated with nesting/brood rearing duties were primarily responsible for increased vulnerability. It was also interesting to note that 47% of the 1985 mortality was associated with 2 nesting pairs of Cooper's hawks (*Accipiter cooperii*) which, combined, accounted for 27 known bobwhite deaths (based on breastbone

Table 3. Physical parameters measured in brood locations and random plots on Tall Timbers Research Station, Tallahassee, FL, in 1985-86.

Physical parameter	Brood locations (n = 353)	Random plots (n = 96)	P^a
% bare ground ^b	204.74	53.41	0.8284
% overhead chick cover ^b	211.80	48.14	0.3617
% overstory cover ^b	151.79	76.90	0.0050
Distance to ecotone (m)	953.10	277.00	0.6196
Intercepts	18,356.00	1,865.00	0.0000

^a P based on X^2 test of hypothesis of no difference between brood and random locations.

^bValues are the sum of proportion per plot.

Table 4. Volume displacement (mL) of insect orders collected in brood and random plots on Tall Timbers Research Station, Tallahassee, FL, in 1985-86.

Insect order	Brood locations	Random plots	P^a
Orthoptera and Homoptera	1,041	157	0.0000
Coleoptera	43	4	0.0271
Hymenoptera and Diptera	23	1	0.0362
Hemiptera	75	10	0.0249
Arachnids	55	9	0.1328
Miscellaneous and larvae	86	16	0.1337
Total	1,326	197	0.0000

^a P based on X^2 test of hypothesis of no difference in volume displacement of insects in brood plots (total sweeps = 14,320) and random locations (total sweeps = 4,000).

counts and not limited to radio-tagged birds) in June, July, and August. Bobwhite represented >70% of the identifiable remains in these 2 nests. Although survival of adults, in particular females, was not different throughout the summer, mortality in 1986 was spread more evenly through the season.

Nest success rates also depend upon a variety of environmental parameters including weather, predator densities, nest concealment, and number and size of nesting areas. Simpson (1972) reported an average nest success rate of 18% in south Georgia, and Dimmick (1974) recorded a 23% rate for Tennessee. Stoddard (1931) examined 602 nests in north Florida and south Georgia and found a 36% success rate. However, these estimates included nests which were not yet at incubation stage. Roseberry and Klimstra (1984) found 33% of all used nests were successful and varied from 25 to 53%. Speake and Sermons (1987) reported a 52% incubated nest success rate during 1984-86 in central Alabama. We found similar postincubation results in our study with success rates of 36% in 1985 to 52% in 1986.

The survival of young chicks and their recruitment into the fall population is important not only for summer habitat management, but for harvest strategies as well (Roseberry and Klimstra 1984). Based on long-term records, Roseberry and Klimstra (1984) estimated chick loss rates to be 25-47% from hatch to fall. Brood mortality studies using radio-tagging yield much higher mortality rates of chicks. Cantu and Everett (1982) studied radio-tagged females in Texas and the fate of 5 broods from hatch to 2 weeks of age. Out of 55 chicks recorded to have hatched, 7 (13%) survived to 2 weeks of age (87% loss). In a radio-tagging study of females and 20 associated broods in Alabama, Speake and Sermons (1987) found that 64% of chicks hatched were lost by 2 weeks of age and 75% were lost within 1 month. Undoubtedly, chick losses are neither consistent from brood to brood nor year to year. Our results support the higher chick mortality rates found by Cantu and Everett (1982) and Speake and Sermons (1987); however, other factors such as double clutching and male/single parent broods may offset these high losses (Curtis et al. 1993).

Annual TTRS adult survival estimates (Curtis et al. 1988), coupled with our data on summer reproductive output, yield a realistic example of a stable population. Low chick mortality estimates previously reported from observational surveys indicate a high rate of population increase, which is undoubtedly not the case across the majority of

the bobwhite's range. In addition, higher summer mortality rates reported in other telemetry studies may be overestimations due to excessive predation caused by transmitter design or mounting technique.

Brood habitat management is rarely defined, because individual components of quality brood range are relatively unknown. Cantu and Everett (1982) felt that woody cover for shade and protection and high percentages of bare ground were of most importance to young broods. Speake and Sermons (1987) found 51% of brood locations were in fire-managed upland pine woodlands, and Hurst (1972) showed that burning increases densities of certain insects. We also noted that most of our principal brood-rearing areas and high insect densities were found in fire maintained upland pine habitat types, especially those where fields were left fallow for several years and were being incorporated back into the woodland management system (i.e., burning and mowing).

The importance of high densities of available insects to chick survival cannot be overstated. Bobwhite with broods appeared to select for brood-rearing areas which had higher concentrations of insects. Brood areas had higher insect densities in 1986; however, one reason for this may have been the superior brood habitat utilized in the Gay field area. Although no differences in chick mortality were noted in high brood use areas, it may be advantageous for females to avoid brood concentration areas due to prey specific searching by predators who "learn" of these areas. Our data characterize quality brood range as open, fire-maintained uplands with greater than average densities of composites, legumes, grasses, *Rosaceae*, shrubs, and lower coverage of vines. Brood habitat includes 50% bare ground and 50% overhead chick cover, <40 m from an ecotone (especially field borders) with approximately 40% overstory canopy coverage and high insect densities.

MANAGEMENT IMPLICATIONS

The ability of northern bobwhite, across their range, to successfully nest, hatch broods, and raise a portion of their young to be incorporated into fall populations is paramount to offsetting inherently high adult losses throughout the year. High mortality rates of chicks less than 2 weeks of age indicate that, prior to reaching flight stage and homeothermic independence, they are preyed upon heavily, primarily by ground predators (Stoddard 1931) or may succumb to environmental factors possibly including starvation. The im-

portance of insects in the diet of these young chicks has been reported. Insect availability, low-growing vegetation with a high percentage of open ground for ease of movement, and overhead cover for chicks may be the most important components. Tiny insects must also be concentrated at approximately 0-10 cm above the ground and chick movement must be relatively unrestricted. Quality brood habitat must also be well distributed to avoid concentrations of broods into small patches, yet also be in close proximity to optimum nesting areas. Large movements or high concentrations of broods may serve to increase their chances of mortality. Finally, adults must survive long enough in the breeding season to successfully nest and raise young to make a contribution.

Bobwhite densities were reported to be unusually high during the tenant farming era in the South (Stoddard 1931), probably due to the many scattered, weedy fields; an abundance of open cover; strong use of prescribed fire; and predator control. He also noted that these tenant "management" systems created "enormously increased food supply, and with lessened natural enemies, the bird in this early stage of agriculture experienced favorable conditions that perhaps never before or since have been equalled." Faced with current declines in bobwhite populations across the Southeast (Johnson 1985), a reevaluation of our management techniques may be in order and a look back to the "good old days" may reveal some forgotten ideas.

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MANIPULATING PESTICIDE USE TO INCREASE THE PRODUCTION OF WILD GAME BIRDS IN BRITAIN

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Abstract: We describe a management technique whereby the adverse effects of pesticides on game-bird chick production were alleviated following selective use or selective avoidance of pesticides on the edges of cereal crops. This technique (known as Conservation Headlands) provided increased amounts of food resources necessary for young gray partridge (*Perdix perdix*) and ring-necked pheasant (*Phasianus colchicus*) chicks. The use of Conservation Headlands has consistently increased average numbers of chicks per brood of both species via increases in the densities of arthropods and weed plants. These findings are discussed in the context of the other prerequisites of wild game-bird production in the UK and how these may be altered by recent Government policies to reduce cereal surpluses.

Key words: Britain, chick foods, Conservation Headlands, gray partridge, indirect effects, pesticides, ring-necked pheasant.

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In 1968, studies were initiated to identify factors contributing to an observed 80% decline over 40 years of the gray partridge in the UK (Potts 1980, 1986). This led to research begun in 1984 on devising management strategies to deal with the causes of poor levels of wild game-bird production on intensively farmed arable land.

Earlier studies (Blank et al. 1967, Potts 1980) identified the key factor causing changes in a gray partridge population in the southern UK as chick mortality, and linked national declines with poor chick survival. Also, chick survival was shown to be linked to availability of sufficient quantities of preferred insects, essential in the diet of young chicks of both gray partridge (Southwood and Cross 1969, Potts 1986) and pheasant (Hill 1985). It has been suggested that increasingly intensive production over the last 40 years has resulted in low densities of preferred insects in cereal fields (Potts 1986, Rands et al. 1988). Use of pesticides (insecticides, herbicides, and fungicides) appeared to be a major contributory factor in reducing populations of preferred insects.

Green (1984) listed preferred food items of young partridge chicks in the UK. These include Coleoptera (Chrysomelidae, small diurnal Carabidae, and Curculionidae), larval forms of Lepidoptera and Tenthredinidae (especially species of the genus *Dolerus*), and many members of the Heteroptera (especially species of the genus *Lygocoris*). Many preferred insects were relatively abundant at the edges of cereal fields where gray partridge broods foraged (Green 1984).

The use of both insecticides and insecticidal fungicides can detrimentally affect these nontarget species (Vickerman 1977, Vickerman and Sunderland 1977, Vickerman and Sotherton 1983, Sotherton et al. 1987, Sotherton and Moreby 1988), as can herbicides. The use of herbicides has probably been the most important factor because they limit cereal field weeds, the host plants of many phytophagous chick-food insects (Southwood and Cross 1969, Vickerman 1974, Sotherton 1982). Approximately 60% of preferred chick-food insects are phytophagous species feeding on weeds of the genera *Polygonum*, *Fallopia*, *Chenopodium*, *Sinapis*, and *Matricaria*. Thus pesticides disrupt the food chains of game-bird chicks both directly (insecticides) and indirectly (herbicides).

The dilemma has been to devise practical management options whereby cereal farmers could continue to maintain high levels of crop production while ameliorating some of the observed effects of pesticides on farmland wildlife. One possible solution was selectively sprayed cereal crop margins or Conservation Headlands. In this management system, the outermost section of the spray boom (in most cases, the outermost 6 m depending on spray-boom width) was either switched off when spraying around crop edges or "headlands" to avoid particular chemicals at certain crucial times of the year, or the headlands were sprayed separately with more selective compounds, approved following field screening for selectivity. The interior of the field

was sprayed with the usual complement of pesticides, and only the outermost crop edge (usually calculated at 6% of total field area) received lower pesticide inputs.

Results of selective use of pesticides have been published in part elsewhere (Rands 1985, 1986, Sotherton et al. 1985). In this paper we update some results and summarize implications, progress, and the future of this work, including prospects for increasing food resources for wild game birds despite current and pending attempts to reduce surplus grain production through land-use changes.

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SITES AND METHODS

From 1983 to 1986 field-scale experiments were carried out on an 11 km² mixed arable and live-stock farm in Hampshire, southern UK. Several large blocks (100 ha) of cereal fields on the principal study farm were sprayed either entirely or except for the outermost 6 m in a randomized block design. Use of pesticide on this outermost strip varied slightly between years as the term "selective spraying" was refined, but in all cases the aim was to avoid use of insecticidal chemicals and broadleaf herbicides. In this way blocks of up to 12 fields had their headland pesticide regime manipulated to not seriously reduce yield, cause problems with harvesting or grain quality, or increase management effort on the farm but which benefited wild game production so that

these techniques could be widely adopted by farmers. A summary of the current set of guidelines updated from Boatman and Sotherton (1988) are given in Table 1.

Similarly, from 1984 to 1986 paired blocks of cereal fields were set up on farms in eastern UK counties. In addition, from 1986 to 1990 pooled game-bird data from within- and between-farm comparisons were available from eastern counties. More rigorous pairings of replicated blocks of cereal fields with different headland pesticide regimes on study areas were no longer available on farms where estate owners abandoned the experimental approach in favor of a more widespread, farm-scale use of Conservation Headlands. Data derived from these farms were therefore based on less rigorous experimental designs.

In all experiments, measures of game-bird breeding success (rates of chick survival and/or mean brood size in autumn) were compared among broods with and without access to Conservation Headlands in brood rearing areas.

Chick-food Insects and Broadleaf Weeds

Details of experimental designs and methods used in 1983 and 1986 to quantify effects of adjusting pesticide inputs on cereal field headlands on the densities of preferred chick-food items have been published elsewhere (Sotherton et al. 1985, Rands 1985). Methods of measuring changes in weed flora are described elsewhere (Boatman 1988). However, on all occasions weed densities were measured. Where possible additional

Table 1. A summary of guidelines for selective use of pesticides on Conservation Headlands in UK cereal fields, 1992.

	Autumn spraying	Spring spraying
Insecticides	Yes (avoiding drift)	No (only up until 15 March)
Fungicides	Yes	Yes (except compounds containing pyrazophos)
Growth regulators	Yes	Yes
Herbicides		
a) Grass weeds	Yes ^a (but only those compounds approved for use; i.e., avoid broad-spectrum residual products) ^b	
b) Broadleaf weeds	No ^a (except those compounds approved for use against specific problem weeds; eg., <i>Galium aparine</i>)	

^aThese guidelines refer to both spring and autumn spraying.

^bTri-allate, dichlofop-methyl, difenzoquat, flumprop-m-isopropyl, fenoxaprop-ethyl, tralkoxydim.

measures such as species diversity, weed biomass, and percentage weed cover were also recorded. For more recent experiments to measure insect abundance the following methodologies were used.

Experimental Design

Spring Wheat 1988.—One headland of a field of spring-sown wheat was divided into 8 plots (100 x 9 m). In April, herbicides were excluded from alternate plots. All plots were sprayed with fungicides and plant growth regulators (straw stiffeners and shorteners) and received equal amounts of fertilizer. As the adjacent field boundary type and its aspect were the same for all plots, only the herbicide application was withheld from the Conservation Headland plots in accordance with guidelines for herbicide use on spring-sown crops. Selective graminicides were not needed on this crop.

Before herbicide application, and on 5 dates afterward, insects were sampled using a vacuum insect sampler. On each sampling date and on each plot per treatment, 5 samples of 0.5 m² were taken.

Winter Wheat 1988.—On 1 block of land on the principal study farm, headlands were fully sprayed, whereas all other cereal fields on the farm had their headlands managed according to guidelines for Conservation Headlands. Headlands within the fully sprayed block were chosen and paired up with headlands in fields with Conservation Headlands, so that their aspect and adjacent field boundaries were the same. Nine pairs of winter wheat headlands were chosen and sampled once in early June with a vacuum sampler again taking 5 samples of 0.5 m² per headland.

Game Birds

Breeding success of gray partridges and pheasants was measured by counting numbers of juvenile and adult birds on cereal stubble after harvest and calculating mean brood size (excluding zeros). Gray partridge censuses began in 1983 and pheasant counts in 1984. Radio-tagging was also used to track individual broods in 1984 (partridge) and 1988 (pheasant). Backpack radios were fitted to sitting females on the nest immediately prior to hatching. Location of broods was estimated by triangulation 3 times per day and once at night to record roosting position. Data gathered using radio-tagging for gray partridges included chick survival per brood to 21 days old, home range size (minimum polygon area), the

proportion of home range including the headland area, and distance between successive roost sites. One estimate of mean survival of pheasant chicks to 10 days old was also obtained. In addition, chick fecal samples were collected from roost sites of both species, and insect fragments were counted and identified (Moreby 1988). Multiple stepwise regression was used to identify which insect taxa were responsible for observed variations in chick survival rates. Percentage data were converted by the arc sin transformation. Further details of the experimental design may be found elsewhere (Rands 1985), as well as methodologies used to assess weed density and details regarding radio-tagging (Rands 1985, 1986, Sotherton et al. 1985, Hill and Robertson 1988). Long-term effects of pesticide use on gray partridge demography were measured by recording annual spring breeding densities (expressed as pairs per km²) on the main study farm in Hampshire.

RESULTS and DISCUSSION

Broadleaf Weeds

Effects of the selective exclusion of herbicides on broadleaf weeds led to as much as a 10-fold increase in total broadleaf weed density where herbicide inputs were reduced, compared to those areas that were fully sprayed. Species diversity, weed biomass, and percentage weed cover all increased significantly in the absence of broadleaf weed herbicides. Data for 1983-88 appear in detail elsewhere (for 1983 and 1984, Sotherton et al. 1985; for 1985 and 1986, Boatman 1988; and for 1988, Sotherton 1991, Chiverton and Sotherton 1991).

Insects

Some insect data showing differences between cereal field headland pesticide spraying regimes have been published elsewhere (Sotherton et al. 1985, Rands 1986). In these trials, conducted in 1983 and 1984, 2- and 3-fold increases in chick-food insect densities on Conservation Headlands were obtained compared to headlands that were fully sprayed. Greater differences between treatments were found for sedentary, weed-feeding species.

In 1988 in spring-sown wheat, the absence of broadleaf weed herbicides resulted in increases in chick-food insect groups. Mean pretreatment densities were very similar and did not differ significantly among plots; in most instances numbers were very low. After treatment, significantly higher densities of Heteroptera ($P < 0.02$; mostly

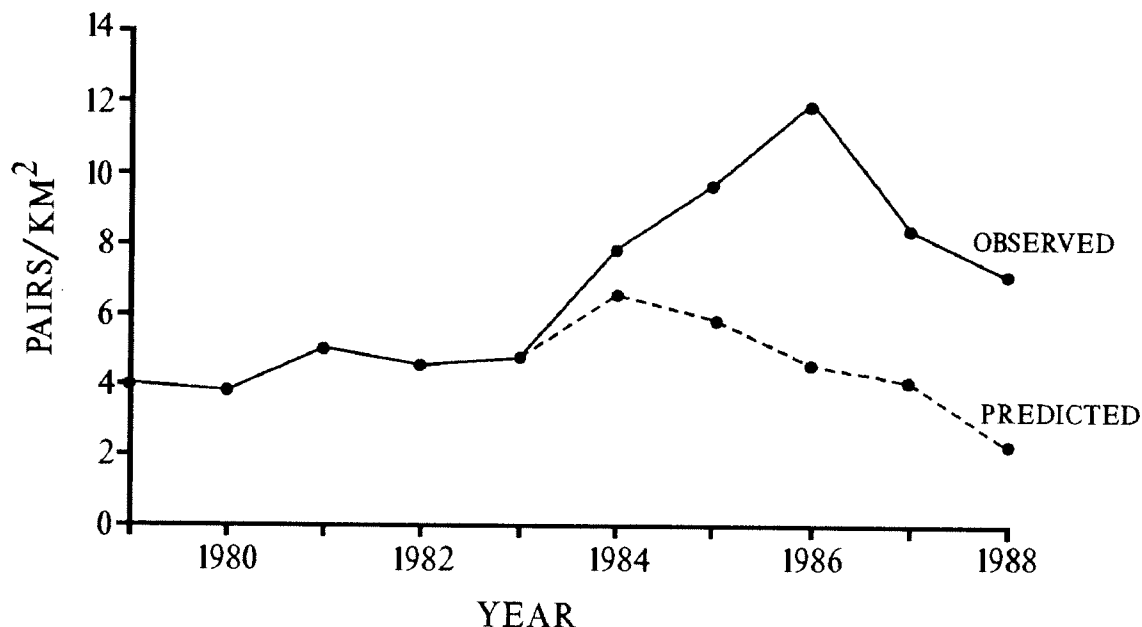


Fig. 3. Changes in gray partridge spring breeding density before (1979-83) and after (1984-88) introduction of selective pesticide application to cereal field headlands on the principal study farm in 1983, together with a predicted estimate of breeding densities without headland pesticide manipulation (1984-88).

Spring Pair Counts.—Longer term consequences of Conservation Headlands on the principal study farm were to increase the breeding stock of gray partridges (Fig. 3). Experiments began on the farm in 1983 when spring breeding density had reached 4 and 5 pairs per km². Game records on this estate have been kept since the last century and the immediate post-war density of gray partridges was recorded at about 18 pairs per km². In the intervening years densities had fallen on the farm to the low levels observed before our experiments began. This decline followed the national rate of decrease in abundance reported earlier and elsewhere (Potts 1986). Spring density rose from about 4 pairs in 1983 to 8 in 1984 and continued until 1986 to peak at 11.7 pairs per km². Data collected over the same period showed that such increases were not observed on other estates in the vicinity (Sotherton et al. 1989).

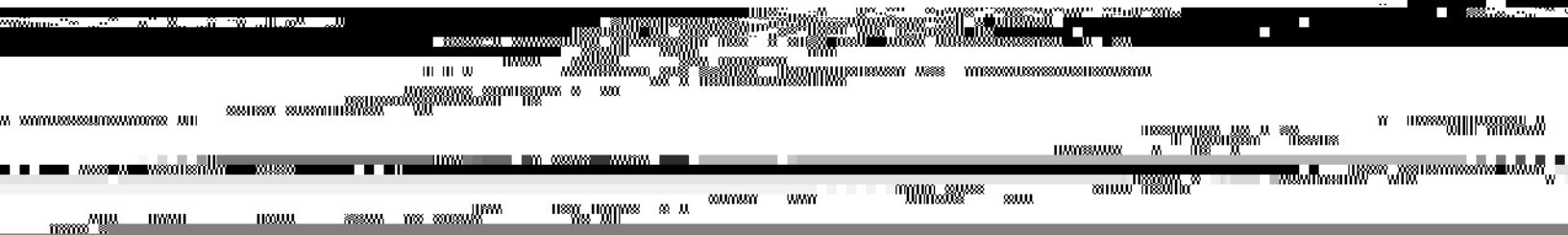
However, after 1986, densities of spring pairs fell back to about 7 pairs per km². It is possible that increasing partridge densities contributed to increased rates of predation which are known to operate in a density-dependent manner (Potts 1986), and this slight decline in abundance coincided with seasons in which cold wet spring/summer weather led to generally low levels of chick survival.

Computer simulations of spring breeding density in the absence of Conservation Headlands,

based on rates of chick survival in these poor years and initial increases in predator pressure were calculated. These revealed that the fall in spring density could have been far greater without the cushioning effects of these management techniques to alleviate pesticide pressures on the food chain (G. R. Potts, unpubl. data; Fig. 3).

CONCLUSIONS

The production of a huntable surplus of wild game birds in the agricultural landscapes of the UK depends on successful management of 3 essential aspects of their biology. This paper has summarized research efforts which have addressed 1 of these essential features: the production of adequate chick-food insects to increase chick survival. The Conservation Headlands technique has been a successful solution to the problem of pesticides and their negative impacts on nontarget organisms in game-bird chick-food chains. However, Conservation Headlands alone cannot be considered all that is necessary to increase population densities. The other 2 essential features must also be considered. These are the provision of adequate amounts of quality nesting cover and, by legal control of predators, protection of eggs and incubating females during the nesting season. Only by provision of all of these elements will sustainable wild game-bird production be achieved.



weight of an individual invertebrate was determined for each order, within each cover planting, and for each time interval by cumulatively weighing all of the invertebrates within that group and dividing by the number of individuals being weighed. Biomass of each invertebrate order was calculated for each sample by multiplying the number of individuals of that order in the sample by the mean order-specific weight per individual during that time interval, in that cover planting. We used the mean number of invertebrate orders per sample as an index to invertebrate diversity.

Invertebrate abundance and biomass data from 1990 and 1991 were analyzed separately because we did not sample all of the same fields in both years. Furthermore, we observed differences in overall invertebrate abundance between years that may have been due to differences in precipitation patterns. Counts of invertebrates per sample were square-root transformed to improve normality and reduce heteroscedasticity (Sokal and Rohlf 1981:423). Transects within a field were treated as subsamples; fields were treated as replicates. We used 2-way ANOVA to test for main effects of sampling week and cover planting on total invertebrate biomass and abundance, and biomass and abundance in 5 selected orders reported to be important bobwhite chick foods (Handley 1931, Hurst 1972, Jackson et al. 1987). We used Tukey's HSD multiple comparison to test for differences among treatments (week or cover planting) following a significant ($P < 0.05$) ANOVA F -test (Day and

Quinn 1989). This test controls experiment-wise error rate at $\alpha = 0.05$.

RESULTS

Sampling periods by cover type interactions were generally not significant for invertebrate abundance (1990: $F = 1.77$, $df = 18$, $P = 0.11$; 1991: $F = 1.46$, $df = 18$, $P = 0.21$), biomass (1990: $F = 4.31$, $df = 18$, $P = 0.0009$; 1991: $F = 1.12$, $df = 18$, $P = 0.39$), or diversity (1990: $F = 1.72$, $df = 18$, $P = 0.12$; 1991: $F = 0.79$, $df = 18$, $P = 0.69$); therefore, we report only main effects.

We observed differences among sampling periods for 1990 and 1991 in total invertebrate abundance (1990: $F = 8.62$, $df = 3$, $P = 0.0006$; 1991: $F = 4.42$, $df = 3$, $P = 0.01$), diversity (1990: $F = 8.83$, $df = 3$, $P = 0.0006$; 1991: $F = 3.06$, $df = 3$, $P = 0.05$), and biomass (1990: $F = 17.17$, $df = 3$, $P = 0.0001$; 1991: $F = 3.07$, $df = 3$, $P = 0.05$). Invertebrate abundance, biomass, and diversity varied widely across sampling periods during 1990 and 1991. In both years, invertebrate abundance, biomass, and diversity were lowest during early August (Table 1).

In both years, total invertebrate abundance differed among cover plantings (1990: $F = 12.44$, $df = 6$, $P = 0.0001$; 1991: $F = 7.19$, $df = 6$, $P = 0.0003$) and was greatest in red clover (Table 2). Soybeans had the lowest numbers of invertebrates, although not significantly so in 1991. Homopterans were the most common invertebrate during both years.

During 1990 and 1991, total invertebrate biomass differed among cover plantings (1990: F

Table 1. Mean^a relative invertebrate abundance, biomass (mg), and diversity in Conservation Reserve Program fields in northern Missouri during 1 July-22 August 1990-91.

	Sampling period ^b			
	1	2	3	4
1990				
Abundance ^c	130.8 A ^d	107.7 B	36.7 D	77.9 C
Biomass ^e	72.3 B	133.1 A	41.5 C	53.9 C
Diversity ^f	7.5 A	7.6 A	6.5 B	6.6 B
1991				
Abundance ^c	63.9 A	46.2 B	32.6 B	65.8 A
Biomass ^e	48.4 AB	51.2 A	25.2 C	39.5 B
Diversity ^f	6.9 AB	6.5 BC	6.2 C	7.1 A

^aMeans computed across 7 cover plantings, 4 fields/cover planting, and 3 D-Vac subsamples/field; $n = 84$.

^bPeriod 1: 1-7 July; period 2: 15-22 July; period 3: 1-7 August; period 4: 15-22 August.

^cMean number of invertebrates/sample.

^dMeans within rows with the same letter are not different, Tukey's HSD, $P > 0.05$.

^eMean invertebrate biomass (mg)/sample.

^fMean number of invertebrate orders/sample.

Table 2. Mean^a number of invertebrates/sample in 6 Conservation Reserve Program cover plantings and soybean fields in northern Missouri, 1 July-15 August 1990-91.

Year	Order	Cover plantings						
		Red clover	Warm-season grass	Orchard-grass/lespedeza	Tall fescue	Timothy	Orchard-grass	Soybeans
1990	Homoptera	109.0 A ^b	35.7 B	13.5 DE	39.9 B	24.7 C	16.7 CD	8.3 E
	Hemiptera	10.7 A	4.4 B	3.7 BC	0.7 D	3.9 BC	2.7 C	4.2 BC
	Orthoptera	1.2 C	1.0 C	2.4 B	3.4 B	5.6 A	3.1 B	0.9 C
	Coleoptera	18.4 A	10.9 B	4.0 C	3.1 C	5.0 BC	2.6 CD	0.6 D
	Diptera	61.0 A	27.4 B	12.0 D	12.6 DE	32.1 BC	15.6 CD	4.4 E
	Total ^c	226.8 A	93.7 B	53.9 CD	68.2 BCD	81.3 BC	49.1 D	20.8 E
1991	Homoptera	43.7 A	30.6 A	12.4 B	7.6 BC	6.2 C	8.3 BC	8.4 BC
	Hemiptera	11.2 A	4.7 B	2.0 CD	0.6 D	3.5 BC	2.0 CD	2.4 BC
	Orthoptera	2.5 A	1.4 A	1.4 A	1.8 A	1.8 A	1.7 A	0.1 B
	Coleoptera	24.6 A	3.0 DE	11.2 B	5.7 CD	7.2 BC	10.6 BC	0.9 E
	Diptera	12.5 A	8.4 AB	14.2 A	4.7 BC	2.7 C	4.2 C	10.0 A
	Total ^c	105.9 A	73.2 B	58.7 B	37.3 C	32.4 C	35.3 C	25.1 C

^a Means computed across 4 sample periods, 4 fields/cover planting, and 3 D-Vac subsamples/field; *n* = 48.

^b Means within rows with the same letter are not different, Tukey's HSD, *P* < 0.05.

^c Total number of invertebrates/sample, summed across all orders.

Table 3. Mean^a invertebrate biomass (mg)/sample in 6 Conservation Reserve Program cover plantings and soybean fields in northern Missouri, 1 July-15 August 1990-91.

Year	Order	Cover plantings						
		Red clover	Warm-season grass	Orchard-grass/lespedeza	Tall fescue	Timothy	Orchard-grass	Soybeans
1990	Homoptera	96.1 A ^b	24.5 C	10.3 DE	50.5 B	23.3 CD	15.6 CDE	3.8 E
	Hemiptera	22.5 A	7.8 B	6.0 BC	0.7 D	6.7 BC	2.0 CD	4.1 BCD
	Orthoptera	16.1 BC	6.3 C	16.3 BC	25.7 AB	34.2 A	32.0 A	7.8 C
	Coleoptera	8.9 A	9.3 A	2.3 B	0.8 B	2.2 B	1.0 B	1.8 B
	Diptera	7.5 AB	5.5 BC	2.1 D	1.7 D	8.9 A	2.3 CD	1.3 D
	Total ^c	178.2 A	61.3 BC	44.1 CD	84.7 B	86.4 B	56.1 C	22.3 D
1991	Homoptera	28.4 A	19.7 B	9.8 C	9.0 C	6.1 C	8.2 C	3.1 C
	Hemiptera	17.6 A	7.4 B	2.3 CD	0.5 D	7.0 BC	1.4 D	1.8 D
	Orthoptera	23.2 A	7.9 BC	10.4 B	11.3 B	10.1 B	10.6 B	0.4 C
	Coleoptera	11.6 A	2.1 BC	5.2 B	1.5 C	2.7 BC	3.4 BC	1.3 C
	Diptera	1.6 BCD	1.7 BC	2.6 AB	0.6 D	0.8 CD	0.7 CD	2.8 A
	Total ^c	90.4 A	50.3 B	39.2 BC	34.7 BC	35.4 BC	27.0 CD	12.3 D

^a Means computed across 4 sample periods, 4 fields/cover planting, and 3 D-Vac subsamples/field; *n* = 48.

^b Means within rows with the same letter are not different, Tukey's HSD, *P* < 0.05.

^c Total invertebrate biomass (mg)/sample, summed across all orders.

Table 4. Mean^a number of invertebrate orders/sample in 6 Conservation Reserve Program cover plantings and soybean fields in northern Missouri, 1 July-15 August 1990-91.

Year	Cover plantings						
	Red clover	Warm-season grass	Orchard-grass/lespedeza	Tall fescue	Timothy	Orchard-grass	Soybeans
1990	7.9 A ^b	7.6 AB	7.1 B	7.3 AB	7.2 AB	6.8 B	4.9 C
1991	7.1 ABC	6.9 ABC	7.5 A	6.7 BC	7.4 AB	6.4 C	4.8 D

^aMeans computed across 4 sample periods, 4 fields/cover planting, and 3 D-Vac subsamples/field; $n = 48$.

^bMeans within rows with the same letter are not different, Tukey's HSD, $P < 0.05$.

= 11.52, $df = 6$, $P = 0.0001$; 1991: $F = 7.51$, $df = 6$, $P = 0.0002$) and was greatest in red clover plantings and lowest in soybean fields (Table 3).

Invertebrate diversity differed among cover plantings in both years (1990: $F = 13.64$, $df = 6$, $P = 0.0001$; 1991: $F = 8.05$, $df = 6$, $P = 0.0001$). Soybean fields had the lowest invertebrate diversity (Table 4).

DISCUSSION

Herbaceous vegetation available in CRP fields may provide quality habitat for upland game species in intensively farmed areas. Most studies focusing on the habitat value of the CRP (Farmer et al. 1988, Hays et al. 1989) and earlier federal cropland diversion programs (Joselyn and Warnock 1964, Edwards 1984, Berner 1988) have discussed the value of these programs in terms of nesting and winter habitat for wildlife. Burger et al. (1990) suggested that vegetative structure in Missouri CRP fields could be conducive to bobwhite brood foraging. Structure only partially determines brood habitat quality; invertebrate abundance is a primary determinant of brood habitat quality (Hurst 1972, Jackson et al. 1987). We observed that abundance, biomass, and diversity of selected invertebrates tended to be greater in CRP plantings than in conventionally-tilled soybeans. This suggests that CRP fields could provide brood habitat superior to that available in rowcrops if structural characteristics are also consistent with brood foraging needs.

Burger et al. (1990) further suggested that the potential value of CRP fields as brood habitat could differ among cover plantings and management practices. We observed differences in invertebrate abundance and biomass among different CRP cover plantings with the highest insect abundance and biomass in red clover. The importance

of legumes in producing invertebrates has been suggested by others (Stoddard 1963, Jackson et al. 1987). Webb (1963) observed higher invertebrate density in clover than in native grasses. Dunaway (1976) reported greater abundance and biomass of invertebrates in kobe lespedeza (*Lespedeza striata*) strips than in native grass/forb communities in pine (*Pinus* spp.) forests. In 1 of 2 years, Jackson et al. (1987) observed higher abundance and biomass of coleopterans in fertilized kobe lespedeza fields than in old fields or fertilized old fields. Others have recommended the inclusion of legumes in plantings as a means of improving brood habitat quality for selected galliforms (Whitmore et al. 1986). Our findings suggest that the addition of a legume component to grass plantings on CRP acres may increase invertebrate abundance and biomass, thereby improving brood habitat quality for bobwhite.

Nelson et al. (1990) reported that dense monotypic stands of switchgrass and mixed warm-season grass plantings had lower invertebrate abundance and biomass than cool-season grass plantings. Furthermore they suggested that the structure of warm-season grass plantings was less conducive to brood foraging needs. They concluded that "... native warm-season grasses, commonly recommended as nesting cover for pheasants and waterfowl, do not provide quality brood-rearing habitat for game bird chicks" (Nelson et al. 1990:110). In contrast, we observed relatively high invertebrate abundance and biomass in 2-5 year old CRP fields planted to warm-season grass, typically being exceeded only by red clover plantings. The differences in their findings and ours may be related to age of plantings, diversity of annual weeds, and management practices. We believe that diverse (weedy) warm-

season grass plantings can provide habitat structure and invertebrate populations consistent with bobwhite brood foraging needs.

Many studies have suggested that galliform chicks selectively feed on certain groups of invertebrates. Beetles (Coleoptera), leafhoppers (Homoptera), true bugs (Hemiptera), flies (Diptera), and small grasshoppers and crickets (Orthoptera) have all been reported to be "preferred" foods in the diets of galliform chicks (Handley 1931, Hurst 1972, Healy et al. 1985, Whitmore et al. 1986, Erpelding et al. 1987, Jackson et al. 1987). These orders commonly occurred in invertebrate samples from the grass and grass/legume habitats that we sampled. Relative abundance of invertebrates in these 5 orders was typically lower in soybean fields than in any of the CRP plantings that we studied.

We also observed greater diversity of invertebrate orders in CRP fields than in soybean fields. Such invertebrate diversity could provide a buffer against short-term environmental change and provide a more reliable food base for galliform chicks than that occurring in rowcrop monocultures.

In intensively cultivated portions of the Midwest, both the quality and quantity of brood habitat may limit brood survival and upland bird populations (Warner et al. 1984, Enck 1987, Nelson et al. 1990). In northern Missouri, CRP fields do provide structural characteristics (Burger et al. 1990) and invertebrate densities consistent with brood foraging needs and can provide brood habitat superior to that available in croplands.

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advantages of the TME system (Sibbald 1977). Furthermore, feeding via gavage assures an exact measure of food ingested and reduces errors associated with *ad libitum* feeding.

Nitrogen corrected TME_n values are calculated by adjusting EE to reflect a zero nitrogen balance. This is of particular importance in the TME assay where food intake is limited, thus increasing the rate of tissue protein catabolism (Parsons et al., 1982). A correction factor of 8.73 kcal/g nitrogen excreted was suggested by Titus et al. (1959) as best representing energy content of the nitrogenous excretory products of the chicken. Sibbald and Morse (1983) reported that TME_n values were 6-7% less than corresponding TME values. Nitrogen correction reduced EE of the unfed controls by 56%. Also, the variation in TME_n values was less than when nitrogen balances of fed and fasted bobwhite were not equilibrated.

Objectives of the research described herein were to: (1) determine if TME and TME_n bioassay techniques (gavaging, short assay periods, etc.) could be used in the bobwhite to establish ME values of selected foods and (2) compare TME and TME_n values determined with nutrient composition and TI activity present in these foods.

We are grateful to Dr. Paul R. Beuselinck, U.S. Department of Agriculture-Agricultural Research Service, University of Missouri, for providing the Marion lespedeza and to Mr. John Lewis, Missouri Department of Conservation for the WT soybeans used in these studies.

METHODS

Foods assayed included corn, Fayette soybeans, WT soybeans (a reseeding strain developed by the Missouri Department of Conservation), Korean lespedeza, Marion lespedeza, and tick-trefoil. Seeds were fed unground and the lespedezas and tick-trefoil were dehulled.

Adult male northern bobwhite, weighing 175-210 g, were housed in individual wire mesh cages, 20-cm wide x 25-cm long x 15-cm high. The room was maintained at 24 ± 2 C temperature, 55% relative humidity, and a 14L:10D photoperiod. Bobwhite were fed *ad libitum* a diet containing 16% crude protein (CP) and 2,737 kcal ME/kg during maintenance periods. A higher protein and energy repletion diet (26% CP and 2,900 kcal ME/kg) was fed after each assay period to expedite the recovery of weight lost during the assay. Water was continuously available.

Bioassays were conducted according to the method described for chickens by Sibbald (1976)

with the following modifications. Fed and fasted bobwhite were not paired by weight since Arvat et al. (1980) found no correlation between body weight and EE. Instead, an average EE value was calculated for the fasted bobwhite and used to compute TME values. A 24-hour fasting period was used rather than 21 hours, and the excreta collection period was extended to 72 hours.

Prior to each assay, bobwhite were weighed and randomly assigned to the fasted control or fed groups. After a 24-hour fasting period, precision-feeding was accomplished by passing a funnel, having a stem measuring 7.5 cm in length and 8 mm in diameter, via the esophagus into the crop. The funnel was lubricated with water prior to insertion into the esophagus.

A blunt glass rod was used to push the seeds from the funnel into the crop. The few seeds larger than the funnel opening were manually placed in the esophagus and then pushed into the crop with the glass rod. Care was taken to ensure that adequate ventilation was maintained. Due to the small size of the desmodium and lespedeza seeds, they were administered in gelatin capsules (No. 000) to ensure accurate delivery of the preweighed quantity to the crop and to prevent regurgitation. The fasted control bobwhite were given an equal number of empty capsules to allow for correction of the energy contained in the capsules. All birds were fed 3-5 g of test foods.

Excreta samples were stored at -7 C until analyzed. Gross energy of the foods and excreta samples was measured in an adiabatic bomb calorimeter according to procedures outlined in Oxygen Bomb Calorimetry and Combustion Methods (Parr Inst. Co. 1960). Nitrogen content was determined by the Kjeldahl procedure (AOAC 1984).

Proximate analyses were carried out on all foods. AOAC (1984) procedures were used except for crude fiber and ash which were determined simultaneously by the method of Whitehouse et al. (1945).

Trypsin inhibitor activity was assayed by the method of Sandholm et al. (1976). Relative TI contents were compared based on the most dilute solution which contained sufficient inhibitor activity to suppress the enzymatic digestion of the casein contained in calcium-caseinate agar plates.

Procedures described in SAS (1982) were used for statistical analysis. The TME and TME_n values of foods were compared by analysis of variance, and significant differences among treatment means were determined using Fisher's

Least Significant Differences (Snedecor and Cochran 1980).

RESULTS

The TME and TME_n bioassays were successfully carried out with bobwhite (Spurlock 1987). Weight loss (data not shown) during an assay varied from 5 to 15% of initial body weight and was generally recovered by the end of a 14-day repletion period. No detrimental effects were observed when the same bobwhite were used in repeated assays.

As shown in Table 1, whole corn had the highest nitrogen free extract (NFE) content (74.9%, air dry basis) but less protein, fat, and fiber than other foods. Of particular interest was the higher fiber and lower fat content of WT soybeans compared to the Fayette variety. Tick-trefoil contained substantially more fiber than did other foods. The lespedezas were similar to the soybean varieties in protein but lower in fat and higher in fiber.

With the exception of corn, TI activity was detected in all foods. The soybean varieties required a dilution of 1:16 before trypsin digestion of the casein was apparent. Other foods showed TI at dilutions of only 1:4. The soybean varieties

therefore have at least a 4-fold higher activity of TI than do the other foods.

Our initial endeavor was to demonstrate that TME and TME_n assays yield accurate, reproducible ME values when using northern bobwhite. The TME and TME_n values for Fayette soybeans and whole corn were determined in 2 different assay periods. As shown in Table 2, no significant differences ($P > 0.05$) were found between TME and TME_n values determined in the first and second assays in which different bobwhite were fed the same test foods. Differences between ME values for assay 1 and 2 ranged from 3 to 5%, indicating that the TME and TME_n bioassays result in accurate, reproducible data.

Because it was desirable to compare TME and TME_n values of the different feedstuffs, we felt it was also necessary to verify that gelatin capsules used to administer the small tick-trefoil and lespedeza seeds would not alter ME values obtained. There were no differences ($P = 0.998$) in TME values (kcal/g dry matter) for corn fed as free grain ($\bar{x} = 4.72 \pm 0.12$, $n = 7$) or encapsulated grain ($\bar{x} = 4.72 \pm 0.08$, $n = 6$). The TME_n values also did not differ ($P = 0.087$) for free grain ($\bar{x} = 4.34 \pm 0.05$, $n = 7$) and encapsulated grain ($\bar{x} = 4.47 \pm 0.05$, $n = 6$). Encapsulation therefore seems to be a prac-

Table 1. Composition of foods (% air dry basis).

	Fayette soybeans	WT soybeans	Corn	Korean lespedeza	Marion lespedeza	Tick-trefoil
Moisture	9.4	11.7	9.8	8.7	8.0	7.9
Crude protein	43.2	48.1	8.4	41.3	45.5	32.8
Crude fat	21.3	14.3	4.2	6.7	6.3	14.2
Crude fiber	5.6	8.2	1.4	13.1	14.0	24.5
Ash	5.7	6.1	1.3	4.2	4.5	4.3
NFE ^a	14.8	11.6	74.9	26.0	21.7	16.3
Gross energy (Kcal/g) ^b	5.38	5.03	4.83	5.14	5.13	5.54

^aNitrogen-free extract.

^bDry matter basis.

Table 2. Repeatability of metabolizable energy estimates for bobwhite foods.

Food	Assay ^a	n	Metabolizable energy values ^{b,c}	
			TME	TME _n
Fayette soybeans	1	11	4.26 ± 0.07	3.89 ± 0.09
	2	7	4.44 ± 0.05	3.99 ± 0.04
			$P = 0.098$	0.357
Whole corn	1	12	4.48 ± 0.12	4.35 ± 0.07
	2	14	4.71 ± 0.06	4.39 ± 0.04
			$P = 0.087$	0.629

^aAssay 1 and 2 means were not different for either food ($P > 0.05$).

^bKcal/g dry matter.

^cMeans ± SE.

Table 3. True metabolizable energy (TME) and nitrogen-corrected true metabolizable energy (TME_n).

Food	n	TME ^a	TME _n
		Kcal/g dry matter	
Whole corn	26	4.60 ± 0.07A	4.37 ± 0.04A
Fayette soybeans	18	4.33 ± 0.05B	3.93 ± 0.06B
Marion lespedeza	8	4.07 ± 0.18BC	3.71 ± 0.09BC
Korean lespedeza	9	3.89 ± 0.14CD	3.73 ± 0.17BC
Tick-trefoil	10	3.71 ± 0.19CD	3.51 ± 0.20C
WT soybeans	15	3.51 ± 0.07E	3.24 ± 0.04D

^aValues (means ± SE) in the same column with different letters differ significantly ($P < 0.05$).

tical means of precision-feeding those test materials which tend to be regurgitated or are difficult to handle during the precision-feeding process.

Whole corn contained the most TME_n (Table 3), followed by Fayette soybeans, the lespedezas, tick-trefoil, and WT soybeans. The high digestible carbohydrate content (NFE-Table 1) of corn and lack of any appreciable TI activity result in most of the GE being available to the bobwhite. Metabolic efficiency of corn was 95 and 90% when based on TME and TME_n, respectively. These values are slightly higher than the 86% obtained by Robel et al. (1979) but are derived after correcting for EE energy and nitrogen elimination.

DISCUSSION

Protein, carbohydrate, and fat fractions of a feedstuff all contribute to its ME content, while fiber is generally inversely related to ME, particularly in monogastric species. These energy-yielding fractions and fiber are of most concern during prolonged periods of harsh winter conditions.

As in the case of most legumes, the nutritional value of the soybean and lespedeza varieties and tick-trefoil is compromised by the presence of trypsin and other proteinase inhibitors (Borchers 1966, Garlich and Nesheim 1966, Rackis 1966). Robel and Arruda (1986) also found that despite the high fat content of soybeans, bobwhite were able to assimilate only a fraction of the GE consumed. Although we found the lespedeza varieties to have TI activity, they contained considerably less than the soybean varieties. The fact that the lespedezas contained less TME and TME_n than Fayette soybeans is probably more the result of their high fiber and lower fat content than impaired protein digestion.

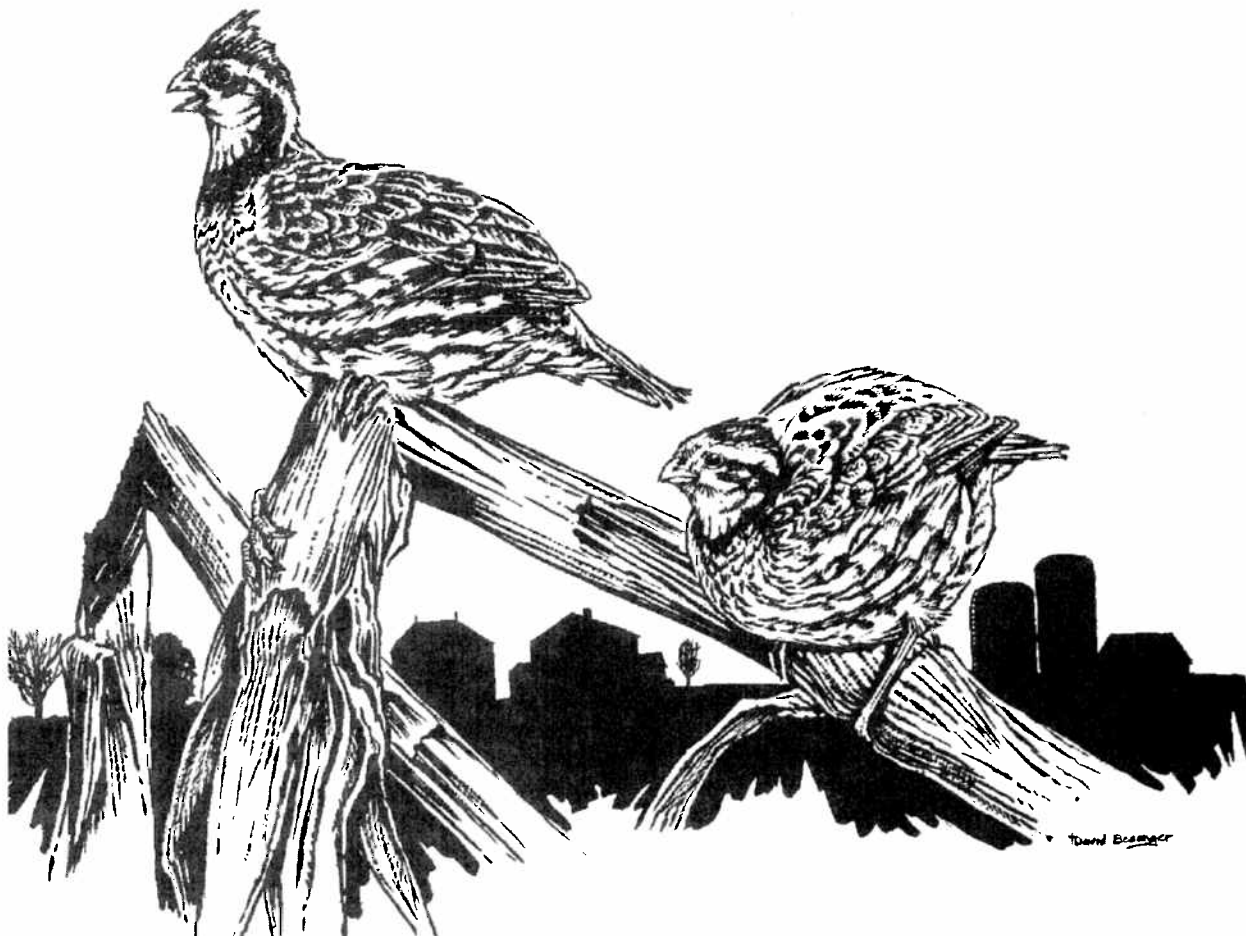
The TI activity of the desmodium was much less than in WT soybeans. This suggests that the high fiber content of desmodium was responsible for its lower ME values. Fiber is largely indigestible in avian species and also accelerates the passage rate of the digesta, thereby decreasing energy and nutrient utilization (Miles et al. 1981).

Correcting the EE of fed and fasted bobwhite for nitrogen elimination (TME_n assay) reduced the TME estimate of every feedstuff. This is because the quantity of the EE which is charged against caloric intake is increased when the negative nitrogen balance of fed and fasted bobwhite is adjusted to zero. The EE is partitioned into that of food origin and endogenous origin. In addition, the endogenous fraction is further partitioned so that the quantity resulting from an elevated rate of tissue catabolism, induced by a limited caloric intake, is identified and subtracted from the endogenous component. The TME_n assay therefore yields the most accurate estimate of the available energy content of a feedstuff because of the more stringent partitioning of the EE.

Since nitrogen correction requires only that food and excreta samples be analyzed for nitrogen, the length of time required for the TME_n assay is not greatly increased over that required for the TME assay. Although the absolute amount by which nitrogen correction changes the total EE is usually small, its importance is magnified by the limited caloric intake. Nitrogen correction generally reduced the mean ME values of the feedstuffs by 5-10% which is similar to results obtained by Sibbald and Morse (1983).

Our studies indicate that the TME_n bioassay is a quick, easily conducted alternative to the traditional AME bioassay. It yields accurate, reproducible estimates of the biologically available energy content of bobwhite foods.

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STUDY AREA AND METHODS

Land-use Information

We used Census of Agriculture (USDC 1976, 1980, 1984, 1989) and National Resources Inventory (NRI; USDA 1984) data to describe county-level agricultural land use and technological applications. Census of Agriculture data were available for all 105 counties in Kansas, while NRI data were available for 47 counties. Census of Agriculture information provided the most accurate estimates of crop types and pesticide use, whereas NRI data provided better descriptions of the sequence of crops over time (crop rotations), soil characteristics, and distances between cover

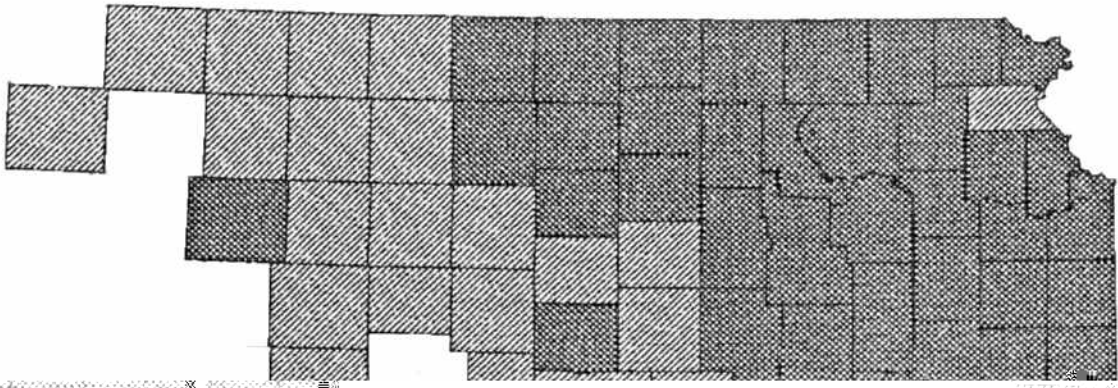
types. Where appropriate, all variables were converted to proportions to control for varying county sizes (Table 1).

Population Indexes

We used Rural Mail Carrier Survey (RMCS) (Wells and Sexson 1982) and BBS (Droege 1990) data to measure distribution and relative abundance of bobwhite in Kansas. The RMCS data were available for all 105 counties, whereas BBS data were available for 36 routes which were then assigned to counties. The RMCS data were gathered incidental to postal delivery by 533 mail carriers driving >435,000 km during a 5-day

Table 1. County-level land use and soil variables from the National Resources Inventory and the Census of Agriculture that were associated with bobwhite distribution and relative abundance in Kansas.

Variable	Description
National Resources Inventory	
% LCC1	% of county in Land Capability Class 1
% LCC2	% of county in Land Capability Class 2
% LCC3	% of county in Land Capability Class 3
% LCC4	% of county in Land Capability Class 4
% LCC5	% of county in Land Capability Class 5
% prime farmland soils	% of county in prime farmland soils
% grazed	% of county grazed by livestock
% cropland	% of county in agricultural crops
% soybeans	% of county in soybeans
% wheat	% of county in wheat
% pasture	% of county in pasture
% woodland	% of county in woodland
% meadow	% of county in hay
% small water bodies	% of county occupied by small water bodies
Mean distance to cropland	Mean distance from randomly selected points to the nearest occurrence of cropland
Mean distance to grassland	Mean distance from randomly selected points to the nearest occurrence of grassland
Mean distance to water	Mean distance from randomly selected points to the nearest occurrence of surface water
Erodibility index (water)	Potential erodibility based on the Universal Soil Loss Equation (Wischmeier and Smith 1978)
Erodibility index (wind)	Potential erodibility based on the Wind Erosion Equation
R factor	Rainfall and runoff factor, measure of the duration and intensity of rainfall used in the Universal Soil Loss Equation
T factor	Tolerable soil loss level or the rate of soil erosion that can occur without degrading the productive capacity of the soil
Length of slope	Length of the effective slope that water will run off as sheet flow before becoming concentrated flow
% slope	The vertical height (rise) of a hillside divided by the horizontal length (run), expressed as a percent
LS factor	Index that compares the soil loss from the field length and percent of slope to a standard unit (9%, 22.1 m)



high-density. Annual BBS estimates of bobwhite abundance revealed no long-term change ($P > 0.1$; Church et al. 1993) since 1967 (Fig. 2). The mean number of bobwhite recorded on BBS routes was 43.3 (SE = 6.6, median = 33, range = 123). In 1982, RMCS data were correlated with the number of individuals ($r_s = 0.78, P < 0.0001$) and the number of stops where bobwhite were observed ($r_s = 0.77, P < 0.0001$) on 32 BBS routes in 29 counties. This supports the use of both data sets as appropriate measures of bobwhite abundance for comparisons with land-use data.

Land-Use Patterns

In general, the amount of farmland in Kansas has remained stable over the last 50 years. In 1982, 20.1 million ha of rural land consisted of 11.8 million ha of cropland, 6.8 million ha of rangeland, 0.9 million ha of pastureland, 0.3 million ha of woodland, and 0.3 million ha of other minor land cover uses (USDA, SCS and ISUSL 1989). About 51% of rural land and 65% of cropland were classified as prime farmland. Fourteen percent of cropland was irrigated. Sixty-six percent of cropland was used to produce wheat,

and the remaining 34% produced sorghum, hay, soybeans, and corn (Fig. 3) (USDC 1984).

Land area used for crop production fluctuates annually because of federal commodity control programs. Techniques for producing crops have been modified by technological advances in conservation tillage for soil erosion control. The area treated with herbicides more than doubled from 1974 to 1987, whereas the use of insecticides has remained relatively constant (Fig. 4). The chemical composition of pesticides has changed dramatically during this period. Beginning in 1986 the Conservation Reserve Program removed about 1.2 million ha of cropland from production for 10 years.

Eight NRI variables (5 positive and 3 negative) were different ($P < 0.05$) between counties where bobwhite were present as opposed to absent (Table 2). Likewise, MRPP identified 14 Census of Agriculture variables (8 positive and 6 negative) that were associated ($P < 0.05$) with the presence or absence of bobwhite.

There were 16 NRI variables (10 positive and 6 negative) that differed ($P \leq 0.05$) between low- and high-density counties (Table 3). Seven NRI vari-

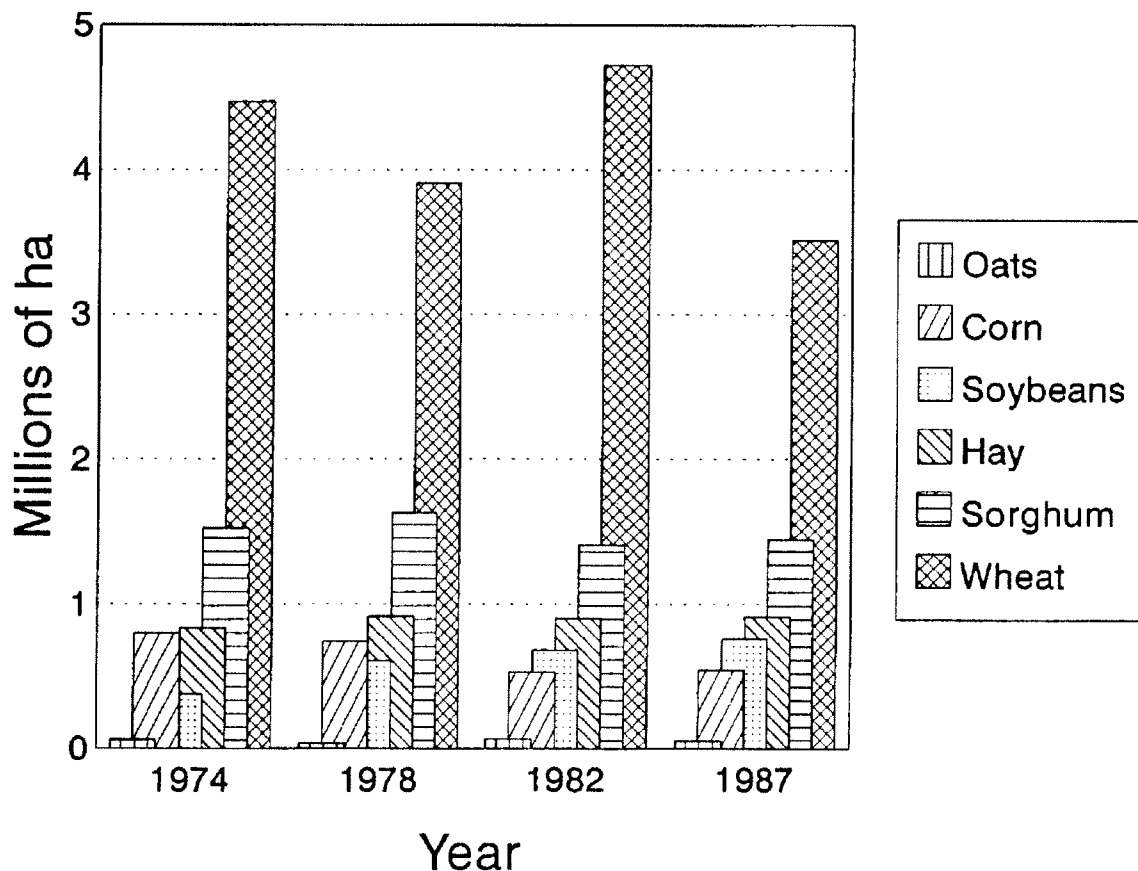


Fig. 3. Major crops produced in Kansas during the last 4 Censuses of Agriculture (USDC 1976, 1980, 1984, 1989).

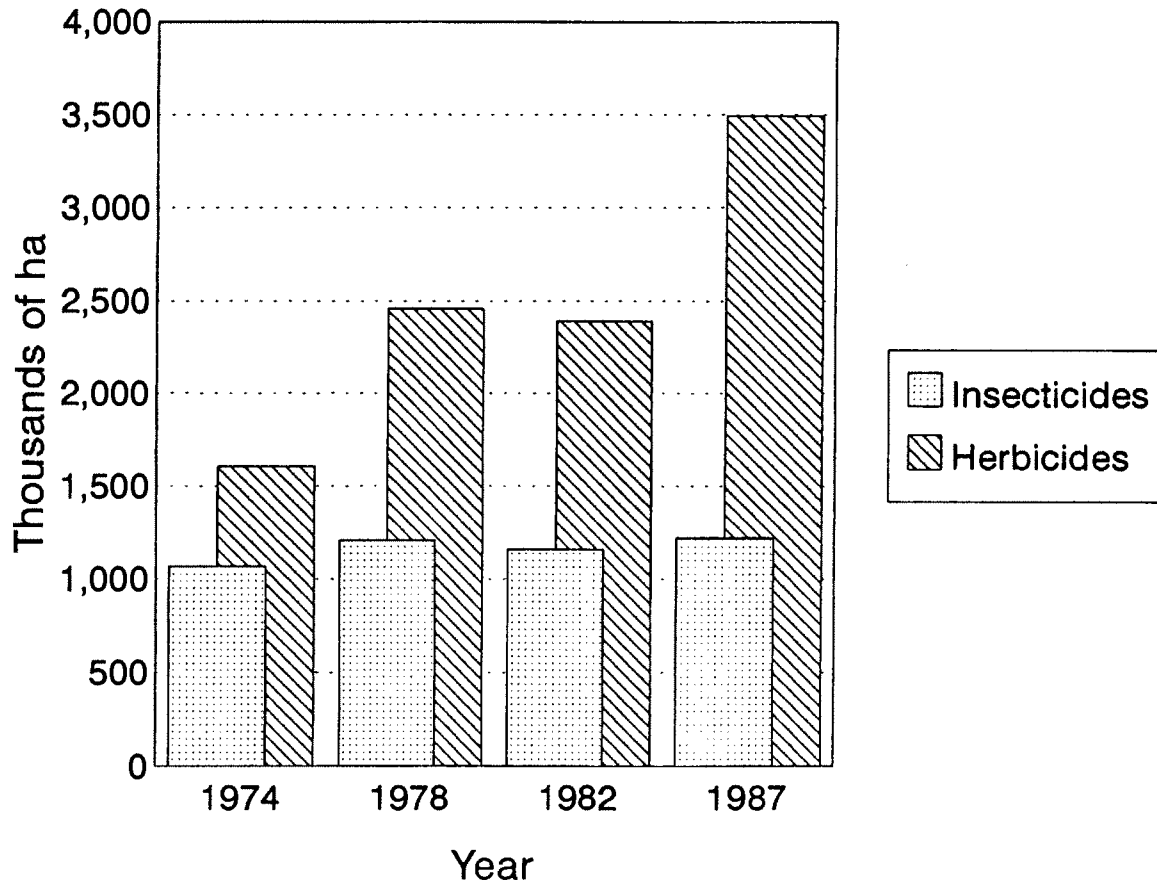


Fig. 4. Kansas agricultural lands treated with herbicides and insecticides during the last 4 Censuses of Agriculture (USDC 1976, 1980, 1984, 1989).

ables were common to both presence/absence and low/high tests. Likewise, 14 Census of Agriculture variables (9 positive and 5 negative) differed ($P < 0.05$) in low-density, opposed to high-density, counties. Twelve variables were common to both distribution and abundance tests.

Bobwhite abundance was correlated ($P < 0.05$) with 19 NRI variables for the counties where bobwhite were present (Table 4). The rainfall factor displayed the strongest positive correlation and the erodibility index for wind the strongest negative relationship. Spearman's rank correlations were generally supportive of the results of the MRPP abundance tests.

Spearman's rank correlations identified 13 variables associated with bobwhite abundance and Census of Agriculture data (Table 5). The proportion of woodland represented the strongest and most consistent relationship. The proportion of cropland diverted out of production was strongly negatively correlated with bobwhite abundance in 1978 and 1982. However, in 1987 the amount of diverted acres was the greatest among the

years examined, and no relationship was identified.

Predictive Models and Trends

The LAD regression analysis indicated that 4 NRI variables best explained northern bobwhite (NBW) abundance (Agreement = 0.48, $P = 0.0001$, $n = 36$). The equation was:

$$\text{NBW} = -0.54 + 52.3 \text{ Ponds} + 68 \text{ Woodland} + 21.6 \text{ Soybean} - 174 \text{ Oats} + 0.004 \text{ Distance to Cropland.}$$

When Census of Agriculture variables were subjected to LAD regression analysis, the best fit came with 3 variables (Agreement = 0.46, $P < 0.00001$, $n = 80$) giving the equation:

$$\text{NBW} = 1 + 78 \text{ Woodland} + 98.9 \text{ Native hay} - 33.3 \text{ Hay (except alfalfa).}$$

When the temporal trends of bobwhite abundance (1967-88) were evaluated against agricultural land-use trends (1974-87), no relationship ($P > 0.05$) was observed. Neither the slope of bobwhite trends nor the slope of agricultural land-use trends was different from 0.

Table 2. Multiple Response Permutation Procedure results of Rural Mail Carrier Survey bobwhite distribution with county level National Resources Inventory data for counties where bobwhite were present ($n = 36$) or absent ($n = 11$) and Census of Agriculture data for counties where bobwhite were present ($n = 90$) or absent ($n = 15$).

National Resources Inventory	<i>P</i>	Census of Agriculture	<i>P</i>
% LCC1 ^a	0.0831	% diverted crops	0.0004
% LCC2	0.2007	% cover crops	0.0828
% LCC3	0.2656	% herbicides	0.1408
% LCC4	0.3156	% insecticides	0.0392
% prime farmland soils	0.0001	% sorghum	0.7448
Erodibility index (water)	0.0002	% oats	0.0018
Erodibility index (wind) ^b	0.0306	Hogs/ha	0.0014
% grazed	0.1178	Cows/ha	0.0011
% cropland	0.0154	% farmland	0.2916
% soybeans	0.0783	% soybeans	0.0100
% wheat	0.1015	% wheat	0.0072
% pasture	0.1532	% past/range fertilized	0.0368
% woodland	0.0107	% woodland	0.0015
% meadow	0.0001	% hay	0.0001
% small water bodies	0.0032	% alfalfa	0.0105
Mean distance to cropland	0.8724	% hay (except alfalfa)	0.0002
Mean distance to grassland	0.0002	% wild hay	0.0198
Mean distance to water	0.0750	Average farm size	0.0001

^aLCC = Land Capability Class.

^bEI wind was only calculated for $n = 23$ counties where bobwhite were present and $n = 11$ counties where bobwhite were absent.

Table 3. Multiple Response Permutation Procedure results of 1982 Rural Mail Carrier Survey data for bobwhite abundance with county level National Resources Inventory (NRI) and Census of Agriculture data for counties with high and low abundance. High abundance was defined as ≥ 1.425 bobwhite/161 km and low abundance was < 1.425 . NRI had 18 counties with high abundance and 18 with low, whereas Census of Agriculture had 58 counties with high abundance and 32 with low.

National Resources Inventory	<i>P</i>	Census of Agriculture	<i>P</i>
% LCC1 ^a	0.4971	% diverted crops	0.0001
% LCC2	0.0424	% cover crops	0.0765
% LCC3	0.0108	% herbicides	0.0235
% LCC4	0.0480	% insecticides	0.0288
% prime farmland soils	0.0315	% sorghum	0.0782
Erodibility index (water)	0.0003	% oats	0.0001
Erodibility index (wind) ^b	0.4128	Hogs/ha	0.0004
% grazed	0.0522	Cows/ha	0.0026
% cropland	0.0037	% farmland	0.0014
% soybeans	0.0030	% soybeans	0.0001
% wheat	0.0239	% wheat	0.0001
% pasture	0.0246	% past/range fertilized	0.1198
% woodland	0.0001	% woodland	0.0001
% meadow	0.0001	% hay	0.0001
% small water bodies	0.0003	% alfalfa	0.3470
Mean distance to cropland	0.0004	% hay (except alfalfa)	0.0001
Mean distance to grassland	0.0130	% wild hay	0.0001
Mean distance to water	0.0023	Average farm size	0.0001

^aLCC = Land Capability Class.

^bEI wind was calculated only for $n = 23$ counties.

Whereas the best regression models did not include the erodibility indexes, they are important in targeting USDA programs. The strong positive correlation of bobwhite with the erodibility index (EI water; Table 4) was not found for populations range-wide when tested in 530 counties with BBS data in 1982. However, when bobwhite from all Kansas BBS routes during the years 1970-88 were tested against the EI (water), the correlation was significant ($0.00005 < P < 0.029$) for each year. The EI is a function of the relatively stable natural factors of climate, soil, and length and percent of slope, which will be relatively constant over time, unlike the agricultural land-use variables that can fluctuate annually.

The physiographic and climatic gradient across Kansas from east to west could confound interpretations of our results. However, we tried to minimize this concern by evaluating both abundance within the occupied range and distribution. Population density may be a misleading indicator of habitat quality, especially with high resolution studies (Van Horne 1983). We found that rank ordering of counties by bobwhite abundance was consistent over time and that bobwhite abundance in the extreme low and high years of 1985 and 1987 were highly correlated ($r_s = 0.77$, $P < 0.00001$). Source and sink bobwhite populations were not distinguishable at the county level.

DISCUSSION

The bobwhite is an edge-associated species whose abundance is generally increased by greater habitat diversity. The EI correlations and correlations with spatial variables (distance to crop, grass, and water in Tables 2-4) confirm this relationship. High values for the EI (water) imply highly dissected landscapes characterized by short, steep slopes, steep waterways, more rainfall, and high topographic relief—hence high habitat heterogeneity. Conversely, high values for the EI (wind) imply gently rolling to flat plains, gentle slopes, less rainfall, wide open spaces—hence high habitat homogeneity. Bobwhite were more abundant in counties where mean distances to grassland and small waterbodies were low. Bobwhite were less abundant in counties where mean distance to cropland was low.

Bobwhite abundance was positively correlated with amount of pasture and hayfields or meadows. Hayfields and pasture in southern Illinois offered some nesting cover, depending upon vegetational composition and structure (Roseberry et al. 1979). These results are also consistent

with the findings of Exum et al. (1982) except for correlations with soybeans. Exum et al. found that although soybeans were a preferred food of bobwhite on the Ames Plantation in Tennessee, population size was negatively correlated with area maintained in soybeans. Large expanses of soybeans replaced large idle fields and permanent pastures on the Ames Plantation, perhaps creating shortages of necessary winter cover (Exum et al. 1982). In contrast, the expansion of soybeans in Kansas replaced other cropland (primarily corn) rather than converting good bobwhite cover to less desirable cropland. Therefore, if crop rotations are shifted from other crops to include soybeans without the concomitant loss of important habitat types, then bobwhite populations might benefit.

Avian habitat use is dynamic (O'Connor 1986), may be nonlinear (Meents et al. 1983), and varies with population demographics (Van Horne 1983, Maurer 1986) as well as with the scale with which we classify habitats (Wiens et al. 1987). Bobwhite were correlated consistently with some variables and inconsistently with others. The inconsistent variables might be less important, or the scale that they operate in might be different from the scale bobwhite population processes operate in. Reconciling the scale of agricultural programs and technologies with bobwhite population processes is only likely to occur in a hierarchical framework. However, EI and proportions in woodlands and soybeans are important variables because of their consistent correlations with bobwhite populations over time.

The fact that woodlands occur and soybeans are grown more in eastern Kansas where rainfall is greater and bobwhite are abundant does not necessarily imply a causal relationship. However, environmental conditions where these land uses occur also provide conditions suitable to higher bobwhite abundance. Managers must recognize bobwhite as a successional species and provide appropriate patterns of plant seral stages (Ellis et al. 1969). Subtle land-use changes can cause substantial changes in bobwhite carrying capacity (Roseberry et al. 1979). Detecting successional patterns was not possible with our coarse-grained data, but patterns of major land-use characteristics were detectable and important in describing bobwhite abundance.

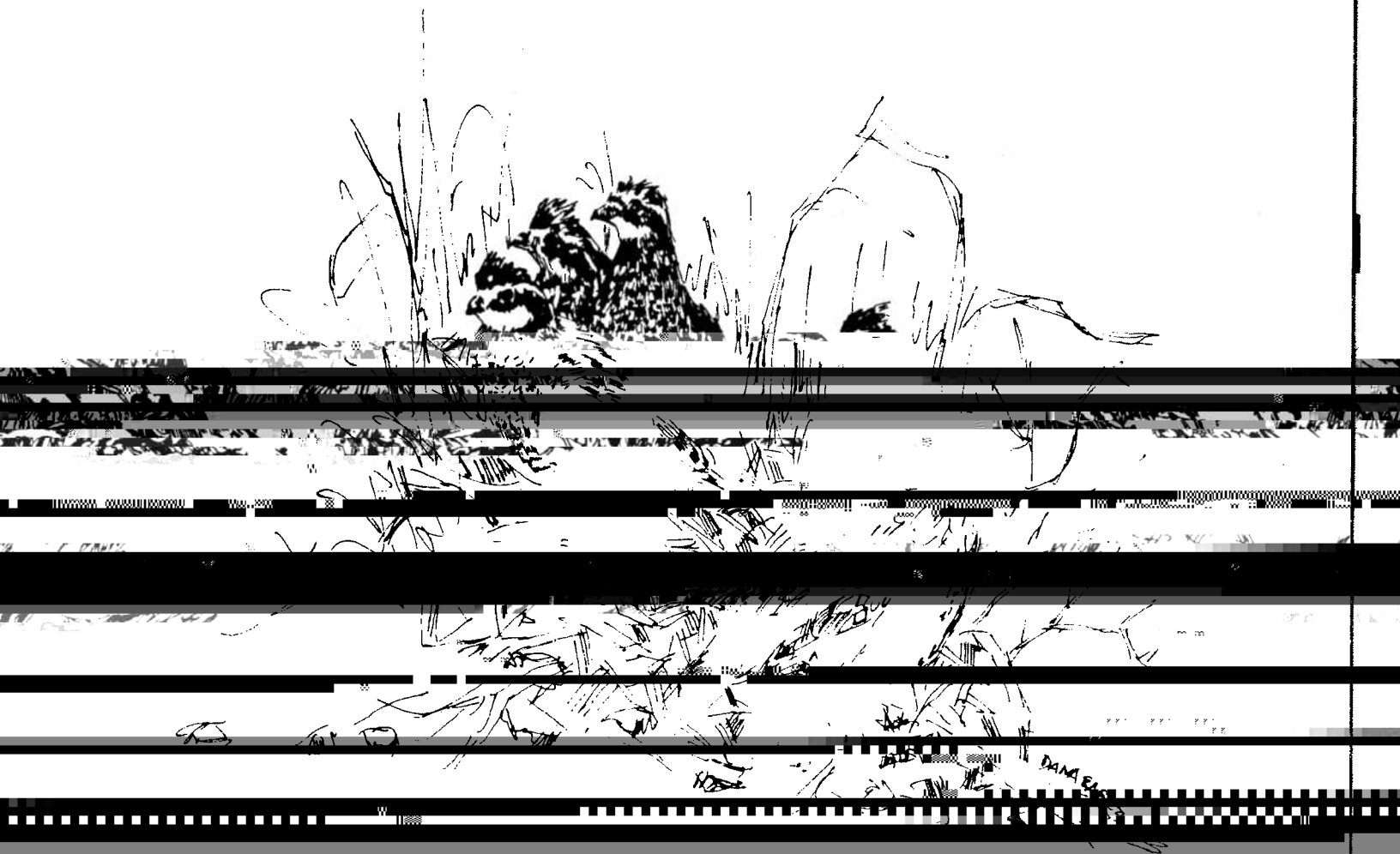
The USDA conservation programs are targeted to highly erodible lands based on the EI. In the eastern 2/3 of Kansas where bobwhite are abundant, those programs will also target areas where bobwhite are abundant. However, in the western

1/3 of Kansas, those programs will target counties where bobwhite are rare or absent since the EI (wind) will be the predominant index used to target highly erodible lands. Conservation programs will enhance bobwhite habitat through planned agricultural practices when requirements of this game bird are kept in mind. Traditional soil conservation practices such as grass-ridged terraces, field windbreaks, contour stripcropping, field border strips, and proper grazing are still good recommendations. Negative correlations with distances to grass cover and to water show the importance of habitat diversity and interspersions. Increasing size of farms and fields may result in the loss of brushy fencerows and odd areas of habitat which will be difficult to mitigate, even with judicious planning.

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NORTHERN BOBWHITE DENSITIES IN BURNED AND UNBURNED REDBERRY JUNIPER RANGELANDS

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Abstract: We estimated northern bobwhite (*Colinus virginianus*) densities in 4- and 8-year-old burned and unburned redberry juniper (*Juniperus pinchottii*) dominated pastures. The 4-year-old burned (800 ha), 8-year-old burned (1,200 ha), and unburned (1,200 ha) treatment sites had 8.6, 14.4, and 22.3% woody canopy coverage, respectively. Fall bobwhite densities were estimated from 122 flushes of quail coveys on 592.8 km of transects. Data histograms indicated that bobwhite were harder to detect in the unburned area than in the 8-year-old burn or the 4-year-old burn. Probability detection functions were smaller in the old burn than the new burn ($P = 0.05$) or unburned area ($P = 0.02$). Bobwhite densities of 43.3, 55.1, and 60.5 birds/100 ha in the 4-year-old burn, 8-year-old burn, and unburned sites, respectively, were similar ($P > 0.10$). Prescribed burning to control redberry juniper and manage bobwhite should be designed to maintain intermittent shrub coverage.

Key words: *Colinus virginianus*, densities, line transects, northern bobwhite, prescribed burning, rangeland, Texas.

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Prescribed burning is used to reduce canopy cover of redberry juniper and reduce downed (chained) woody debris on the Rolling Plains of Texas. Areas subjected to brush control burns support populations of northern bobwhite. Jackson (1969:32) hypothesized that complete brush control on the Rolling Plains would eliminate quail populations. However, prescribed burns generally do not consume all brush; furthermore, redberry juniper resprouts following fire (Steuter 1982). Although bobwhite are not likely to be eliminated from areas treated with fire, Renwald (1979) reported that quail loafing coverts were reduced following burning of honey mesquite (*Prosopis glandulosa*).

Historically, bobwhite management on the Rolling Plains was superseded by livestock management. While landowner interest is shifting away from single-goal management schemes (Jackson 1969:32), few plans exist for integrated management of quail and livestock. Our objective was to estimate fall densities of northern bobwhite in 4- and 8-year-old burned and unburned redberry juniper habitat.

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STUDY AREA

The study area was on the Masterson JY ranch in northeastern King County, Texas. Mean daily maximum temperature in summer was 35.4 C and the mean daily minimum in winter was -1.2 C (Richardson et al. 1974). Topography varied from level to steep, and average annual precipitation was 59 cm. Soils are lithic and of the Talpa series (Steuter 1982). Primary shrub species were redberry juniper, honey mesquite, lotebush (*Ziziphus obtusifolia*), skunkbush (*Rhus aromatica*), littleleaf sumac (*R. microphylla*), catclaw mimosa (*Mimosa biuncifera*), and catclaw acacia (*Acacia greggi*). Dominant grasses on the site included perennial three-awns (*Aristida* spp.), sideoats grama (*Bouteloua curtipendula*), blue grama (*B. gracilis*), buffalograss (*Buchloe dactyloides*), hairy tridens (*Erioneuron pilosum*), rough tridens (*Tridens muticus*), tobosa (*Hilaria mutica*), and Texas wintergrass (*Stipa*

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leucotricha). Common forb species were basket flower (*Centaurea americana*), fleabane (*Erigeron modestus*), spurge (*Evolvulus nuttallianus*), rabbit-tobacco (*Evax verna*), evening primrose (*Calylophus drummondianus*), bitterweed (*Hymenoxys scaposa*), white aster (*Leucelene ericoides*), flax (*Linum* sp.), plantains (*Plantago* spp.), silver-leaf nightshade (*Solanum elaeagnifolium*), scarlet globe-mallow (*Sphaeralcea coccinea*), wood sage (*Teucrium canadense*), green-thread (*Thelesperma filifolium*), Dakota vervain (*Verbena bipinnatifida*), and common broomweed (*Xanthocephalum drancunculoides*).

Three treatment sites were surveyed in fall 1986: an 800-ha pasture that was in its fourth growing season following fire treatment (new burn), a 1,200-ha pasture in its eighth growing season (old burn), and a 1,200-ha unburned control. All sites were chained in 1974 or 1975 and had similar plant associations before fire treatment (Steuter 1982). Treatment sites were burned with strip headfires in March under a prescription of 21-26 C air temperature, 25-40% relative humidity, and 12-24 km/hour wind speeds which resulted in burned coverage of 80-90%. Pastures were grazed on continuous systems at stocking rates of 1 cow-calf per 20-22 ha and received light quail hunting pressure.

METHODS

Line-intercept (Canfield 1941) was used to estimate percent live brush in each treatment. Five 100-m lines were randomly placed in each treatment and intersecting shrub lengths recorded. Potential differences in redberry juniper, mesquite, and total canopy cover were tested using analysis of variance and least-significant difference mean separation tests when the *F*-test was significant ($P < 0.05$).

In each treatment site, line-transects were established at ≥ 400 m intervals and were marked by attaching plastic flagging along fences at both ends of each line. An adequate sample of 40 observations (Burnham et al. 1980) was not obtained along initially established lines. Therefore, additional lines were established between those present and were surveyed until ≥ 40 observations were recorded in each area. Adding more lines was chosen over repeatedly walking original lines, to decrease the probability of encountering a covey already observed at the same approximate site which would bias variance estimates.

Lines were surveyed from 21 August to 31 October 1986. Each line was surveyed by an in-

dividual equipped with a compass, measuring tape, and an aerial photograph of the treatment site. Upon observing a covey, a marker was driven into the ground and the observer moved to the site of the flush. After marking the flush site, the observer returned to the marker, took the proper compass bearing, and moved along the line until perpendicular with the flush site. Right-angle distance and covey size were recorded at each observation. Transect lengths were determined by measuring lines established on aerial photographs (2 cm/km).

Covey density estimates were derived for each treatment site using program TRANSECT (Laake et al. 1979) and the Fourier series estimator (Burnham et al. 1980). Bobwhite densities were estimated by multiplying each covey density by its mean covey size, and corresponding density variances were calculated as described by Burnham et al. (1980). Potential differences in probability detection functions and bobwhite densities between treatments were tested with a *Z*-test.

RESULTS

Total canopy cover differed ($P = 0.02$) among treatment sites (Fig. 1). Redberry juniper accounted for 55, 50, and 60% of woody cover in the new burn, old burn, and unburned areas, respectively.

Histograms of perpendicular-distance distributions of bobwhite varied with treatment site (Fig. 2). Thirty-two percent of observations were within 4 m of transects in the unburned area. Only 12 and 15% of observations were within 4 m of transects in the new and old burns, respectively. Chi-square goodness-of-fit probabilities (with pooling) were 0.59, 0.38, and 0.58 in the new burn, old burn, and unburned areas, respectively; therefore the detection curve fit the data histogram.

Probability detection functions [$f(0)$], which are inversely related to covey detectability were lower for bobwhite in the old burn than in the new burn ($P = 0.05$) and unburned areas ($P = 0.02$) (Table 1). Autumn densities of northern bobwhite did not differ with treatment site ($P > 0.10$).

DISCUSSION

Although no statistical differences were detected, bobwhite densities were 40% higher in the unburned area than in the new burn (Table 1). Coefficients of variation were $< 20\%$ for all density estimates. Reduction of variation terms (which would allow more powerful comparisons of

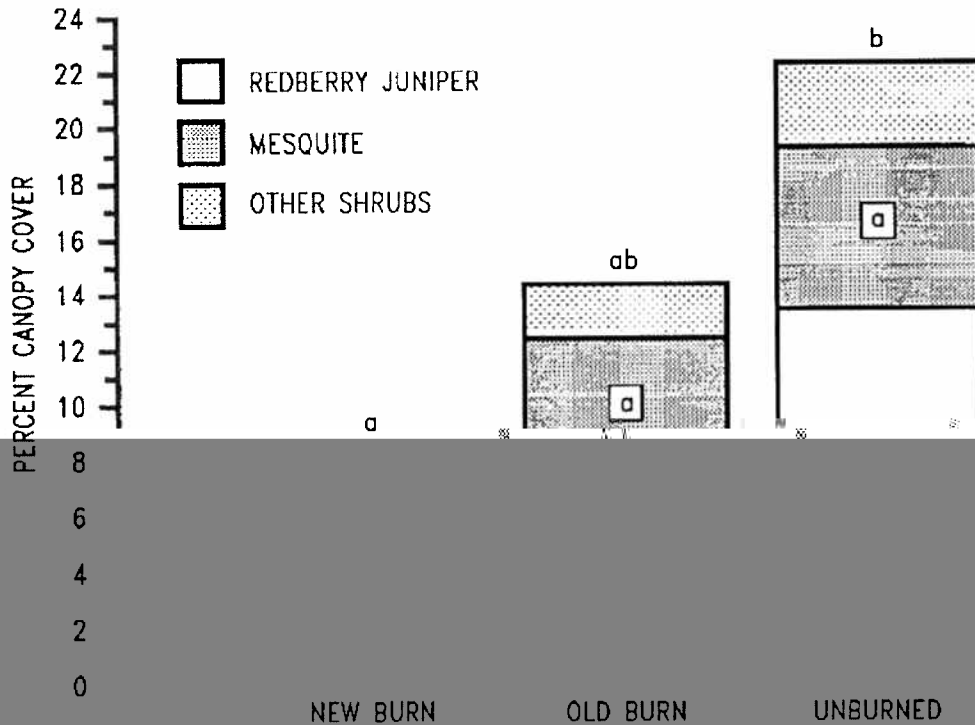


Fig. 1. Line-intercept estimates ($n = 15$) of woody canopy cover in burned (new burn = 4 years and old burn = 8 years following fire treatment) and unburned redberry juniper-dominated rangeland on the Rolling Plains of Texas, 1986. Bars and species segments denoted by the same letter were not different ($P > 0.05$).

densities) by 1/2 could have been obtained by increasing the number of observations 4 fold. However, on our study area, this could only have been accomplished with 2,400 km of transects.

Prescribed burning can be used as a bobwhite management tool. However, burns investigated in this study were large (≥ 800 ha) and were conducted under hotter (> 21 C air temperature), drier ($< 40\%$ relative humidity) conditions than burns aimed at improving bobwhite foraging areas (Stoddard 1931:406, Rosene 1969:301, Ellis et al. 1969, Seitz and Landers 1972, Whitehead

and McConnell 1979, Wilson and Crawford 1979). Primary objectives of prescribed burns in this study were to remove downed woody debris and decrease canopy cover of redberry juniper, thereby increasing livestock grazing potential (Steuter 1982). In the process of reducing shrub canopy cover, bobwhite loafing areas may be sacrificed in an area which is already "barely habitable" (Jackson 1969:2).

Areas having the greatest potential for bobwhite hunting have high densities of easily detected birds. Burning can improve accessibility

Table 1. Density estimates (\pm SE) of northern bobwhite (Fourier series estimator) in burned and unburned redberry juniper-dominated rangeland on the Rolling Plains of Texas, 1986.

Treatment	n	Km of lines	$f(0)^a$	Coveys/100 ha	Covey size	Birds/100 ha
New burn ^b	41	249.8	0.050 ± 0.007	4.12 ± 0.72	10.51 ± 0.81	43.3 ± 7.6
Old burn ^c	40	153.9	0.037 ± 0.003	4.75 ± 0.79	11.60 ± 0.85	55.1 ± 9.2
Unburned	41	189.1	0.057 ± 0.008	6.22 ± 0.12	9.73 ± 0.85	60.5 ± 11.8

^a Probability detection function.

^b Fourth growing season following fire treatment.

^c Eighth growing season following fire treatment.

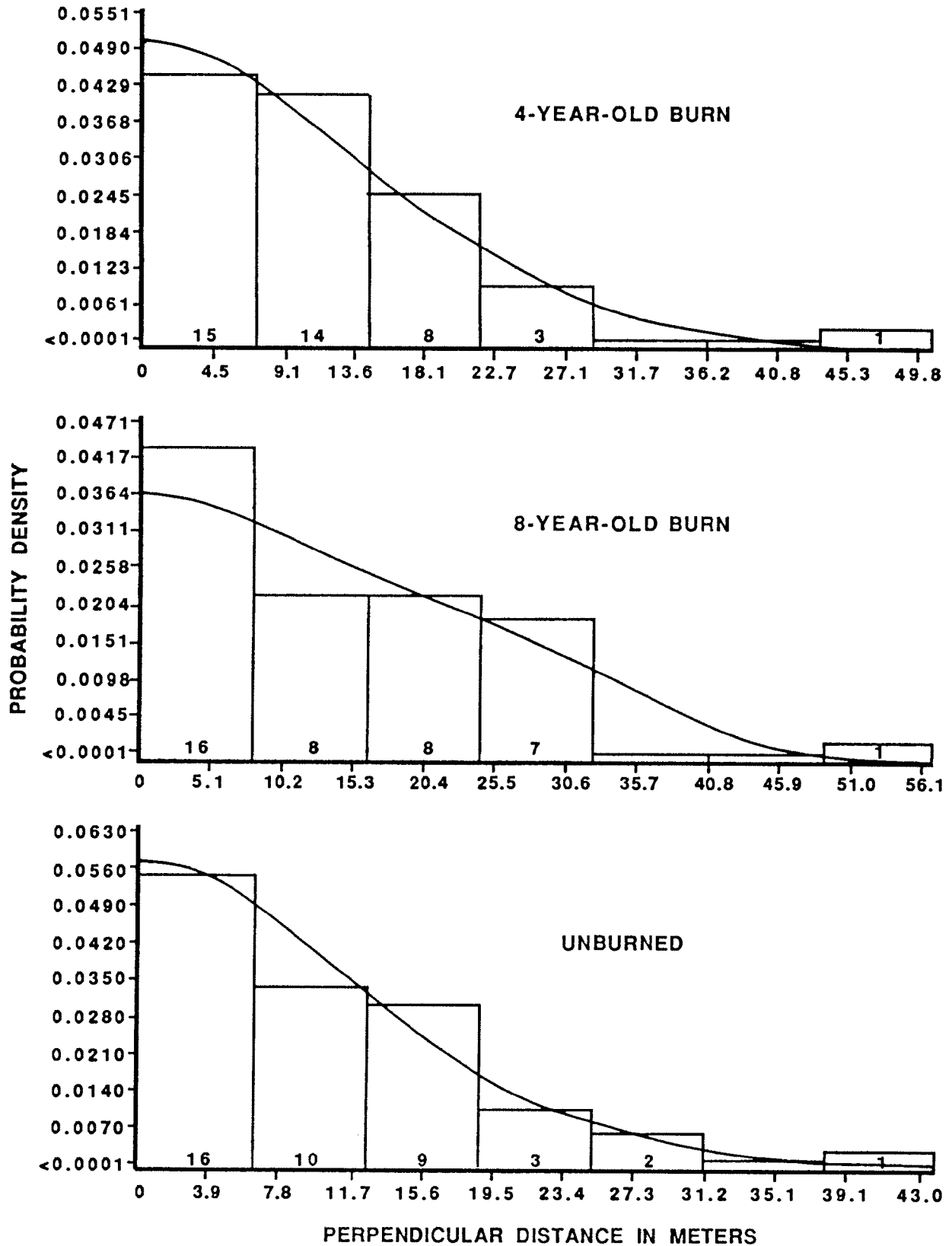


Fig. 2. Untruncated, perpendicular distance distributions and fit of the Fourier series estimator for northern bobwhite in burned and unburned redberry juniper-dominated rangeland on the Rolling Plains of Texas, 1986. Values within bars represent observations in each interval.



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METHODS

The study was conducted March-August 1985 and 1986 on the Rob and Bessie Welder Wildlife Foundation Refuge (WWR), which is in the northern portion of San Patricio County on the Texas Coastal Bend. The 3,157 ha refuge is in the transitional zone between the Gulf Prairies and Marshes and the South Texas Plains ecological regions (Gould 1975). The climate is subtropical with hot summers and cool winters. Peaks in vegetative growth are associated with rainfall which occurs mainly in spring and fall. Annual precipitation averages 88.9 cm; rainfall on the WWR totaled 116.0 cm in 1985 and 63.5 cm in 1986.

A SDG cell was established on the WWR in 1982. The 219-ha cell consisted of 10 paddocks, 20-30 ha each. From 14 March to 25 December of 1985 and 1986, 1 herd of cattle was rotated clockwise to successive paddocks every 2-9 days. The grazing period of each paddock was based on paddock size and relative quality of vegetation. During calving (26 December-13 March), all paddocks were open to continuous grazing. The SDG cell was stocked at 4.0 and 3.2 ha/animal unit (AU) in 1985 and 1986, respectively. Within-paddock stocking rates were 0.4-0.5 ha/AU in 1985 and 0.3-0.4 ha/AU in 1986. The adjacent 267-ha CG pasture was grazed year-round at 4.0 and 3.2 ha/AU in 1985 and 1986, respectively.

Soils in both pastures were primarily Victoria clays with 0-1% slope. The SDG cell was comprised of mesquite-mixedgrass and chaparral-mixedgrass communities, and the CG pasture was comprised entirely of a mesquite-mixedgrass community (Drawe 1991, Drawe et al. 1978). Although soils and vegetative communities of the pastures were similar, treatments were not replicated, thus site effects may have confounded treatment effects.

Bobwhite females were occasionally radio-located in mesquite-mixedgrass and chaparral-mixedgrass communities on the Ford Ranch, a private ranch adjacent to the southern border of the study area. That ranch used continuous grazing in a cow-calf operation at a stocking rate of 6.1 ha/AU (J. D. Hollan, pers. commun.).

Bobwhite were live-trapped 31 March-27 June in 1985 and 4 March-19 June in 1986 using modified Stoddard quail traps. Each bird was weighed, sexed, and aged as subadult (151-270

days old) or adult (>270 days old) based on wing characteristics (Rosene 1969). A 6-g radio-transmitter was mounted on the back or neck of each female. A backpack-mounting method was used during 1985. To reduce handling time of birds during radio-tagging and to prevent loss of transmitter packages due to loose harnesses, poncho-mounted as well as backpack-mounted transmitters were used in 1986.

Coveys or pairs trapped together were released simultaneously to maintain covey or pair integrity. Upon release, radio-tagged females were observed for flight strength and abnormalities. Successful traps were relocated so that the presence of bait would not influence behavior of radio-tagged birds.

Radio-tagged females were located daily. Females repeatedly located in the same area were assumed to be nesting. Nest termination was indicated by repeated daily locations of a female away from the nest site, a location far from the nest site, or lack of an activity signal which suggested predation of the female.

A 4-element hand-held directional yagi antenna or a collapsible H-antenna was used to obtain directions from permanent stations to radio-tagged birds. Azimuths of directions were measured using a handheld compass. Accuracy checks showed that the 95% confidence interval for mean error of the telemetry system was -0.9 to $+1.5^\circ$ for readings taken at distances of 80-150 m, the range within which most radio locations were taken.

DATA ANALYSES

Activity patterns

Computer programs that incorporated signal-direction azimuths and receiving-station locations were developed at Stephen F. Austin State University and were used to determine locations and to calculate straight-line distances between successive locations. Distance values were compared between grazing systems using Student's *t*-tests. Values assigned to a grazing system included those within the grazing system and those between the grazing system and a location out of the grazing system.

Student's *t*-tests utilizing separate variance estimates indicated that 1985 and 1986 movement data could be pooled for the SDG cell ($P = 0.10$), but not for the CG pasture ($P = 0.01$). Therefore, 1985 and 1986 data were analyzed separately. Statistical tests were considered significant at $P \leq 0.05$ for this and all other comparisons.

We used harmonic home range sizes (Dixon and Chapman 1980) to determine if the type of grazing system affected home range sizes of females during the breeding season (April-August). Mean home ranges were calculated for each bird with ≥ 21 locations (White and Dimmick 1978) within a grazing system. The criterion for assignment to a particular grazing system was that $\geq 70\%$ of the total locations of an individual be contained within that grazing system. Home range isopleths in 50-m increments were drawn for each female. The isopleth that encircled $\geq 95\%$ of the bird's locations defined the home range (Dixon and Chapman 1980). This isopleth was traced with a polar planimeter to determine home range size in hectares. Student's *t*-tests and 2-sample median tests were used to compare home range sizes between the 2 grazing systems.

Habitat use

On the WWR, vegetation along fencerows, road shoulders, and rights-of-way was mowed for brush control. Because of more fencing, a much greater proportion of the SDG cell was mowed than was the CG pasture. Computerized maps of the 2 grazing systems were built using the Map Analysis Package (Tomlin 1980). Infrared aerial photographs of the SDG cell and CG pasture were enlarged to scales of 1:3682 and 1:4023, respectively. Structural features, including fencelines, roads, underground pipeline rights-of-way, creeks, stock tanks, and the Aransas River, were digitized for storage in the computer. Each map was partitioned into 90,000 grid cells, each representing about 8.33 m². For each mowed feature, 3 zones were delineated: (1) < 25 m from the center of a mowed strip, (2) 25-50 m from the center of a mowed strip, and (3) > 50 m from the center of a mowed strip. Chi-square goodness-of-fit tests were used to test the null hypotheses that bobwhite females used these zones in proportion to their availability during each year in each grazing system. If significant differences between use and availability of zones were found, the null hypothesis was rejected and Bonferroni confidence intervals (Neu et al. 1974) were used to determine which zones were preferred or avoided in each grazing system.

Response to the SDG rotation

Simple linear regression and Spearman's rank correlation were used to determine if there were correlations between grazing status of a paddock and its use by bobwhite. The grazing status of a paddock was assigned a number ranging 0-9, with

0 indicating that the paddock was currently being grazed and the numbers 1-9 designating the number of grazing periods since the paddock had been grazed (Bareiss 1985). For each year, the number of locations in each paddock by grazing status was determined; these numbers were regressed on grazing status and were used in correlation analyses.

For each female bobwhite in the SDG cell, dates on which cattle and the bird shared a paddock were identified. Using 10-14 locations before cattle were moved into a paddock and an equal number after cattle were moved out of the paddock, preentry and postentry activity areas and activity centers were plotted. The size of each activity area was determined using a polar planimeter, and preentry and postentry activity area sizes were compared using paired *t*-tests. Distance between activity centers and direction of activity center change in relation to the grazing rotation were also determined for each bird. Finally, in order to compare between grazing systems, activity area sizes and distances between activity centers were likewise determined for females in the CG pasture; these data were compared to those of the SDG birds using *t*-tests.

RESULTS

Activity Patterns

In 1985, 19 females yielded 502 locations, 354 in the study area. Twenty-eight radio-tagged females provided 971 locations in 1986, 821 of which were in the study area. During both years, females in the CG pasture moved farther between successive locations than did those in the SDG cell; the differences were not significant in either year, however (Sloan 1987:57).

Mortality and emigration reduced the number of birds meeting the criterion for home range size analysis to 21. As only 1 SDG and 3 CG birds met the criterion in 1985, the sample was considered too small, consequently only 1986 data were analyzed. For 1986, home range sizes of 10 birds in the SDG cell (28.1 ha \pm 10.0 ha [SD]) were compared to those of 7 birds in the CG pasture (25.5 ha \pm 5.2 ha [SD]). Both a *t*-test ($t = 0.62$, 15 df, $P = 0.55$) and a 2-sample median test ($P = 0.33$) indicated that home range sizes were similar during the 1986 breeding season.

Habitat Use

Zones < 25 m from the center of a mowed strip comprised the majority of the SDG cell, while the majority of the CG pasture was zones > 50 m from

Table 1. Northern bobwhite female use of zones extending from the centers of mowed strips in the short duration grazing (SDG) and the continuous grazing (CG) systems of Welder Wildlife Refuge, San Patricio County, TX, in 1985 and 1986.

System	Zone	Area (ha)	Proportional usage		Simultaneous confidence interval
			Actual	Expected	
1985					
SDG	<25 m	112	0.679	0.579	$0.591 \leq P_1 \leq 0.767^a$
	25-50 m	42	0.252	0.219	$0.169 \leq P_2 \leq 0.333^a$
	>50 m	39	0.069	0.202	$0.021 \leq P_3 \leq 0.117^a$
CG	<25 m	79	0.585	0.295	$0.577 \leq P_1 \leq 0.593^a$
	25-50 m	37	0.148	0.138	$0.088 \leq P_2 \leq 0.210$
	>50 m	151	0.267	0.567	$0.259 \leq P_3 \leq 0.275^a$
1986					
SDG	<25 m	120	0.667	0.624	$0.611 \leq P_1 \leq 0.723$
	25-50 m	44	0.208	0.225	$0.160 \leq P_2 \leq 0.256$
	>50 m	29	0.125	0.151	$0.085 \leq P_3 \leq 0.163$
CG	<25 m	98	0.347	0.365	$0.291 \leq P_1 \leq 0.403$
	25-50 m	48	0.210	0.180	$0.163 \leq P_2 \leq 0.259$
	>50 m	121	0.443	0.455	$0.385 \leq P_3 \leq 0.501$

^a $P \leq 0.05$.

the center of a mowed strip (Table 1). For 1985, 159 SDG and 195 CG bobwhite locations were analyzed for zone use. Expected and observed numbers of locations within zones differed in the SDG cell ($X^2 = 17.41$, 2 df, $P < 0.01$) and CG pasture ($X^2 = 86.63$, 2 df, $P < 0.01$). In both grazing systems, zones <25 m from the center of mowed strips were preferred, zones >50 m away were avoided, and intermediate zones were used in proportion to availability (Table 1). For 1986, 403 SDG and 418 CG locations were analyzed. Zones were used in proportion to their availability in the SDG cell ($X^2 = 3.65$, 2 df, $P = 0.16$) and the CG pasture ($X^2 = 2.68$, 2 df, $P = 0.26$) (Table 1).

Response to the SDG Rotation

Analysis of 135 bobwhite locations in the SDG cell in 1985 regressed on the number of periods since the paddock had been grazed did not reveal a linear relationship ($r = 0.17$, $P = 0.18$). Likewise, Spearman's rank correlation showed no relationship between the number of locations and grazing status ($r_s = -0.05$, $P = 0.34$).

In 1986, 268 locations showed a linear relationship ($r = 0.26$, $P = 0.01$) with the number of periods since grazing, with increased paddock use by female bobwhite as the number of periods since grazing decreased. Spearman's rank correlation also indicated a negative relationship ($r_s = -0.29$, $P < 0.01$) between the number of locations in a paddock and its grazing status.

Mean activity area sizes before cattle were moved into a paddock (1.443 ha) and thereafter (1.586 ha) were not different ($n = 10$ females, $\bar{x} = 13$ preentry and 13 postentry locations, $P = 0.53$). Activity centers of 5 birds shifted in the same direction as the cattle were rotated, 3 centers shifted in the opposite direction, and 2 centers shifted in a neutral direction. Activity centers shifted an average of 98 m.

The same numbers of birds and locations were used to plot paired sets of activity areas and activity centers in the CG pasture. Activity area sizes averaged 1.943 and 1.954 ha and the distance between activity centers averaged 171 m. There were no differences between these values and those of the SDG cell ($P = 0.08$ and 0.10 for activity area sizes and distances between centers, respectively).

DISCUSSION

Activity Patterns

Urban (1972) and Bell (1983) reported that bobwhite mobility and home range size were negatively related to habitat quality during spring. In this study, we could not detect differences between the 2 experimental sites in distances between successive locations or in home range sizes; we speculate that habitat quality of the sites was similar. Steger (1981) reported that 20-30% more cattle may be stocked in SDG systems than

in CG systems without loss of livestock performance or deterioration of the range. We speculate that the equal stocking rates reduced differences inherent to the grazing systems that may have otherwise affected bobwhite habitat quality.

We recorded extreme movements by females following nest depredation or abandonment. In 7 instances, birds moved a greater distance immediately following nest disturbance than would be expected by inspection of 95% confidence intervals of predisturbance movement means. Urban (1972) and Lehmann (1984) indicated that females abruptly moving long distances from nest sites are probably leaving disturbed or depredated nests.

Habitat Use

Bobwhite have difficulty traveling and feeding in dense herbaceous cover (Lay 1965, Guthery 1986, Schulz and Guthery 1988). We believe that the preference for zones near mowed strips in 1985 resulted from the birds' avoidance of dense vegetation which was due to unusually wet conditions (>15 cm of rain were recorded in both April and May of that year). Cattle also used the mowed zones extensively, thus the heavier grazing and trails in and around these areas may have provided preferred habitat by exposing soil for dusting and roosting sites (Klimstra and Ziccardi 1963, Rosene 1969). We suggest that in 1985 neither grazing system was stocked heavily enough to allow full use of the rangeland by female bobwhite.

Response to the SDG Rotation

It is not surprising that the number of locations was not related to the grazing status of the paddocks in 1985. In 1983, the wettest year on record at WWR, Bareiss (1985) found that cattle rotation had no effect on bobwhite densities in the SDG paddocks. In both 1983 and 1985, vegetative cover was excessive, even in recently grazed paddocks.

In 1986, when rainfall was below average and stocking rates were increased, radio locations indicated heavier use of more recently grazed paddocks by female bobwhite. These results are similar to those of Campbell (1981) who observed more bobwhite in paddocks being grazed than in those being rested. Conversely, neither Bareiss (1985) nor Schulz and Guthery (1988) showed a relationship between bobwhite densities and cattle rotation through paddocks. In fact, Schulz and Guthery (1988) found that mean density was lowest in the paddock being grazed and highest in the paddock that had been rested for the longest

period; they suggested that bobwhite moved out of a paddock when cattle entered it.

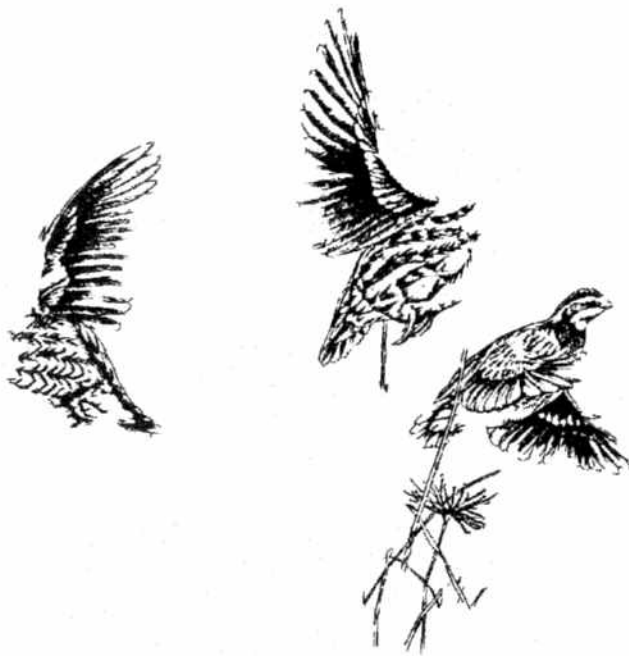
We believe that effective grazing in the SDG cell in 1986 was accompanied by heavier use of recently grazed paddocks by bobwhite females. The birds were probably responding to improved habitat quality; grazing may have improved vegetative structure (Wilkins 1987, Schulz and Guthery 1988), which allowed ease of movement and suitable sites for dusting, roosting, and nesting. While the birds benefited from vegetative changes resulting from grazing in the SDG cell, they apparently were not disturbed by the presence of the cattle. Data for 10 females suggest no change in activity area size or activity centers attributable to contact with the intensively grazing cattle. Likewise, there was no discernible pattern in direction of activity center changes in relation to cattle rotation direction.

MANAGEMENT IMPLICATIONS

Our results support Schulz and Guthery's (1988) suggestion that SDG systems have positive effects on bobwhite populations, probably because of improved vegetative structure. In this study, the major difference between the 2 grazing system sites was the increased proportion of mowed areas in the SDG cell during the abnormally wet year. Although the percentages of mowed zones on the WWR may not be representative of all SDG and CG systems, SDG systems typically contain more fencing and require more brush control than CG systems. On the WWR, brush control consisted primarily of mowing; discing and the use of chemicals are possible alternatives. In the Texas Coastal Bend, landowners unable to adjust cattle stocking rates during wet years should consider mowing or discing to improve bobwhite habitat.

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METHODS

Habitats intersected by state (total length = 24 km) and the first 24 km of federal mourning dove call-count transects within the 10 ecological areas (Gould 1975) of Texas were classified and inventoried between 20 May and 10 June 1976 from within a vehicle using methods previously described (Grue et al. 1976). Habitats were classified into 1 of the following types based on canopy height, composition, and spatial distribution: barren, cropland (grain, nongrain, forage, plowed ground), pasture and fields, shrub savannah, shrub parkland, shrubland, brush parkland, brushland, savannah, parkland, woodland, orchard, forest, or urban (detailed descriptions are in Grue 1977). Shrub savannah, shrub parkland, and shrubland containing >49% mesquite also were classified as mesquite-shrub savannah, mesquite-shrub parkland, and mesquite parkland, respectively. Habitat types containing trees (savannah-forest) were separated further based on whether the canopy was primarily (>74%) deciduous (including mesquite), mesquite, coniferous, or mixed, and the presence or absence of understory.

We also enumerated structural features within habitat types (structures or characteristics other than height, composition, and spatial distribution of the canopy) that others (reviewed by Reid [1977]) have suggested may be important as nest sites, song posts, or sources of food or grit for breeding scaled quail. Within this category we included the number of fences, shrubrows, windbreaks, powerlines, roads, and railroad rights-of-way, and whether or not these structures paralleled or intersected the transects. The number of edges (an abrupt change in the physiognomy of the vegetation excluding ecotones), permanent water sources, buildings, washes, livestock feeders and feedlots, gravel pits, and irrigation and oil pumps; the presence of snags; and the type of surface and width of the shoulder on the survey route also were noted. The position of some structural features relative to the whistle transects was recorded because those that paralleled the survey route may have provided more nesting or calling sites per unit area than those that intersected the transects. In addition, structural features (e.g., fences and roads) that intersected the survey routes may have been indicative of habitat fragmentation or differential land use and, therefore, habitat diversity. The

number of irrigation and oil pumps was included because the former may have been associated with sources of water and the latter was associated with clearings within the homogeneous shrublands of west Texas. The type of road surface on survey routes was recorded because the amount of grit, wind-blown seeds, and water runoff associated with different road surfaces may vary. We estimated the width of the shoulder on survey routes because highway rights-of-way may support vegetation important to nesting quail.

The habitat on both sides of each transect was surveyed starting 0.8 km before the first stop and ending 0.8 km after the fifteenth stop. State call-count routes consisted of only 15 stops, so only the first 15 stops of the federal routes (20 stops) were used. The linear distance of each observation of a habitat type intersecting a survey route was measured to the nearest 0.02 km.

Through the cooperation of the Texas Parks and Wildlife Department, scaled quail whistle counts were obtained for the transects. Each transect was surveyed 3 times between 20 May and 10 June 1976 (Dunks 1975). Whistle-count data were collected at 1.6 km intervals (stops) along each transect, beginning 0.5 hour before sunrise and ending 1.5 hours after sunrise. An audio count was made of the total number of quail heard whistling during a 3-minute period at each of the 15 stops along each transect. Whistle counts were not conducted if it was raining or the wind speed was greater than 3 on the Beaufort Scale.

Habitat variables significantly ($P < 0.10$) correlated with whistle counts were identified from a matrix of product-moment correlation coefficients (Barr and Goodnight 1972). Correlation analyses were conducted within ecological areas using mean whistle counts for each transect. Habitat interspersions and diversity (Shannon-Wiener Index; Shannon 1948) indices for each transect also were included as habitat variables. An index to minimum habitat interspersions (Grue 1977) based on the number of habitat types present within a transect, as well as presence or absence of each habitat type within adjacent 1.6-km intervals, was used. Crop categories were not included in the interspersions and diversity indexes because it was not possible to include cropland as a whole, and divisions thereof, within 1 index.

Significance of Correlations

Correlation analyses between habitat parameters and whistle counts within the 5 ecological areas of Texas in which whistles were heard indicated density of breeding scaled quail was correlated with habitat parameters that provided adequate food, cover, and nest sites. Habitat types which provided 1 or more of these requisites differed between ecological areas and appeared to depend on the kind, amount, and distribution of habitat types and the structural features associated with them. If any habitat type or structural feature providing 1 or more of these requisites was limited, it was usually positively correlated with whistle counts. Conversely, an excess of a habitat parameter which did not provide all these requirements was usually negatively correlated with scaled quail density. This is illustrated by the positive correlation between cropland and call counts in the Trans-Pecos and the negative correlation between this habitat type and call counts on the High Plains. In the Trans-Pecos, nesting substrate was abundant, whereas sources of food and water were generally restricted to cultivated areas. Cropland comprised less than 1% of the Trans-Pecos (Grue 1977). The opposite was true on the High Plains, where food and water were more abundant (cropland comprised more than 76% of the area), but nest sites within woody vegetation were limited.

By chance ($P < 0.10$), some spurious correlations between habitat variables and whistle counts may have surfaced in our study. We also recognize that significant correlations do not necessarily represent causation. This is illustrated by the positive correlation of irrigation and oil pumps with whistle counts in the Trans-Pecos. We do not suggest that these structures are needed by breeding scaled quail. However, the presence of irrigation pumps suggest that sources of food (cropland) or water were nearby; cropland was positively correlated with whistle counts in this ecological area. Oil pumps were often associated with the only clearings in the extensive shrublands in the Trans-Pecos and growth of grasses and forbs on the disturbed areas may have provided food for nesting quail. That mourning dove (*Zenaida macroura*) call counts also were positively correlated with irrigation and oil pumps within the Trans-Pecos (Grue et al. 1983) suggests the correlation was not spurious.

Comparisons Between Ecological Areas

Shrubland appeared to be the most important habitat type associated with scaled quail whistle counts. It was positively correlated with whistle counts in all regions except the Trans-Pecos. In the Trans-Pecos it was negatively correlated; however, this is misleading. In the Trans-Pecos, shrubland comprised greater than 50% of habitat types intersecting the transects, and whistle counts along these transects averaged twice those of any other ecological area, indicating the importance of shrubland. Schemnitz (1961) observed that plants having a shrubby growth form were used frequently by scaled quail and provided the overhead shelter that was apparently essential to quail welfare. Wallmo (1957) noted the majority of scaled quail habitat in Texas was characterized by low shrubs. Schemnitz (1961) noted where suitable shrub cover was lacking or very restricted, scaled quail made use of man-made structures. He further stated that shrubs and man-made structures were essential components of the regional habitat of quail in Cimarron County, Oklahoma. Stebler and Schemnitz (1955) observed that habitat constituting the shrub life-form and certain kinds of artifacts usually found around farmsteads comprised the regional habitat of scaled quail.

Shrubland was negatively correlated in the Trans-Pecos not because it was unimportant, but because mixed mesquite shrubland associated with wetter areas was of even greater importance to scaled quail populations. It stands that shrubland is the 1 most important habitat type for scaled quail. Changes in this type such as openings created by man or diversity created by nature only add a more positive effect to scaled quail numbers. However, if these changes are too great, populations decrease.

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SCALED QUAIL HABITATS REVISITED—OKLAHOMA PANHANDLE

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Abstract: Scaled quail (*Callipepla squamata*) populations declined 50% from 1954-56 to 1990-91 in a 125 km² study area. Food habits based on a sample of 150 quail crops remained unchanged. Abandonment of farms, land use, and climatic changes were hypothesized to be major factors responsible for the population decline.

Key words: *Callipepla squamata*, food habits, habitat, population, scaled quail.

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The idea for this paper was triggered by a similar effort by Leedy (1987), who returned after 45 years to his Ohio haunts and documented total disappearance of ring-necked pheasants (*Phasianus colchicus*) and most pheasant habitat. Leedy attributed the loss of pheasants primarily to deterioration in habitat because of changing agricultural land-use practices. I returned to Cimarron County, Oklahoma, after an absence of 34 years to evaluate possible changes in scaled quail populations and distribution since previously reported by Schemnitz (1961).

STUDY AREA

Cimarron County, the most westerly county in the Oklahoma Panhandle, is primarily grassland and agricultural farmland. The intensive main study area was in the sandsage (*Artemisia filifolia*)-grassland community. The area features rolling dune-like topography with calcareous, deep sandy, well-drained soils. Other common shrubs are soapweed (*Yucca glauca*), skunkbush (*Rhus trilobata*), and sand plum (*Prunus watsonii*). Sand bluestem (*Andropogon hallii*), big sandgrass (*Calamovilfa gigantea*), switchgrass (*Panicum virgatum*), and needle and thread grass (*Stipa comata*) are the principal tall grasses. Mid grasses include sand dropseed (*Sporobolus cryptandrus*) and field sandbur (*Cenchrus pauciflorus*). False buffalo grass (*Munroa squarrosa*), sand paspalum (*Paspalum stramineum*), and blue grama (*Bouteloua gracilis*) compose the main short grasses. Common forbs include western ragweed (*Ambrosia psilostachya*), Texas croton (*Croton texensis*), sand lily (*Mentzelia stricta*), buffalo-bur (*Solanum rostratum*), and Russian thistle (*Salsola kali*).

The climate is semiarid, characterized by hot summers and relatively mild winters. Average annual precipitation is 42.7 cm. The altitude is 1,281 m.

METHODS

Field reconnaissance of previously verified (1954-56) occupied home ranges was undertaken during late December of 1990 and 1991 on a 125-km² sandsage-grassland study area. Observations of scaled quail and their tracks in the sand and snow were used to determine presence of quail. Covey size was determined from direct observation. A thorough reconnaissance of the study area was made on foot with the assistance of a trained bird dog.

Scaled quail crops were collected from hunters to determine food habits during the early winter of 1990-91 and 1991-92. Every effort was made to contact active hunters via the local Boise City (a small town with a population of 1,509) "grapevine" and the game warden to maximize the quail crop collection total. Due to the small sample size, these data were pooled by vegetation type and year. I used the aggregate volume technique to measure foods as described by Martin et al. (1946). Statistical significance was accepted at $P < 0.05$.

RESULTS

Population Changes

A population decline from 587 (SE = 26) quail (mean for 1954-56) to 293 (SE = 21) in 1990-91 was noted, which represents a decrease of 50% (Fig. 1). Six of 17 previously occupied home ranges

declined from 45 to 13 ($t = 1.75$, $P = 0.18$, $df = 3$). One of the abandoned home ranges around some occupied buildings had several house cats (*Felis domesticus*) present. The other range, formerly in farmland, was now a housing development on the edge of Boise City.

Foods

I found little change in the main foods of scaled quail between the 2 study periods (Table 1). Twelve of the top 20 foods in the 1954-56 sample also were in the top 20 of the 1990-91 sample (Schemnitz 1961). The top 5 foods in 1954-56 comprised 56.5% of the diet by volume while these same 5 foods totaled 46.4% in the 1990-91 sample. Insect volumes of 4.8 (1954-56) and 4.2% (1990-91) remained similar ($P > 0.05$). Forb seeds totaled 62.4 (1954-56) and 57.6% (1990-91) of the diet and showed little difference between sample periods. Grain (sorghum, corn, wheat) which made up 24.7% of the 1954-56 sample and 33.9% of the 1990-91 diet did not differ ($P > 0.05$). Only 3 of 50 foods, (0.6%) in 1990-91 were not found in the 1954-56 crop samples, and they were all in trace amounts. The major difference was the low use of Russian thistle, 1.6% volume in 1990-91 versus 15.1% in 1954-56. The average number of food items per crop in 1990-

91 of 7.1 was nearly identical to the 7.0 for 1954-56 ($P > 0.05$).

DISCUSSION

Habitat Changes

A notable difference in habitat conditions in recent years is the retirement of cultivated land under the Conservation Reserve Program (CRP) in Cimarron County. Farmlands in the CRP totaled 59,896 ha during 1990 (Soil Conservation Service, pers. commun.); this represents more than double those in 1987 (28,653 ha in the CRP). In contrast, only 7 farms had 621 ha in unharvested cover crops in 1959. Active farmland acreage declined 33.8% between the past, 1954-56, and present, 1990-91, periods of this study.

Most CRP fields were revegetated with dense weeping lovegrass (*Eragrostis curvula*) with some old world (*Bothriochloa* sp.) and little bluestem (*Schizachyrium scoparius*), Indian (*Sorghastrum nutans*), and switchgrass. These grasses provide some quail cover, but little food. Scaled quail nest in a large variety of habitats (17 total, Schemnitz 1961). In 1954-56, only 1 nest of 50 was found in a dense grass habitat similar to the CRP. In contrast to pheasants, scaled quail may derive few benefits from CRP retired fields.

Table 1. Summary of 20 main foods eaten by scaled quail based on the analysis of 150 crops collected December 1990 and 1991, Cimarron County, OK.

Food	Freq.	% freq.	Volume (cc)	% volume
<i>Triticum aestivum</i>	35	23	82.8	20.2
<i>Helianthus</i> sp.	120	80	62.3	15.2
<i>Amaranthus</i> sp.	121	81	59.8	14.6
<i>Mentzelia stricta</i>	101	67	52.4	12.8
<i>Sorghum vulgare</i> (milo)	97	65	41.3	10.8
Insects	28	19	17.4	4.2
<i>Ambrosia psilostachya</i>	73	48	16.1	3.9
<i>Croton</i> sp.	51	34	13.1	3.2
<i>Zea mays</i>	17	11	12.3	2.9
<i>Heterotheca subaxillaris</i>	58	39	8.6	2.1
<i>Salsola kali</i>	45	30	6.5	1.6
<i>Polanisia trachysperma</i>	16	10	6.5	1.6
<i>Sorghum halepense</i>	66	44	4.3	1.1
Green herbaceous vegetation	30	20	4.0	1.0
<i>Grindelia squarrosa</i>	9	6	3.6	0.9
<i>Paspalum stramineum</i>	31	21	3.0	0.7
<i>Solanum rostratum</i>	12	8	2.7	0.6
<i>Kochia scoparia</i>	6	4	2.6	0.6
<i>Psoralea tenuiflora</i>	4	3	2.2	0.5
<i>Cenchrus</i> sp.	7	5	1.2	0.3
Total			402.7	98.8

Comparative acreage of total cropland (including CRP) and rangeland in Cimarron County have not changed (Table 2). Also, average farm size has increased only slightly. Cropland patterns have varied, with less acreage in sorghum while wheat acreage has remained the same (USDC 1954, 1987).

Number of farms decreased from 616 in 1950, to 559 in 1954, and to 448 in 1987. Many active farmsteads occupied in the 1950's have been abandoned, thus livestock and grain feeding no longer occur. Sasser (1991) documented the decline of bobwhite with the disappearance of small farms in east Texas.

Food Habits

Scaled quail consume a more diverse diet than northern bobwhite (*Colinus virginianus*) (Campbell-Kissock et al. 1985, Rollins 1981, Schemnitz 1964). Scaled quail in the winter in western Oklahoma continue to use agricultural grains and forbs that thrive under livestock grazing conditions. They showed high energy utilization and weight maintenance when fed sorghum, sunflower, and amaranth seeds (Saunders and Parrish 1987). All of these are important quail foods.

Hunting Pressure

Hunting mortality does not seem to be a major factor in the scaled quail population decline in this area. Empirical data on numbers of active local quail hunters suggest a decline in quail hunting. Availability of crops from hunters is a rough index of hunting pressure and success. During the 1954 and 1955 hunting seasons 9 hunters contributed 50 or more scaled quail crops (minimum 450). During the recent study 150 crops were contributed by 4 hunters.

Hunting interest and pressure seem to have switched from scaled quail to pheasants. While quail populations have declined, pheasant numbers have increased as exemplified by season lengths. During 1954 and 1955 pheasant hunting seasons were 2 days in length, while the 1956 hunting season lasted 3 days. In contrast the pheasant hunting season length was 32 days in Cimarron County in 1991-92.

Climate Change

Climatic factors influence quail populations by affecting vegetative vigor, composition, growth, and reproductive success (Campbell et al. 1973).

Table 2. Changes in land-use practices, Cimarron County, OK.

Land use	Time period	
	1954	1987
Farmland (ha)	179,345	178,534 ^a
No. of farms	559	448
Average farm size (ha)	794	889
Cows and calves	39,323	90,756
Acres planted sorghum	48,554 (391) ^b	32,217 (247)
Acres planted wheat	37,270 (339)	39,909 (300)

^aIncludes Conservation Reserve Program acreage.

^bNumber of farms (USDC 1954, 1987).

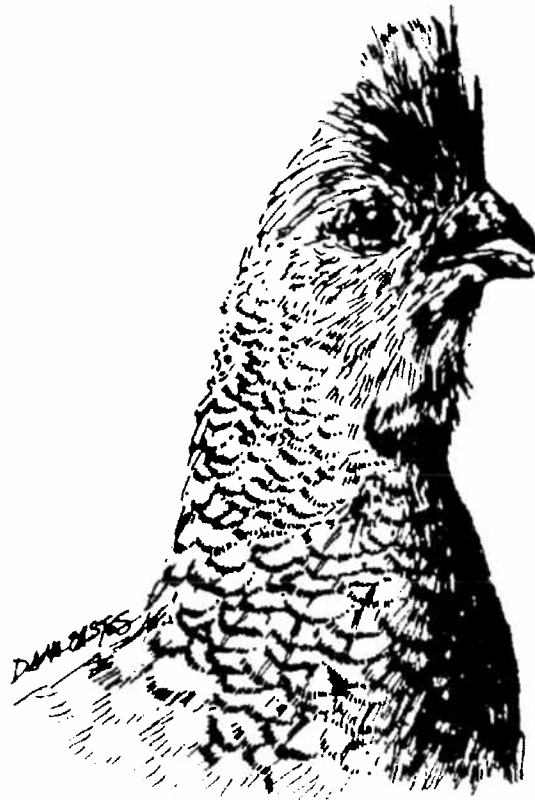
During the period of my original study, a severe drought existed (-42.5% deviation from mean annual precipitation). Despite seemingly adverse climatic conditions, scaled quail populations thrived (Schemnitz 1961). In contrast, climatic data for 1981-91 at Boise City, Oklahoma, showed a mesic trend with precipitation 19% above normal (\bar{x} = 50.8 cm 1981-91). In only 1 year, 1983, was precipitation slightly below the norm of 42.7 cm.

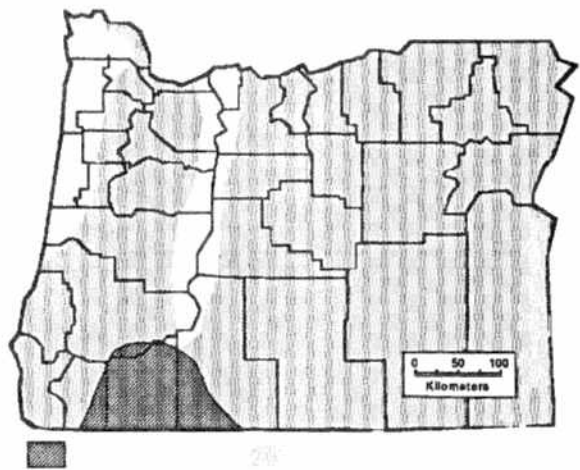
Scaled quail are a xeric-adapted species. They thrive in the vicinity of Las Cruces, New Mexico, with an average annual precipitation of 21.6 cm (N.M. Dep. Game and Fish 1967). Perhaps in western Oklahoma they do not thrive under the mesic conditions that occurred in 1981-91.

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and I have undertaken a number of studies to better understand the biology and ecology of California quail in western Oregon. The objective of this paper is to provide a synthesis of these studies and to elucidate management implications of the investigations.

During the past 18 years, California quail research was conducted on lands administered by the Oregon Department of Fish and Wildlife to whom I am genuinely grateful for their cooperation. K. L. Blakely, K. M. Kilbride, and R. M. Oates were responsible for much of the data collection and analysis. The U.S. Environmental Protection Agency, the Mzuri Wildlife Foundation, and the National Rifle Association supported portions of the work reported herein.

STUDY AREA

Investigations used as the basis for this paper were conducted on the 650-ha E. E. Wilson Wildlife Area (Wilson WA), located 16 km north of Corvallis, Benton County, Oregon. During the 1940's, this site served as an extensive military base but was abandoned and buildings removed by 1950; the system of approximately 25 km of paved roads was left intact. When secondary succession began in approximately 1950, the area resembled a rather typical housing development but only the foundations of barracks, offices, and other buildings remained. Rainfall averaged 108 cm from 1951 through 1989.

Management activities on the study site included: burning of 40-55 ha areas annually on a rotational basis from 1953 through 1967 and 2-49 ha from 1980 through 1989; establishment of 24 food plots, averaging 0.7 ha, which were gradually eliminated by 1989; disking of plots (<5 ha) and strips throughout the area from 1988 through 1992; farming operations, primarily wheat and grass seed production on as much as 120 ha, which were terminated in 1988; and installation of 4 gallinaceous guzzlers.

When my work began, the Wilson WA was composed of shrub/grassland (67%); cultivated areas (18%); woodlands (8%); and roads, graveled roadsides, and concrete foundations (7%). Shrub/grassland areas were dominated by blackberries, Scot's broom, rose (*Rosa* spp.), fescue (*Festuca* spp.), oxeye daisy (*Chrysanthemum leucanthemum*), thistle (*Cirsium* spp.), wild carrot (*Daucus carota*), Klamath weed (*Hypericum perforatum*), tarweed (*Madia sativa*), vetch, and teasel (*Dipsacus sylvestris*). Approximately 85% of shrub cover in shrub/grassland habitat was

composed of blackberries (Crawford 1978). The most commonly cultivated crops included ryegrass, wheat, orchardgrass, and fescue. Two stands of Oregon white oak (*Quercus garryana*) were present on the Wilson WA. Other common trees included Oregon ash (*Fraxinus latifolia*), black cottonwood (*Populus trichocarpa*), black hawthorne (*Crataegus douglasii*), willow (*Salix* spp.), and apple (*Pyrus malus*). The remaining portion of the area was composed of a complex system of asphalt roads, graveled ditches and parking lots, and the concrete remains of numerous buildings. A critical assumption of our studies was that habitat use by quail on the Wilson WA was characteristic of use by these birds throughout the Willamette Valley and representative of use in other mesic regions.

QUAIL POPULATIONS

Long-term (approximately 30 years) trends of California quail in the Willamette Valley indicated rather stable populations (Kilbride et al. 1992). On the Wilson WA, however, population indexes collected by the Oregon Department of Fish and Wildlife from 1953 through 1976 revealed that the population declined. This decrease in quail numbers was attributed to the advance of plant succession in the area because of the inverse relationship of quail abundance ($r = -0.58$) to time (Crawford 1978). Subsequently, fall populations increased from approximately 250 birds in 1976 (Crawford and Oates 1986) to an estimated 400 birds in 1990 (unpubl. data). Breeding density for 1988 and 1989 was approximately 1 bird/5 ha (Kilbride et al. 1992). Since 1975, immatures composed 62-80% of fall populations on the Wilson WA (Crawford 1986 and unpubl. data). Throughout the semiarid portion of their range, California quail typically exhibit great variations in annual productivity; Leopold (1977:115-118) noted young in fall populations in California ranged from 4 to 81%.

Weather factors may influence productivity and survival of California quail in western Oregon. Hatching chronology at the Wilson WA (Crawford 1986) was related to total precipitation during May and June (e.g., the greater the amount of precipitation, the later the hatching date). Furthermore, a 3-week period of unusually high rainfall in July 1976 was associated with a lapse in hatching. In comparison, Raitt and Genelly (1964) found that high amounts of rainfall during January through March in northern California were related to delayed hatching.

Heavy rainfall and cold temperatures apparently affected quail survival at the Wilson WA during winter 1977-78. Indexes to abundance during that period decreased substantially compared with the previous year (Oates and Crawford 1983), and sex and age ratios shifted strongly to favor males and adults (Crawford and Oates 1986). Browning (in Leopold 1977) noted that rainfall was a major factor influencing availability and nutrient content of key foods and commented that inadequate amounts of rainfall were not conducive to high populations. Consequently, annual variations in productivity may relate to diet and ultimately to precipitation.

FOODS AND DIETARY PREFERENCES

Diets of California quail and availability of foods on the Wilson WA were examined seasonally from winter 1975 through summer 1978 (Oates 1979, Oates and Crawford 1983) and from winter 1985 through fall 1987 (Blakely et al. 1988, Blakely 1990). Crops from 222 quail were examined. Three measures were used to assess importance of individual foods in the diet: (1) percent frequency of occurrence in crops; (2) relative percent dry mass; and (3) relative preference indexes (RPI), frequency of occurrence in crops (%) ÷ frequency of occurrence in available habitat (%) (see Van Dyne and Heady 1965).

The composite annual diet was comprised of 70% forbs, 21% shrubs/trees, 8% grasses, and 1% invertebrates on the basis of relative mass. Among the most frequently occurring foods in the diet (Table 1) were vetch-67%, wild carrot-58%, teasel-37%, and dandelion (*Taraxacum officinale*, *Hypochoeris radicata*, and similar milky-juiced composites of the Cichorieae)-36%. Of 53 plant taxa in the diet of California quail, 4 legumes contributed >60% of the relative dry mass of the diet: deervetch-20%, peavine-16%, Scot's broom-16%, and vetch-11% (Table 1). Collectively, legumes contributed 67% of the relative mass of the diet (Blakely 1990). Among foods with the highest preference indexes (Table 1) were peavine, deervetch, and clover (*Trifolium* spp.). Five of these 8 most important foods were legumes and all were introduced forbs or escaped crops. Blackberry, apple, and sorrel (*Rumex* spp.) were seasonally common plants in the diet of California quail (Oates and Crawford 1983, Blakely 1990). All grasses combined occurred in 60% of crops but amounted to only 8% of the relative mass of the diet. Sudan grass and wheat,

the only cultivated crops in the diet, had frequencies of 5% each during 1976-78 but, except for a small amount of wheat placed at feeding stations, were not available on the area during 1985-87. Remaining plant foods were found infrequently in the diet and collectively contributed 12% of the mass. Relative availability of primary plant foods was similar between 1976-78 and 1985-87 (Blakely 1990).

Invertebrates occurred with an annual frequency of 51% and ranged from 37% in fall to 80% during summer, but contributed only 1% of the diet by mass (Blakely et al. 1988). Fifteen invertebrate groups were represented in the diet but 4 composed 87% of the relative mass of invertebrate matter: ants (Hymenoptera)-27%, grasshoppers (Orthoptera)-22%, moths and butterflies (Lepidoptera)-20%, and beetles (Coleoptera)-18%. Ants and beetles occurred with the highest annual frequencies, 34 and 20%, respectively.

Leopold (1977:172-174) summarized dietary studies of California quail from much of their California range and concluded that diets were diverse and differed with location. Legumes, filarees, and grasses constituted 70% of diets in California, and invertebrates made up 1-6% of the diet. Legumes commonly constitute 25-35% of the diet (Edminister 1954:314), but Shields and Duncan (1966) found that legumes composed 60% of

Table 1. Frequency of occurrence, relative mass, and mean relative preference indexes (RPI) of foods of California quail, E. E. Wilson Wildlife Area, OR, 1975-78 and 1985-87 (from Oates 1979 and Blakely 1990).

Food	Frequency (%)	Mass (%)	RPI ^a
Vetch	67	11	2
Wild carrot	58	4	2
Teasel	37	2	3
Dandelion	36	1	6
Sorrel	28	1	8
Deervetch	26	20	17
Peavine	26	16	19
Scot's broom	24	16	5
Blackberry	24	2	1
Apple	22	3	5
Clover	20	2	11
Other forbs	—	12	—
Other shrubs/trees	—	1	—
Grasses	60	8	—
Invertebrates	51	1	—

$$^a\text{RPI} = \frac{\% \text{ frequency of occurrence in diet}}{2\% \text{ frequency of occurrence in foraging habitat}}$$

plants, particularly in disked areas, roadsides, or sites of compacted rock with escape cover (typically blackberries) within 10 m. California quail also foraged on plants used for roosting and loafing; among these plants, blackberries, apple, and Scot's broom were the most common.

In a study of seasonal relationships between population abundance of California quail and habitat characteristics, Oates and Crawford (1983) found quail numbers were positively related to amounts of forb cover, especially legumes (excluding vetch, which was widely available), dandelions, and wild carrot. Quail abundance was negatively related to amount of grass cover. In California, McMillan (1964), Francis (1970), and Leopold (1977:175) noted direct relationships between quail productivity and forb abundance.

HABITAT MANAGEMENT TECHNIQUES

Numerous techniques were used to manage California quail on the Wilson WA; 3 of these methods (disking, food plots, and wheat plantings) were evaluated (Oates and Crawford 1983). Twelve 16.2-ha plots were established on the Wilson WA: 3 had disked areas of 2.4 ha, 3 were planted with 0.4-ha plots of sudan grass and corn (food plots), 3 had 3-6 ha wheat plantings, and 3 were controls. Abundance (seasonal transects) and productivity (summer production routes) of quail were used to evaluate the merits of each management technique. Disked areas supported the most birds on a year-round basis (Table 3). Productivity was highest on disked areas; the fewest young hatched on food plots and wheat plantings. The fewest breeding adults were present on wheat plantings. The initially favorable response of quail populations to diskings, however, lasted only approximately 1 year (Oates and Crawford 1983).

Responses of key habitat components, primarily food, were evaluated for diskings (Oates and Crawford 1983, Blakely et al. 1990) and prescribed burning (Blakely et al. 1990) as management techniques. Key foods that responded positively (measured as percent cover) to diskings treatment included deervetch, vetch, clover, wild carrot, dandelions, and sorrel. Grass cover declined in response to diskings; no key trees or shrubs were evaluated. No changes in the amount of cover of peavine and teasel were noted after diskings. Blackberries, clover, and vetch responded positively to burning; however, teasel, wild carrot, and dandelions seemingly were unaffected. Grass cover also declined after burning. Bare ground increased to 20 (burned)-40% (disked) of total ground cover immediately after treatments. Bare ground, however, returned to pretreatment levels of $\leq 4\%$ within 2.5 years of treatment. Cover of key vegetative features that initially responded positively to treatment returned to control levels within 3 years (Blakely et al. 1990).

IMPLICATIONS

Results of these studies implied that abundance and productivity of California quail in western Oregon were related closely to vegetative communities, particularly to certain exotic plants, and the stage of plant succession. Stands with abundant food supplies of largely exotic species of legumes (deervetch, peavine, vetch, Scot's broom, and clover) and several other groups (wild carrot, teasel, sorrel, and dandelions) and adequate amounts of cover (also of primarily introduced plants such as blackberries, Scot's broom, and apple), were favored habitats for California quail. Contrastingly, areas with dense stands of grass, in the form of either agricultural fields (e.g., ryegrass or fescue) or naturally occur-

Table 3. Abundance and productivity of California quail on treatment and control sites, E. E. Wilson Wildlife Area, OR, 1976-78 (from Oates and Crawford 1983).

Category	Number of observations			
	Disked	Food plots	Wheat plantings	Control
Seasonal transects ^a				
Birds	451	293	56	151
Summer censuses				
Adults	47	46	5	45
Chicks	71	11	11	18

^aSum of seasonal counts from winter 1976 through spring 1978.

ring stands, were used little by these birds. Bare ground is apparently another characteristic feature of California quail habitat in western Oregon. Areas of bare ground afford travel lanes for birds, serve as sites for production of early seral plants used as food by quail, and may facilitate detection of predators and allow maintenance of visual contact with conspecifics. Bare ground reflects the very earliest stages of secondary plant succession. Because abundance and productivity of quail were related to availability of key foods, land management practices that encourage these foods presumably would benefit quail. Conversely, practices that reduce availability of these important forbs, such as use of herbicides and other clean-farming techniques, may negatively impact populations.

Timing and amount of spring and summer rainfall seemingly influence quail populations in western Oregon by affecting the chronology of hatching and, to a limited extent, recruitment of young into the fall population. Quail populations in this region, however, are relatively stable in numbers and consistent in productivity compared with populations in much of California. The greater amount and consistency of rainfall in western Oregon may affect quail productivity through more consistent production of key foods.

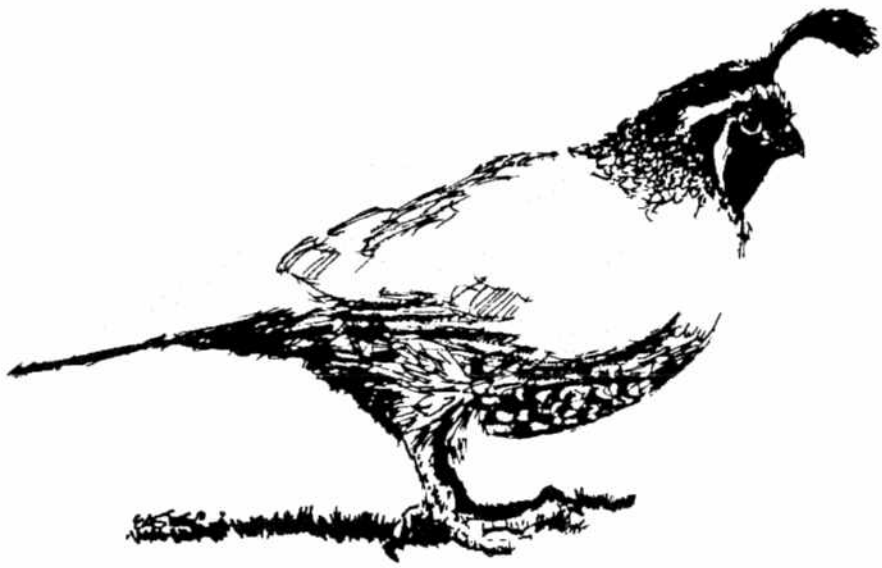
Like other species of wildlife, California quail are a product of land-use practices within their habitat. Results of our studies indicated that plantings of wheat or corn and sudan grass were not particularly beneficial for California quail and neither management method was as effective as disking in encouraging early seral forbs eaten by these birds. This work also revealed that both disking and burning encouraged production of important food forbs and, by implication, it is not necessary to seed these legumes or other food species, which are widespread throughout the Willamette Valley. Disking allows for production of more desirable foods at less cost than does planting of legumes or grains. California quail relied on blackberries to a great extent for escape, roosting, and loafing cover and secondarily for food. In the Willamette Valley, blackberries seemingly are an essential habitat component. In some areas, however, blackberries may form very large stands; in these cases, thinning of blackberries by bulldozing or burning may be desirable to achieve a favorable balance of food and cover. Blackberries are common landscape features in the Willamette Valley and form hedges along ditches, fencerows, and railroad tracks. Commonly,

areas typically support quail populations but often are lacking in abundant year-round food supplies. Disked strips (no more than 2 m wide) between blackberry stands and agricultural crops will provide proportions of food and cover capable of supporting larger populations of California quail.

Our studies revealed that California quail at the Wilson WA were associated with early stages of plant succession and relied heavily on introduced plants for food and cover. Reliance on early seral and nonnative vegetation for primary food and cover needs may explain why these birds that evolved in semiarid lands were not native inhabitants of the Willamette Valley.

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SYMPOSIUM WRAP-UP: WHAT IS MISSING?

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Abstract: The program committee requested that I provide a symposium wrap-up. Generally such presentations provide 1 individual the opportunity to summarize and integrate the information presented during the meeting. That overview is often helpful, if there are several concurrent sessions or if most of the attendees spend their time interacting in the hallways and, thus, miss some of the presentations. Also, the wrap-up speaker can congratulate the organizers of the meeting for a job well done. I intend to neither summarize the information presented nor thank the organizers for doing a good job. Neither of these is necessary, because you all attended the majority of presentations and can summarize and integrate the data in your own head; the fact that the sessions were so well attended attests to an extremely good job done by the organizing committee. So, rather than doing what is not necessary, I intend to discuss what was missing in this symposium, the problems that were not addressed in the papers, and the data gaps that must be filled if we are to successfully manage quail populations in North America. From my perspective, these fall into 6 categories.

Citation: Robel, R. J. 1993. Symposium wrap-up: what is missing? Pages 156-158 in K. E. Church and T. V. Dailey, eds. Quail III: national quail symposium. Kansas Dep. Wildl. and Parks, Pratt.

Predation and Hunting

When most of us attended college to receive our professional training, we were taught that predators fed on the sick, the old, and the weak. In fact, we were taught that predators were beneficial to wildlife populations, because they removed the less fit individuals. Certainly, we were never taught that predators were harmful to the well-being of wildlife populations, i.e., predators merely removed excess individuals from the population, those that would most likely die anyway. We were also taught that humans acted similarly to predators and removed surplus game when they hunted during legal seasons. Hunting mortality was compensatory mortality, "Hunters kill those animals that would have died naturally; therefore, hunting does not adversely affect wildlife populations." Research conducted during the past 2 decades does not entirely support these concepts. Predators can severely impact wildlife populations, especially ground-nesting birds. And, legal hunting mortality can eat into the breeding stock of wildlife populations by being additive rather than compensatory. These deleterious impacts are normally more likely to occur as quality habitat decreases and habitat fragmentation becomes more widespread. In today's setting, what are the effects of predation and hunting on North American quail populations?

Diseases and Parasites

We also were taught that diseases and parasites, like predation and hunting, seldom were problems for wildlife populations in good habitats. That may have been the case 30 years

ago; however, wildlife populations are no longer in unaltered high quality habitats. We are restricting wildlife populations to isolated habitats; contaminating their habitats with agricultural chemicals and industrial pollutants; invading their pristine ranges with homes, roads, and other bits of civilization; upsetting their gene pools by introducing exotic species and transplanting game animals; and forcing wildlife to mingle with domestic livestock as we expand our use of the remaining habitat. How do these events alter the effects of pathogenic organisms on wildlife? How does the stress of human intervention alter the immunosuppression systems of game species? Specifically, what are the effects of the above alterations on susceptibility and vulnerability of quail to diseases and parasites, and how do these factors alter the reproductive responsiveness of North American quail?

Habitat Loss

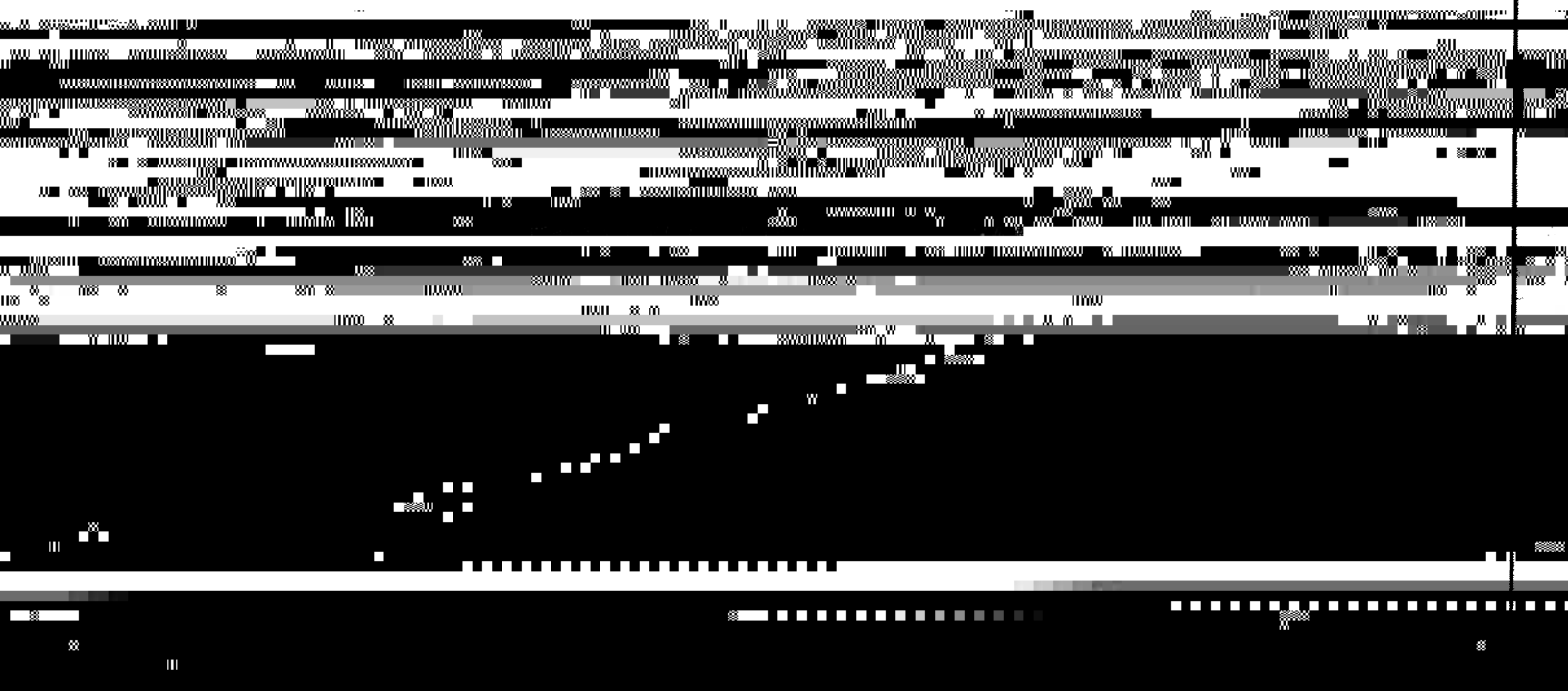
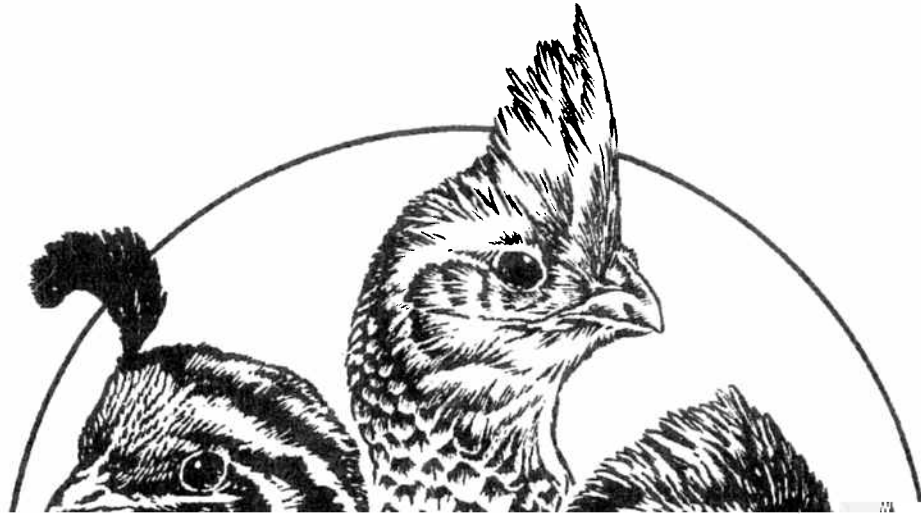
We are all aware of the loss and alterations of habitat for quail in North America. Farm sizes are increasing, urban expansion is widespread, agricultural practices are changing, vegetative composition in agricultural and forest areas has been altered by herbicide applications, and insect populations have been drastically reduced and/or changed in composition by insecticide use. Long-term studies have not been conducted to determine effects of these events on wildlife populations at the local level, much less at the national level. What are the effects of habitat alteration and fragmentation on quail populations in North America?

WHAT NEEDS TO BE DONE?

Each of the preceding areas needs to be addressed before we can knowledgeably manage the quail populations of North America. I believe we all agree that some North American quail populations are declining and, unless efforts are made to reverse those trends, viable quail populations that can withstand moderate hunting mortality will not be widespread. We can liken some quail populations to a patient in declining health. The symptoms of declining health in our quail populations are declines in numbers and reduced ability to quickly recover from low population levels. Releasing pen-reared birds into the environment is treating the symptoms, not curing the patient. We must fully understand the cause of the problem, then correct it. Essentially we must cure the patient of the disease not merely bandage the injury. However, to do so requires that we address

each of the 6 issues that we did not address in this symposium. It will not be an easy task, nor can we expect to accomplish the job in 2 or 3 years. Some quail populations have been on the decline for more than 2 decades; it will require at least that amount of time to understand the causes of those declines and institute corrective measures to reverse the trends. There is so much to do, and so little time. If we do not begin now, the huntable quail populations of North America will be only memories or historical anecdotes by the early part of the 21st Century. Each of us has a role to play in the battle to preserve viable quail populations in North America. State and federal agencies, private organizations, biologists, and sportsmen and sportswomen must coordinate their efforts in this important task. To do otherwise is to abrogate our responsibility.





APPENDIX A. STRATEGIC PLANNING WORKSHOP

STRATEGIC PLAN FOR QUAIL MANAGEMENT AND RESEARCH IN THE UNITED STATES: INTRODUCTION AND BACKGROUND

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Abstract: I assessed the current, broad-scale status of populations, research, and management for 6 species of quail in the U.S., and used this information as an introduction, background, and justification for a national strategic planning effort for quail management and research. Long-term (1960–89) trends determined from Christmas Bird Count data indicate that California quail (*Callipepla californica*), northern bobwhite (*Colinus virginianus*), and scaled quail (*Callipepla squamata*) populations have undergone ($P < 0.05$) declines. Geographic distribution of mountain quail (*Oreortyx pictus*) has contracted dramatically in the northeastern portion of this quail's range. Neither Gambel's (*C. gambelii*) nor Montezuma quail (*Cyrtonyx montezumae*) showed evidence of long-term increases or decreases. Wildlife professionals have apparently paid scant attention to quail in the U.S. during the past 10 years. A recent survey of *Wildlife Review* indicated <0.2% of the publications pertained to quail. During 1990, <1.0% of Federal Aid in Wildlife Restoration funds were allocated to quail-related projects. Habitat management by the private sector is apparently having little broad-scale impact on bobwhite populations. Contemporary quail management efforts in the U.S. are clearly in the doldrums and in dire need of leadership from professionals with a creative vision for solving problems caused by changing land-use practices. These factors point to a critical need for a national strategic planning effort to develop a comprehensive, coordinated program for quail management and research. An outline of the structure of the Strategic Planning Workshop that was held at Quail III is provided. Specific management and research problems and associated strategies for solving them are available in Issues and Strategies, which follows (page 181).

Key words: California quail, *Callipepla californica*, *C. gambelii*, *C. squamata*, Christmas Bird Counts, *Colinus virginianus*, *Cyrtonyx montezumae*, Federal Aid in Wildlife Restoration, Gambel's quail, literature, management, Montezuma quail, mountain quail, northern bobwhite, *Oreortyx pictus*, population trends, scaled quail.

Citation: Brennan, L. A. 1993. Strategic plan for quail management and research in the United States: introduction and background. Pages 160-169 in K. E. Church and T. V. Dailey, eds. Quail III: national quail symposium. Kansas Dep. Wildl. and Parks, Pratt.

Quail that are native to the conterminous 48 states (Table 1, Fig. 1) clearly hold the fascination of hunters and naturalists. Settlers from Europe brought with them a rich tradition of hunting "partridges" and adapted these rituals to the different species and habitats of game birds they encountered in the New World. Quail hunting style reached the highest levels of sophistication in the southeastern United States where vast tracts of land were, and in some places still are, intensively managed for northern bobwhite. There once was a time when good quail hunting was available, virtually free of charge, to anyone who lived within the southern half of North America. Today, unfortunately, this is not the case. Changing patterns of land use have had a dramatic, and mostly negative impact on virtually all species of North American quail. Modern agriculture and forestry practices, and the ever-increasing expansion of suburbanization, have

Table 1. Common and scientific names of quail addressed in this plan.^a

Common name	Scientific name
California quail	<i>Callipepla californica</i>
Gambel's quail	<i>Callipepla gambelii</i>
Masked bobwhite	<i>Colinus virginianus ridgwayi</i>
Montezuma quail	<i>Cyrtonyx montezumae</i>
Mountain quail	<i>Oreortyx pictus</i>
Northern bobwhite	<i>Colinus virginianus</i>
Scaled quail	<i>Callipepla squamata</i>

^aMaps of geographic ranges provided in Fig. 1.

taken a tremendous toll on populations of native quail.

This paper assesses the current status of 6 species of quail in the United States (Table 1, Fig. 1). My objectives are to assess: (1) research trends, (2) effort and funding allocated to quail management by federal and state agencies and the private sector, (3) broad-scale population trends, and (4) the role of quail in the larger scheme of wildlife management and research during the

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1990's. I also provide a background for issues and strategies addressed beginning on page 181.

This paper is dedicated to my mentor, colleague, and friend Stephen E. Wright, who inspired me to pursue a career in the natural resource sciences. Special thanks are extended to K. E. Church, T. V. Dailey, and the Quail III Program and Steering Committees for the opportunity to develop this material. K. E. Church and W. E. Mancini provided key editorial guidance in structuring the content of both this paper, and the companion paper on issues and strategies. Comments by R. W. Dimmick, G. A. Hurst, B. D. Leopold, J. L. Roseberry, and R. J. Gutiérrez were also very helpful. Support was provided jointly by the Department of Wildlife and Fisheries at Mississippi State University; the Mississippi Department of Wildlife, Fisheries and Parks; the Oktibeha Chapter and the National Office of Quail Unlimited. J. Lowe of the Cornell Laboratory of Ornithology kindly provided the computerized version of Christmas Bird Count (CBC) data. J. Heard of the Department of Information Services at Mississippi State University drew the figures. J. M. Lee, R. S. Fuller, and S. W. Manley assisted in numerous ways. S. J. Stultz compiled the summary of titles on quail research from *Wildlife Review*. C. Wasson and C. Hillhouse provided secretarial support. T. L. Pruden assisted with proof-reading and provided editorial advice.

RESEARCH LITERATURE

Johnson (1983) published a summary of titles on quail listed in *Wildlife Review* from 1935 to 1982. I added to Johnson's summary by compiling an additional 9 years of titles from *Wildlife Review* to determine if there had been any change in (1) the number of papers published on quail, or (2) the percentage of wildlife literature devoted to quail during the past 9 years. Despite an explosion of wildlife-related titles during the 56 years from 1935 to 1991 (Fig. 2A), the number of papers on quail has steadily declined (Fig. 2B). Likewise, the percentage of wildlife literature on quail has undergone a nearly exponential decline from 1935 to 1982. This decline continued during the next 9 years (Fig. 2C).

Additionally, I performed a computer search of the Current Research Information System managed by the USDA Cooperative State Research Service. This data base provides computer access to research projects being conducted by scientists at Land-grant University Agricultural Experiment Stations. I searched for studies relat-

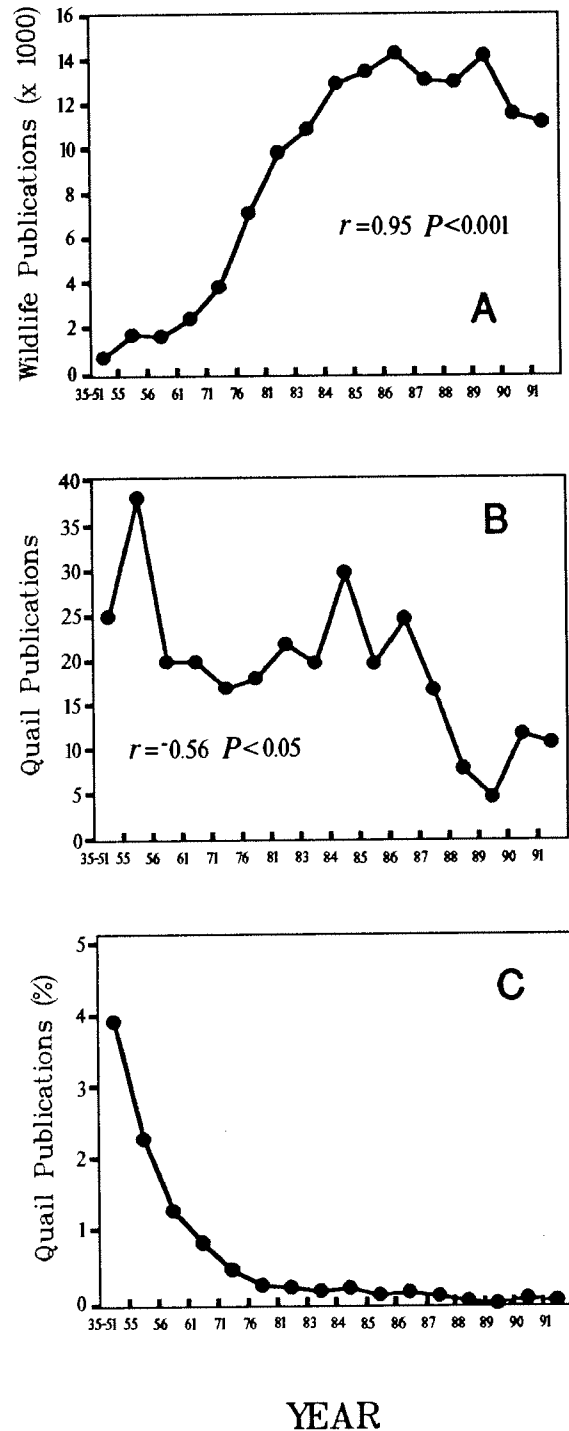


Fig. 2. Trends in publications produced from quail research projects, 1935-91, based on a survey of titles in *Wildlife Review* (WR). (A) number of wildlife publications listed in WR 1935-91, (B) number of publications on quail listed in WR, 1935-91, (C) percentage of total number of publications in WR pertaining to quail, 1935-91. Data for 1935-82 compiled by Johnson (1983), remaining data compiled for this study.

ing to quail and associated farm wildlife research conducted in agricultural environments. Of >30,000 projects, only 5 contained information that was specifically related to quail, or addressed quail-related topics in the larger scheme of farm wildlife.

MANAGEMENT

The recent summary of Federal Aid in Wildlife Restoration Activities compiled by Stephens (1990) provides a convenient window to access information on quail activities on a state-by-state basis. Although some states—such as Mississippi, Missouri, and Kansas—support or supplement quail management activities with state appropriations, Federal Aid summaries provide a good index of where quail-related projects rank in relation to other wildlife projects.

I categorized 770 Federal Aid in Wildlife Restoration projects summarized by Stephens (1990) into 8 groups (Fig. 3). Projects related to quail made up only about 3% of the number of projects supported by Federal Aid monies during 1990 (Fig. 3). Projects related to big game, and nongame and endangered species are receiving the most attention. Additionally, >\$40,000,000 were spent in 1990 for Federal Aid activities, while allocations to quail were <\$500,000, or about 1.25%.

The USDA Forest Service and USDI Bureau of Land Management are developing programs to enhance quail habitat and populations on public lands. For example, USDA Forest Service (1991) lists their "Answer the Call" program of quail habitat management as having a potential of \$2.1 million in FY 92. This 5-year program identifies 18 million ha of quail habitat on National Forest and Grasslands. Whether this program will develop into a broad-scale, cooperative program involving state wildlife agencies and private interest partners such as Quail Unlimited (QU) remains to be seen. The USDI Bureau of Land Management is also taking a serious, comprehensive look at quail and game-bird management. They have produced an impressive document (Sands and Smurthwaite 1992) outlining a program that has planned the distribution of \$45 million in funds for game-bird habitat enhancement between 1992 and 2000.

The QU organization has experienced phenomenal growth in membership and associated monies raised for habitat improvement projects during the past decade. From 1981 to 1991, membership soared from 1,000 to nearly 45,000 (QU National Office, unpublished data,

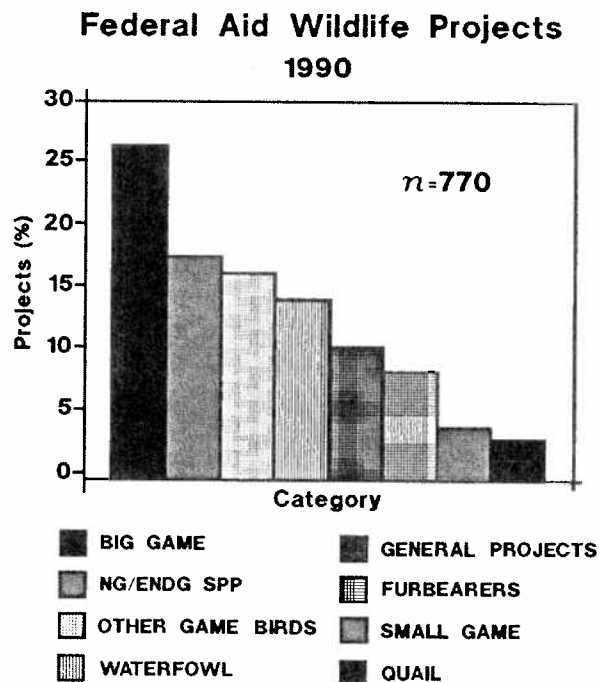


Fig. 3. Categories of Federal Aid in Wildlife Restoration projects funded during 1990. Data compiled from Stephens (1990).

Fig. 4). Evidently, there is a large pool of people in the private sector who are concerned about quail and want to do something positive to enhance this resource. However, the huge growth in QU membership and associated activities of QU chapters have apparently had little or no impact on reversing the broad-scale decline northern bobwhite populations have experienced (Fig. 4). Clearly, efforts of QU have been insufficient to overcome widespread deterioration in bobwhite habitat caused by land-use changes in agriculture and forestry. Despite this, the large and growing QU membership indicates that there is a tremendous amount of interest in quail within the private sector.

POPULATION TRENDS, SPECIES STATUS REPORTS, AND LAND-USE ISSUES

I used Christmas Bird Count (CBC) data from 1960-89 to assess broad-scale trends of quail populations in the U.S. Arbib (1981) provides a description of CBC methodology. These data were standardized by dividing raw counts by the number of terrestrial party-hours. Trends were evaluated using simple linear regression of standardized count data using year as the dependent

QUAIL UNLIMITED AND BOBWHITE TRENDS

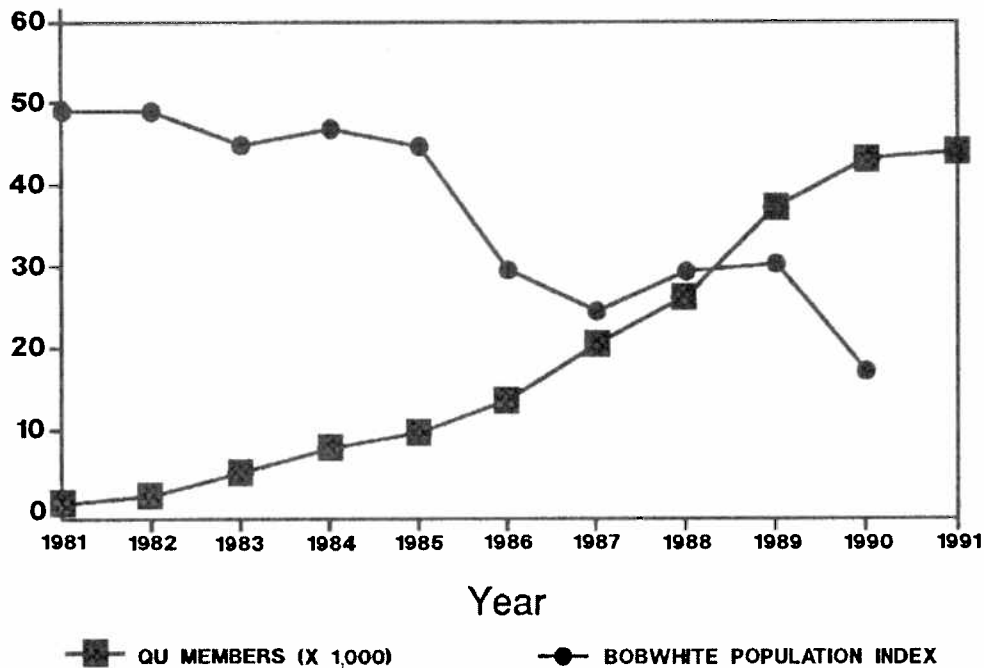


Fig. 4. Comparative trends in Quail Unlimited (QU) membership and northern bobwhite populations, 1981-91. Bobwhite trends based on Christmas Bird Count data from the southeastern region of the U.S. published by Brennan (1991). QU membership data furnished by the QU National Office.

variable. If slopes of the regression analysis had an associated P value <0.05 they were considered different from 0.

California Quail

The California quail is the most widely-distributed of the western quails (Fig. 1A). Its distribution throughout low and mid-elevation habitats in California, Oregon, Idaho, and Washington puts it in the proximity of most avid western quail hunters. Thus, there is probably more demand in the form of hunter days for pursuit of California quail than any other western species. Currently, 1 of the major issues facing California quail populations is the controversy over the status of oak (*Quercus* spp.) woodlands in California. Whether or not oak woodlands in California are classed as commercial forests has great bearing on future management options for this quail. The California quail is clearly the most well-studied of all western quail. Leopold (1977) provides a full account of the biology and ecology of the species. CBC data indicate that California

quail populations have exhibited a significant, long-term population decline since 1960 (Fig. 5A).

Gambel's Quail

The Gambel's quail is a desert-adapted analog of the California quail (Fig. 1B). Unlike California quail, its distribution and movements are not tied to availability of, or access to, free surface water. It is 1 of the primary game birds in the state of Arizona, and is also important in southern California and New Mexico. Population abundance is profoundly influenced by rainfall patterns. Although relationships are not entirely clear, cattle grazing and land-use patterns also play a major role in year-to-year abundance of Gambel's quail and associated hunting opportunities in the arid southwest (Brown 1989). Apparently, ungrazed or lightly-grazed habitats are able to support greater numbers of birds during the winter period than heavily-grazed areas (Brown 1989). Christmas Bird Count data indicate that Gambel's quail populations have apparently remained stable for the past 31 years (Fig. 5B).

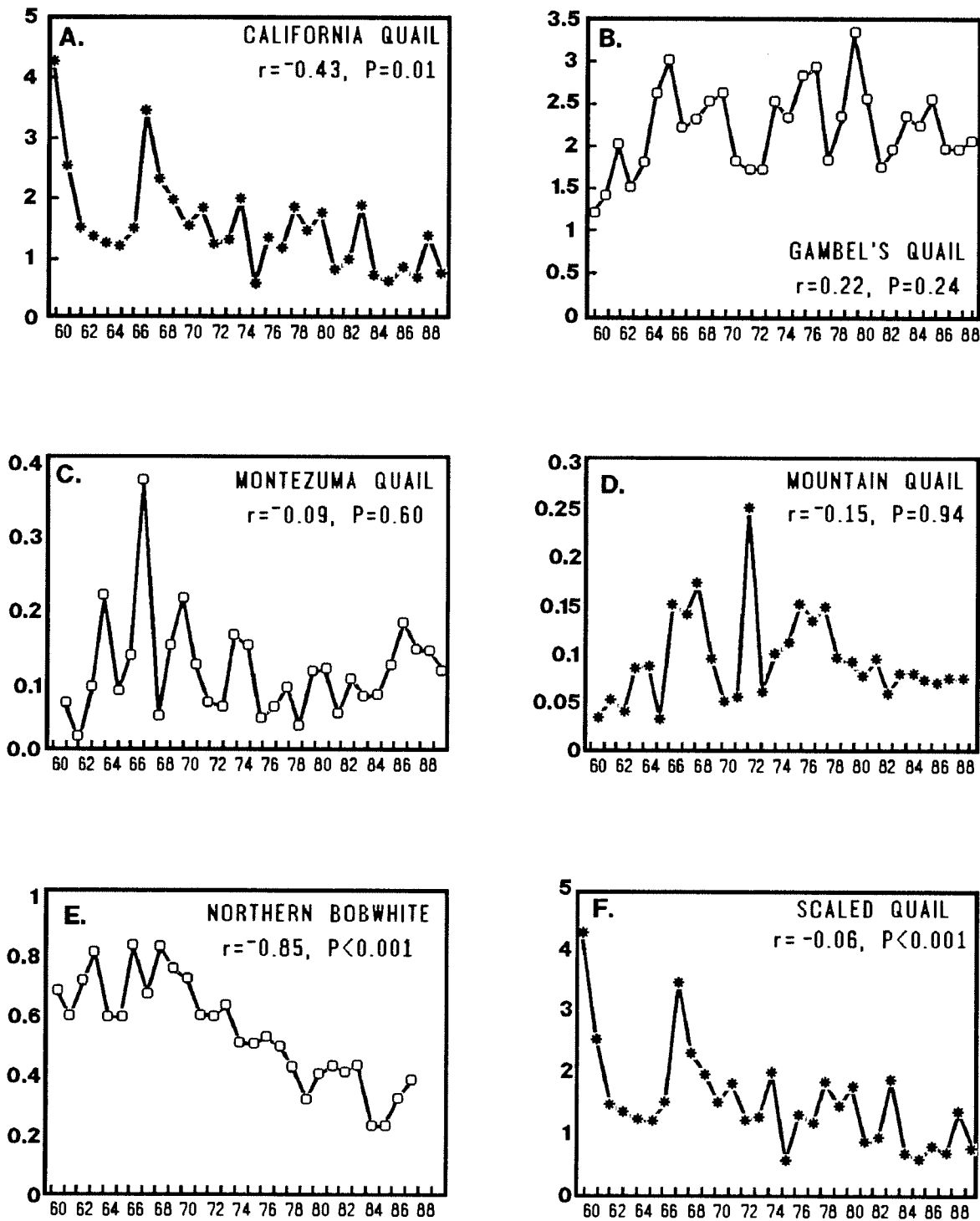


Fig. 5. Quail population trends in the United States based on 31 years of Christmas Bird Count data.

Montezuma Quail

Leopold and McCabe (1957) summarized the natural history of this species. Montezuma quail received very little attention from the research

community until Stromberg (1990) studied movements and quantified habitat structure. This quail is closely associated with the tall grass understorey of pine-oak woodlands. The center of its geographic distribution is in Mexico (Fig. 1C).

Excessive grazing has had a long-term, mostly negative, impact on Montezuma quail across much of its range. Brown (1989:116) pointed out that the "effects of grazing on Mearns' [Montezuma] quail populations has long been recognized but not understood." This was apparently because some workers (e.g., Wallmo 1954) observed that there were certain situations where Montezuma quail populations were lower on ungrazed areas than they were on adjacent, grazed areas. Others, however, have concluded that grazing destroys key food sources (e.g., Leopold and McCabe 1957) and has extirpated this species from large regions of its historic range (e.g., Miller, 1943). In the U.S., populations of Montezuma quail have apparently remained stable after reaching a peak of abundance during the mid-1960's (Fig. 5C). Population status of Montezuma quail in Mexico is unknown.

Mountain Quail

The mountain quail remains the least-studied of native North American quail. Basic habitat relationships are known and have been quantified in portions of its geographic range. Brennan and Block (1986) provided the first reliable estimates of population density, and Brennan et al. (1987) quantified the structure of habitats used across northern California. Gutiérrez (1980) provided evidence to eliminate the myth that standard management practices used for California quail were also appropriate for mountain quail. Numerous factors need to be addressed in light of the widespread declines and local extinctions that have been documented on the northeastern edge of this quail's range (Brennan 1990). Formerly distributed throughout much of southern and western Idaho, the species is now largely extinct in that region (Fig. 1D). Despite local extinctions in Idaho, there apparently has not been a long-term decline in mountain quail numbers elsewhere (Fig. 5D). The fact that many populations undergo long (perhaps at times >50 km) altitudinal migrations between breeding and wintering habitats must be considered in management strategies for this quail.

Northern Bobwhite

The northern bobwhite remains the most widely-distributed North American quail (Fig. 1E). Despite this wide distribution, populations have undergone significant declines in >75% of the states within the geographic range of the bobwhite (Droege and Sauer 1990, Brennan 1991). Overall, declines in bobwhite populations

are the most precipitous of the 3 species that are declining in the U.S. (Fig. 5E). On a regional basis, the most precipitous declines have occurred in the southeastern region of the U.S. (Brennan 1991). This is especially disturbing because the southeast has historically been associated with good bobwhite management and abundant populations.

The northern bobwhite is 1 of the most studied game birds in the world; nearly 2,800 titles are cited by Scott (1985). This quail has been the subject of 3 major book-length monographs (Stoddard 1931, Rosene 1969, Roseberry and Klimstra 1984). Brennan (1991) outlined 1 opinion about the northern bobwhite decline and potential solutions.

Masked bobwhite.---Although this quail is a subspecies of the northern bobwhite, it has received an enormous amount of attention because of its limited distribution, highly specialized habitat requirements, and status as an endangered species. Brown (1989) provides a comprehensive review of factors responsible for the decline of populations, and various attempts at population recovery. Curiously, at least 2 attempts at population reestablishment nearly met with success but were thwarted when cattle were allowed to return to and graze in habitats occupied by this quail. A decision by the Fish and Wildlife Service to purchase a parcel of critical habitat and establish a cattle-free refuge in southern Arizona has been central to success of the most recent population recovery efforts. Nevertheless, the masked bobwhite continues to hang by a slender and fraying thread over the abyss of extinction. If there is a single, unifying purpose of this plan, it is to prevent other species of North American quail from meeting a fate similar to the 1 faced by the masked bobwhite.

Scaled Quail

The scaled quail is distributed throughout the western half of Texas; most of New Mexico; and parts of Arizona, Oklahoma, Kansas, Colorado, and central Mexico (Fig. 1F). It has been the subject of 2 monographs that address habitat ecology (Schemnitz 1961), effects of hunting, and other environmental factors (Campbell et al. 1973). Like other members of the genus *Callipepla*, and northern bobwhite in portions of Texas, scaled quail populations undergo dramatic fluctuations in relation to rainfall patterns. Climatic variation and habitat conditions are the 2 primary factors that influence scaled quail numbers (Campbell et al. 1973). Although removal of

dense shrub stands on ridges can be used as a strategy to improve habitat for scaled quail (Brown 1989), homogenous grasslands without a shrub component are usually unsuitable for scaled quail (Schemnitz 1961). Scaled quail numbers have declined significantly since 1960 (Fig. 5F). Reasons for this decline are largely unknown.

SYNTHESIS

Based on the foregoing information, it is clear that quail populations in the United States are facing widespread, serious problems, not the least of which is a lack of attention by the research community. Wildlife professionals have apparently paid scant attention to quail populations during the past 10 years. Efforts from the private sector are clearly having no impact on slowing or reversing a broad-scale long-term decline in bobwhite populations.

Historically, with the exception of traditional quail plantations in the South and scattered efforts in Texas and the Midwest, quail management in the U.S. has been characterized by a *laissez-faire* approach. This worked fine when land uses in agriculture and forestry were compatible with producing abundant, huntable populations of quail. However, now that abundant quail populations are no longer a by-product of land use, 4 species of quail in the U.S. are declining or experiencing range reductions. Although wildlife agencies are beginning to take notice of the problem, much of the quail hunting public seems to be either unable or unwilling to: (1) undertake broad-scale quail habitat enhancement projects, or (2) bring political pressure to bear on state and federal agencies so that they will make quail management and research a priority. Bird watchers and others who value non-consumptive aspects of the quail resource should also get involved in raising awareness about quail problems.

Furthermore, current policy in the agricultural and forestry arenas seems to be exacerbating the problems quail face in many areas. Despite economic incentives within the Conservation Reserve Program (CRP) for taking land out of agricultural production and therefore reducing erosion and pesticide use, criteria for compliance (e.g., noxious weed control, high-density planting of pine) may actually be decreasing quail habitat quality on a broad scale. Landowners who participate in CRP or other set-aside programs have virtually no economic incentive to perform comprehensive quail habitat management actions

such as strip-disking or prescribed burning. Below-market fees for cattle grazing in the arid West is another example of a policy that continues to have devastating effects on quail.

Clearly, contemporary efforts at quail research and management are floundering in the doldrums. Despite localized, isolated case histories of quail management successes such as the recent increase in masked bobwhite on Buenos Aires National Wildlife Refuge, or apparent stabilization of northern bobwhite numbers in Texas and a few Midwest states (Droege and Sauer 1990, Brennan 1991), the outlook for quail is relatively bleak. This prognosis can be reversed if wildlife professionals and natural resource policy-makers do a complete about face and begin to make quail management and research a priority. These problems, and the strategies for their solution identified at this symposium, are examples of efforts to raise awareness of the wildlife profession and natural resource policy-makers about the current quail situation.

Priorities need to be changed, and additional resources must be allocated to enhance quail programs, and ultimately populations. If not, the huge interest in big game, and other wildlife issues, will most likely continue to siphon away resources that might otherwise be allocated to making quail research and management a high priority entering the next century. Perhaps Quail III and the associated Strategic Planning Workshop will inspire more members of the wildlife community to take creative, comprehensive, integrated management actions, and conduct and publish original research on wild quail.

GOALS, PURPOSE, AND OBJECTIVES OF THE WORKSHOP

The main reason for conducting the Strategic Planning Workshop was to establish a national framework for guiding policies that influence quail management and research. The 4 goals of the workshop were to: (1) identify factors responsible for declines in populations of native, wild quail in the U.S.; (2) identify specific solutions, when known, to factors that are either causing quail populations to decline or preventing their increase; (3) identify strategies that can be used to sustain and increase quail populations in the U.S. in light of changing land-use practices; and (4) increase awareness of issues that affect quail with respect to changing land-use practices in agriculture, forestry, and expanding urbanization.

The purpose for conducting this workshop was to provide a forum for people to discuss and help solve problems that affect quail in the U.S. This document should be useful for natural resource managers, biologists, researchers, administrators, and private interest groups, such as Quail Unlimited. It can be used as a basis for prioritizing local and regional efforts to enhance quail populations and habitats. It can also be used as a mechanism for identifying gaps in our basic knowledge about quail population and habitat ecology in the U.S. This plan can be used to provide objective information about quail problems to administrators, policy-makers, and other people who influence resource management decisions.

The objective of the workshop was to produce a document which contains a smorgasbord of major issues and opportunities that pertain to quail management and conservation as we enter the 21st Century. With the exception of identifying major issues that pertain to all species of wild quail, there was no effort to prioritize particular issues or strategies. Prioritization of issues that affect quail, and strategies for implementing specific solutions to these issues, is the domain of the technical staff within each state and federal agency, and nongovernmental organizations that have quail management responsibilities.

STRUCTURE OF THE WORKSHOP

The workshop was organized into groups aligned with 5 broad categories. These groups identified issues and associated management or research strategies that relate to particular species of quail. Information presented in and discussed at the workshop was structured according to the needs of native quail in the U.S. as they relate to broad categories of land use. The 5 categories were: (1) agricultural practices and pesticides, (2) forest practices, (3) grazing and range management, (4) releases of pen-raised quail, and (5) population dynamics and effects of hunting.

These broad categories were chosen because they have profound implications for many species of quail, are aligned with the major land-use practices that influence quail populations, and transcend taxonomic boundaries. Some categories have a strong regional flavor, such as the liberation of pen-raised bobwhite in the Southeast, or effects of cattle grazing on quail in the West. Other categories, such as population

dynamics, clearly pertain to all species. Additionally, a separate section of this document contains a list of general issues applicable to all species of quail in the U.S.

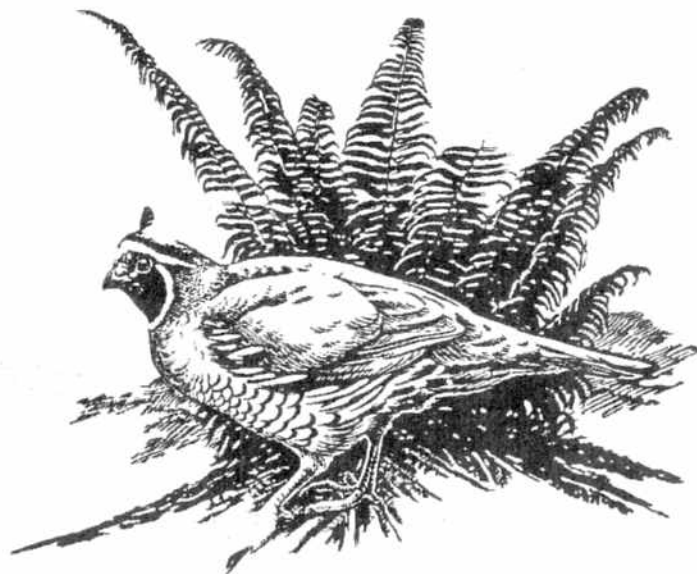
The workshop began with a brief general meeting and overview, and then divided into 5 different sessions. Depending on the category, between 3 and 5 scientists or managers with well-established backgrounds in each particular topic, and familiarity with the species of quail most likely to be impacted, developed a topical outline, chaired each session, and guided discussion. Participation in a particular workshop group was open to any person attending Quail III.

STRUCTURE OF THE PLAN

An issue-strategy structure is used throughout the body of this Strategic Plan. This structure helped identify and explicitly state management issues or information gaps in our knowledge about wild quail in the conterminous 48 states. These issue statements were then followed with strategies that could be used to: (1) solve the problem or (2) collect information required to make informed management decisions about the particular issue. As stated below, specific mechanisms for implementation of solutions will be left to state and federal agencies, and private organizations interested in quail conservation and management.

IMPLEMENTATION OF SOLUTIONS

This plan contains broad, rather than specific, information about how solutions to issues that affect quail should be implemented. When strategies for implementation are mentioned, they are outlined in general terms. This is intentional. There are >40 state and federal resource management agencies that are mandated to conserve and enhance quail resources within their particular jurisdictions. Additionally, there are hundreds of private conservation groups interested in myriad issues relating to quail. Mechanisms for setting policy, establishing budgetary priorities, and responding to political pressure from user-groups vary widely among state and federal resource agencies that have quail management responsibilities. Therefore, it would not be practical, much less possible, within the limited space available, to list specific, localized strategies for implementing solutions to the issues outlined in this document.



STRATEGIC PLAN FOR QUAIL MANAGEMENT AND RESEARCH IN THE UNITED STATES: ISSUES AND STRATEGIES

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Citation: Brennan, L. A., ed. 1993. Strategic plan for quail management and research in the United States: issues and strategies. Pages 170-182 in K. E. Church and T. V. Dailey, eds. Quail III: national quail symposium. Kansas Dep. Wildl. and Parks, Pratt.

This portion of the plan identifies several broad actions that can be implemented immediately. It is followed by 5 sections on specific issues and strategies: (1) agricultural practices and pesticides, (2) forest practices, (3) grazing and range management, (4) releases of pen-raised quail, and (5) population dynamics and hunting.

Issue 1.0

POPULATION DECLINES

Widespread population declines and local extinctions of quail in the U.S., along with the relative lack of resources and attention allocated to these birds are highly significant problems currently facing natural resource management agencies.

Strategies

1.1.—Develop a program for quail population and habitat management and research modeled on the Accelerated Research Program for the Management of Upland Shore and Migratory Game Birds described in Sanderson (1977). Enlist support and cooperation of state and federal resource management agencies, and non-governmental organizations for such a comprehensive program.

1.2.—Develop cooperative working groups of biologists and managers from state and federal agencies and private conservation organizations to direct management and research efforts. A working group should be established for each region of North America that supports quail.

Issue 2.0

ECONOMIC VALUES

Few contemporary data are available on the economic values associated with consumptive and nonconsumptive uses of native quail.

Strategies

2.1.—Perform research that quantifies consumptive and nonconsumptive economic values of each species of North American quail on local, state, regional, and continental scales.

2.2.—Disseminate information on economics of quail hunting to landowners, resource agency administrators, and state and federal legislators.

Issue 3.0

LACK OF COMMON VOICE

Constituency groups generally lack a single, common voice and technical expertise to effectively address issues related to quail habitat and population ecology and management.

Strategies

3.1.—Form a national constituency group coalition that will promote strategic planning efforts, influence the political process, and act as a clearing-house to provide information on access to funding sources for research and management projects.

3.2.—Establish a centralized, structured account within each state and have this account administered by a state constituency group council. Constituency groups can develop competitive proposals for habitat improvement or educational projects and, after review and approval, fund them from this account.

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Issue 4.0

DEALING WITH MYTHS

There are many widespread and persistent myths held by resource agencies and the general public about quail and quail management.

Strategies

4.1.—Use documented evidence of introduction failures to convince state agencies that introduction of exotic game birds is not cost-effective.

4.2.—Encourage constituency groups to take an active and aggressive stance against translocating species of quail into regions and habitats that are clearly not within their historic range.

4.3.—Provide incentives for sponsorship of short courses and seminars with resource management agencies.

4.4.—Provide incentives for wildlife specialists to write popular newspaper and magazine articles about quail management.



AGRICULTURAL PRACTICES AND PESTICIDES

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Citation: Capel, S., J. A. Crawford, R. J. Robel, L. W. Burger Jr. and N. W. Sotherton. 1993. Strategic plan for quail management and research in the United States: issues and strategies—Agricultural practices and pesticides. Pages 172-173 in K. E. Church and T. V. Dailey, eds. Quail III: national quail symposium. Kansas Dep. Wildl. and Parks, Pratt.

Agricultural practices have broad-scale influences on quail populations. As time has passed, these once positive influences have now become largely negative. In spite of many problems faced by quail in contemporary, clean farmed agricultural environments, numerous proactive management and research opportunities exist. The participants for the Agricultural Practices and Pesticides portion of the Strategic Planning Workshop identified 3 broad categories of issues that have the greatest potential to impact quail populations in contemporary agricultural environments: (1) general habitat loss and strategies for development and improvement, (2) use and management of agricultural chemicals, and (3) agricultural programs and policies.

Issue 1.1

HABITAT LOSS AND STRATEGIES FOR DEVELOPMENT AND IMPROVEMENT

Extensive farming practices and water development projects have eliminated vast areas of quail habitat and caused widespread fragmentation of the remaining habitat.

Strategies

1.1.1-Establish and maintain quail management areas within watersheds that are impacted by reclamation projects.

1.1.2-Develop and implement inventory and monitoring systems (e.g., geographic information systems) to identify the quality and extent of quail

habitat, particularly where habitat has been severely restricted.

1.1.3-Conduct research to determine minimal and optimal sizes of management units and populations for quail in areas impacted by reclamation projects and habitat fragmentation.

1.1.4-Conduct studies of quail productivity in no-till and conservation till agricultural lands compared with traditional rowcrop and small grain environments.

1.1.5-Encourage acceptance of low-input, sustainable agriculture (cf., Robinson 1990), and use working demonstration farms to show application of economically practical quail habitat management techniques.

1.1.6-Add wildlife to the list of traditional beneficial uses of water.

Issue 1.2

USE AND MANAGEMENT OF AGRICULTURAL CHEMICALS

Pesticides (e.g., herbicides, insecticides, and nematocides) directly and indirectly have adverse effects on game-bird populations. However, sufficient data are lacking to clearly support or refute the relationship between pesticides and quail.

Strategies

1.2.1-Determine the direct (e.g., White et al. 1990, Kilbride et al. 1992) and indirect (cf., Sotherton et al. 1993) effects of pesticides on quail populations.

1.2.2-Encourage agronomic methods and cultural practices that reduce quantities and change temporal use of chemicals to mitigate their effects

on quail populations (e.g., Conservation Headlands, *sensu* Potts 1986).

1.2.3-Develop safe methods of applying pesticides.

Issue 1.3

AGRICULTURAL PROGRAMS AND POLICIES

Federal farm programs include practices that severely limit the value of these programs for quail. For example the CRP and other set-aside programs include practices such as mandatory mowing in summer, promotion of exotic cool-season grasses (e.g., tall fescue [*Festuca* spp.]), emphasis on establishing tree monocultures, and lack of management options (e.g., strip-disking) for maintaining old fields, all of which reduce potential benefits of these programs for quail. In addition, state and local programs (e.g., weed control) reduce the quality of quail habitat.

Strategies

1.3.1-Enlist Congressional support to modify current programs, such as the CRP, so they are maintained or improved for quail.

1.3.2-Establish "top down" (federal, state, county) policy formulation for implementation and enforcement with respect to enhancing wildlife habitat.

1.3.3-Identify specific problems and needs of quail in contemporary agricultural environments

and conduct research directed toward farm and quail management issues.

1.3.4-Develop a more flexible set of regional, statewide, and national guidelines for farm conservation programs that better fit local requirements of quail (e.g., use of native warm-season grasses opposed to exotic cool-season grasses).

1.3.5-Quantify differences in weed control, erosion, and soil quality among fields that are mowed, strip-disked, and traditionally planted to crops.

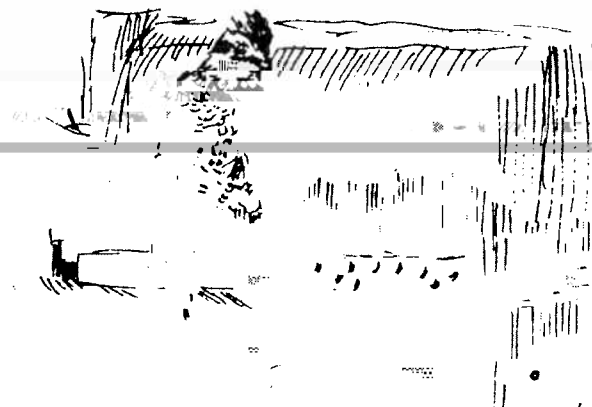
1.3.6-Change weed control regulations in federal programs to specify the control of only noxious plants.

1.3.7-Seek development and implementation of new and existing legislation that mandates improved interagency cooperation and more equitable allocation of agricultural conservation program funds at all levels of government.

1.3.8-Use government agencies and private constituency groups to jointly sponsor informational materials (e.g., pamphlets and videos) pertaining to management practices benefiting quail in productive and fallow croplands.

1.3.9-Provide U.S. Department of Agriculture personnel (e.g., Soil Conservation Service agents) with training and information about beneficial management practices for quail.

1.3.10-Seek implementation of State Technical Committees, provided for in the 1985 and 1990 farm bills to improve interagency cooperation and provide better opportunities for input on wildlife implications of farm programs.



Issue 2.3

SPECIFIC ISSUES IN SILVICULTURAL SYSTEMS

More information and awareness is needed regarding forest management practices, forest management areas adjacent to agricultural environments, and their influences on quail.

Strategies

2.3.1-reevaluate timber classifications in light of quail requirements.

2.3.2-Perform research to quantify distribution, habitat use, and abundance of quail according to age classes of regenerating forest stands and under different silvicultural regimes.

2.3.3-Perform research to assess distribution and abundance of quail in forests that are managed or not managed for endangered species.

2.3.4-Perform research on topics related to satisfaction of quail hunters who use early stage forest regeneration stands and examine how different forest regeneration strategies relate to quail hunting success, and how forest regeneration techniques that provide the best quail hunting can be reconciled with maximizing timber production.

Issue 2.4

NEGATIVE EFFECTS OF CERTAIN SILVICULTURAL PRACTICES ON QUAIL

Some silvicultural practices adversely affect northern bobwhite populations in forest ecosystems.

Strategies

2.4.1-Develop policies and incentives that mandate multiple use values on public areas as a basis for practicing long-rotation sawlog production.

2.4.2-Determine the lowest replanting rate that is commercially viable and encourage planting rates that sustain quail.

2.4.3-Develop policy and legislation that encourage wise use of prescribed burning in relation to historic burning cycles.

2.4.4-Develop policy that encourages replacement and alternative techniques for enhancing quail habitat quality in loblolly pine stands in public areas where longleaf was historically located.



3.3.2-Perform research to assess the impact of brush control on quail population abundance.

Issue 3.4

FINANCIAL AND SOCIAL INCENTIVES

Grazing can be an important and economical quail management tool, and public land management agencies need to reduce the numbers of livestock on public lands. Moreover, proliferation of introduced grasses for pasture and erosion control has contributed to negative attitudes toward grazing. Unfortunately, native forages are not now universally available for restoring pastures.

Strategies

3.4.1-Restore native species of grasses and legumes on public land, educate landowners and ranchers in better grazing practices such as use of rotation grazing, and use complementary forage systems instead of cool-season monocultures.

3.4.2-Locate funding for seed sources of native grasses and legumes for pasture restoration.

3.4.3-Distribute information on the negative effects of how grazing affects quail.

3.4.4-Encourage agencies to adopt a proactive approach to rangeland conservation and continue efforts toward developing management plans for upland game birds on public lands.



RELEASES OF PEN-RAISED QUAIL

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Citation: Hurst, G. A., W. R. Davidson, T. DeVos, E. L. Kozicky and A. D. Peoples. 1993. Strategic plan for quail management and research in the United States: issues and strategies—Releases of pen-raised quail. Pages 178-179 in K. E. Church and T. V. Dailey, eds. Quail III: national quail symposium. Kansas Dep. Wildl. and Parks, Pratt.

As northern bobwhite populations declined over the past 3 decades, increasing numbers of quail enthusiasts have resorted to releasing pen-raised quail. Most state game agencies are no longer directly involved with release programs. Nevertheless, many private landowners continue to make releases of pen-raised quail the center of their game-bird management efforts, rather than focus on habitat improvement and limit their quail hunting to what the carrying capacity of the land will provide. The impact of releasing pen-raised quail in the midst of remnant wild quail populations is not understood. Therefore, managers and biologists should strive to err on the conservative side when considering use of pen-raised quail to provide recreational opportunities. The northern bobwhite is a game-bird resource that is treasured by a diverse user group, and should not be put in jeopardy by massive annual releases of pen-raised stock.

Issue 4.1

PEN-RAISED TO WILD QUAIL DISEASE TRANSMISSION

We have virtually no information on whether liberated pen-raised northern bobwhite transmit disease to wild quail. The extent and dynamics of such processes are virtually unknown.

Strategies (summarized from Landers et al. 1991):

4.1.1-Perform research on potential disease risks for wild quail or other game birds that might be associated with releases of pen-raised quail.

4.1.2-Immediately initiate a program to minimize disease risks by conveying appropriate disease prevention and control practices to producers and users of pen-raised bobwhites.

Issue 4.2

GENETIC MAKEUP OF PEN-RAISED AND WILD QUAIL

There is very little information on the importance of heredity and environment on the production of pen-raised quail for release on private lands. Furthermore, there is little published information on how releases (especially large and widespread ones) of pen-raised quail may affect the genetic integrity of wild quail.

Strategies

4.2.1-Conduct research on relative importance and roles of heredity and other factors (pens, people, contact, etc.) on field behavior of pen-raised quail after release.

4.2.2-Conduct laboratory research to establish genetic make-up of pen-raised quail.

4.2.3-Compare genetic makeup of pen-raised quail to genetic makeup of quail in museum

specimens, or in populations that have not been subjected to releases of pen-raised quail.

4.2.4-Conduct field research on the extent of gene flow from released pen-raised quail to wild quail.

Issue 4.3

GAME FARM QUAIL FOR HUNTING

Nonhunters and the general public seem to have either a neutral or negative perception of game farm production of quail for shooting.

Strategies

4.3.1-Develop materials to explain the reasons for game farm production of quail.

4.3.2-Use extension service and public outreach programs to educate people about the social traditions and other positive aspects of quail hunting.

Issue 4.4

INFLUENCE OF PEN-RAISED QUAIL ON WILD QUAIL

There is virtually no reliable, published information about how releases of pen-raised quail influence movements, habitat use, and social structure of wild bobwhite populations.

Relationships of releases of pen-raised quail to possible excessive mortality of wild quail as a result of increased hunting pressure are not un-

derstood. Furthermore, we do not know if large-scale releases of pen-raised quail can cause a functional and numerical response of predators that will carry over into increased predation on wild quail.

Strategies

4.4.1-Conduct research to determine if released pen-raised quail influence habitat use, movements, and social structure of wild coveys.

4.4.2-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 releases of pen-raised quail.

Issue 4.5

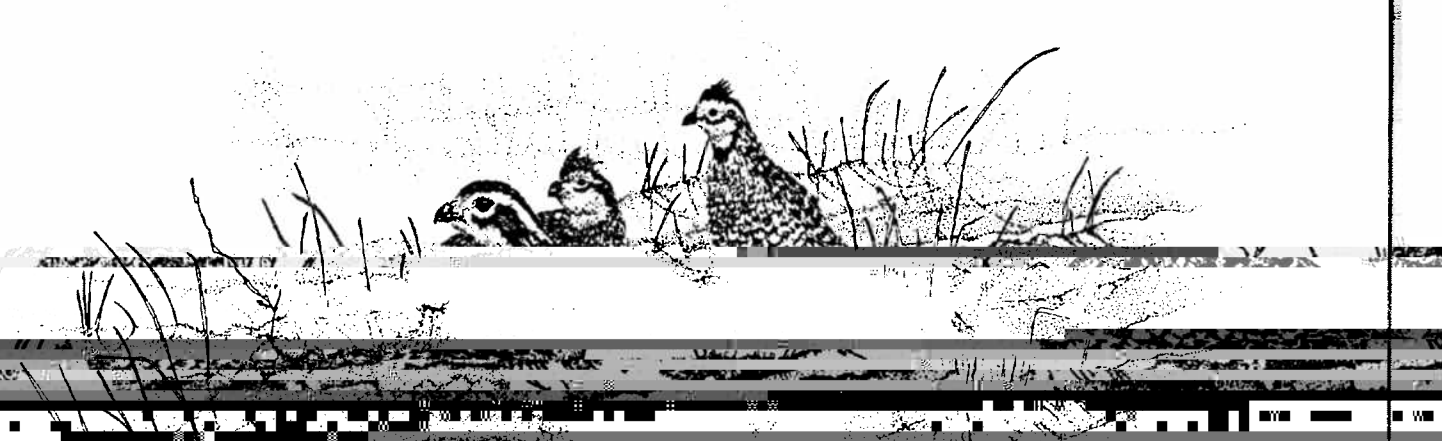
PEN-RAISED VS. WILD QUAIL FOR HUNTING

Release and subsequent pursuit of pen-raised quail do not simulate the hunting experience associated with wild quail.

Strategies

4.5.1-Develop methods of producing pen-raised quail that will behave like wild birds under hunting conditions.

4.5.2-Study effects release techniques and cover conditions have on behavior of pen-raised quail. This information can be used to better simulate the experience of hunting wild quail, e.g., covey flushes.



POPULATION DYNAMICS AND EFFECTS OF HUNTING

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Citation: Kuvlesky, W. P. Jr., B. D. Leopold, P. D. Curtis, J. L. Roseberry and T. Hutton. 1993. Strategic plan for quail management and research in the United States: issues and strategies—Population dynamics and effects of hunting. Pages 180-181 in K. E. Church and T. V. Dailey, eds. Quail III: national quail symposium. Kansas Dep. Wildl. and Parks, Pratt.

Despite nearly 70 years of research on quail in North America, we have only a meager understanding of the mechanisms that regulate abundance and productivity of quail populations. Many state agencies and private landowners continue to use guidelines developed by Stoddard (1931) and Rosene (1969). However, many of these recommendations were developed during an era when land-use practices in agriculture and forestry were drastically different from what they are today.

The workshop group on Hunting and Population Dynamics reached a consensus that 4 broad areas need to be addressed: (1) standardization of census and population monitoring methods, (2) issues related to maintaining a sustainable harvest of wild quail through hunting, (3) assessment of population response to management actions and fragmentation, and (4) adoption of a proactive philosophy for quail population and habitat management on both public and private lands. Additionally, some issues related to releases of pen-raised quail have a bearing on this workshop session.

Issue 5.1

STANDARDIZATION OF CENSUS AND MONITORING METHODS

Despite the use of broad-scale data bases, standardization of analytical and assessment

techniques to assess annual census and harvest data on a state-by-state basis do not exist and may confound comparisons of trends.

Strategies

5.1.1—Develop a cooperative, broad-scale quail population monitoring program that assesses quail population trends from state and federal agency data bases and is readily accessible by all interested parties.

5.1.2—Enlist support of constituency groups to distribute information and publications on status reports for local, regional, and national quail population trends.

Issue 5.2

HUNTING AND HARVEST OF QUAIL

We do not have a quantitative assessment of whether quail hunting results in compensatory or additive mortality in habitats dominated by present-day land-use regimes or whether disturbance of quail from hunting-related activities have negative, indirect effects on populations.

Strategies

5.2.1—Conduct research that identifies threshold densities and hunting pressures for additive mortality and indirect effects of hunting.

5.2.2—Encourage state wildlife agencies to be creative in their approaches to season length and bag limits.

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Issue 5.3

EFFECTS OF FRAGMENTATION ON QUAIL POPULATIONS

Effects of habitat fragmentation need to be assessed at the landscape level because widespread changes in agricultural and forestry land-use practices have had broad impacts on quail habitat quality.

Strategies

5.3.1-Coordinate research efforts with management actions (supported by constituency groups) to take advantage of manipulations in an experimental context, and monitor population trends in areas of differing habitat quality.

5.3.2-Standardize analytical techniques on a statewide or regional basis before implementation.

5.3.3-Perform research to assess interactions between habitat fragmentation and population isolation in the context of population genetics, population response to local management actions, intensity of harvest, and weather-related extirpation.

Issue 5.4

TRANSLOCATION OF WILD QUAIL

Translocation of wild quail may be a viable management action for restoration of local populations in areas where habitat improvement has been attempted, but population response is

limited. State wildlife agencies often receive tremendous amounts of political pressure to become involved in releases of pen-raised quail.

Strategies

5.4.1-Perform controlled experiments to test the impact of translocating wild quail on restoring native populations.

5.4.2-Educate the public about the futility of using pen-raised quail as a mechanism for population restoration.

Issue 5.5

PROACTIVE PHILOSOPHY OF POPULATION AND HABITAT MANAGEMENT

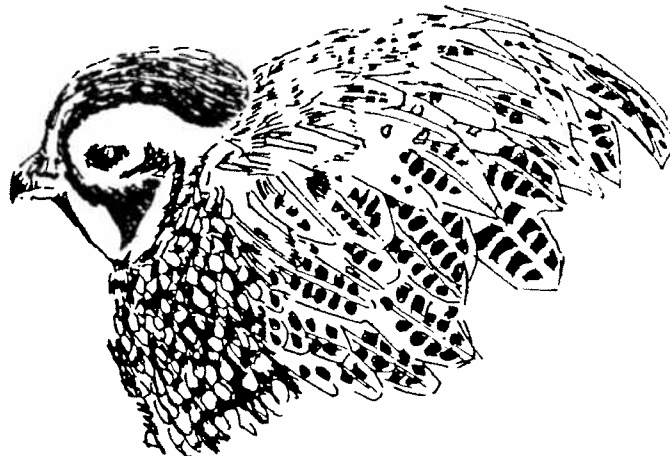
Current perceived public apathy about quail resources may in reality be ignorance or frustration resulting from inadequate agency public information programs. Additionally, biologists often disagree among themselves with regard to specific management strategies.

Strategies

5.5.1-Reach a consensus on specific agency research goals and take a unified position on issues when dealing with the public.

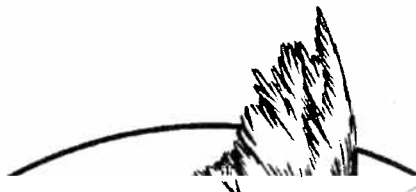
5.5.2-Initiate programs that permit local constituency groups to adopt specific management projects on public areas.

5.5.3-Seek opportunities to make presentations on quail management.



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AN INTERACTIVE COMPUTER PROGRAM FOR DISPLAY, MANIPULATION, AND ANALYSIS OF HABITAT DATA

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Abstract: An interactive graphic display program was developed that mimics functions of Geographical Information System (GIS) programs, does not require GIS software, and runs on smaller personal computers. The program utilizes digital GIS output from remote-sensing sources (e.g., Landsat TM) and allows users to display land use and simulate habitat changes in selected areas. Two preliminary models that calculate habitat suitability indices for northern bobwhite are linked to the main display program. One model accepts user inputs regarding habitat quality, the other model does not. The system is potentially useful for bobwhite land management planning and for predicting responses to habitat alteration.

LONG-TERM TRENDS OF NORTHERN BOBWHITE POPULATIONS IN THE SOUTHEASTERN U.S.: THE ROLE OF ABIOTIC FACTORS

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Abstract: We assessed the potential influence of precipitation variation and drought-severity on long-term trends of northern bobwhite population indexes using data derived from the Christmas Bird Count (1961–89) in the southeastern U.S., and harvest data (number of bobwhite bagged per unit effort) from Groton Plantation (1957–89) and Oakland Hunting Club (1927–87) in South Carolina. We calculated long-term yearly drought-severity indices to simultaneously scale precipitation, average temperature, water holding capacities of soil, and evapo-transpiration, and used these data as independent variables in regression analyses of long-term bobwhite population indices. Drought-severity indices were correlated ($P < 0.5$) with long-term bobwhite population trends and explained approximately 50% of the year-to-year variation in population changes. Variation in population indices not explained by drought-severity indexes is apparently the result of biotic factors associated with changes in land use.

STATUS OF MOUNTAIN QUAIL IN THE INTERMOUNTAIN WEST

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Abstract: Mountain quail (*Oreortyx pictus*) populations inhabiting the inland areas of Washington, Oregon, Idaho, and Nevada have declined dramatically during the last 20–30 years. In Idaho, distribution of this bird has declined by over 90% and the season closed on the once common species in 1984 after harvest dropped by about 96% from the 1950's to the 1970's. As a result, this species has received increased attention from sportsmen and management agencies and is currently listed as a "Sensitive Species" by the U.S. Forest Service and Bureau of Land Management. Existing data suggest that these declines in mountain quail populations are related to losses of riparian habitat quantity and quality.

EFFECT OF RED IMPORTED FIRE ANT CONTROL ON NORTHERN BOBWHITE

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Abstract: The impact of the red imported fire ant (RIFA) on northern bobwhite has been a matter of controversy for more than half a century. The recent advent and spread of high-density, multiple-queen fire ant mounds has increased interest in RIFA-bobwhite interactions. Texas Tech University, and cooperators including the U.S. Department of Agriculture, the Texas Department of Agriculture, American Cyanamid, Quail Unlimited, and the Houston Livestock Show and Rodeo Association are investigating the impact of RIFA on bobwhite and other vertebrates. Ten approximately 2 X 2-ha study sites in the coastal bend of Texas were selected and paired based on similarity of their rangeland habitats. One randomly chosen site from each pair was treated with AMDRO fire ant bait (1.67 kg/ha) during April and October 1991 to reduce RIFA numbers. Bobwhite (as well as white-tailed deer, small mammal, and herpetological) populations are being monitored during 1991 and 1992 to assess the impact of RIFA control. Bobwhite densities were estimated via line-transects. An average 81% reduction in RIFA numbers was achieved on treated sites 8 weeks after spring 1991 treatment with AMDRO. Bobwhite densities averaged 4/ha on treated sites and 1.3/ha on untreated sites, but were not different ($P > 0.25$). RIFA were again treated in spring 1992, and bobwhite populations were intensively monitored in the fall of 1992.

CURRENT RESEARCH ON MOUNTAIN QUAIL IN IDAHO

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Abstract: Mountain quail numbers in Idaho have been declining over the past several decades. As a result, the species has been classified as a "Sensitive Species" by the Idaho Department of Fish and Game, U.S. Bureau of Land Management, and Region 4 of the U.S. Forest Service. Consequently, management agencies need information on the ecology of mountain quail in Idaho to develop management strategies that will prevent further population decline. Various aspects of the ecology of mountain quail have been studied in California, but no in-depth study has been conducted on the habitat-use patterns, movements, and population characteristics of Idaho mountain quail. Such a study is needed before managers can adequately assess impacts of land-use practices on mountain quail habitat and populations, or identify areas suitable for reintroductions. The study area will include several tributaries within the lower Salmon River and Little Salmon River drainages in Idaho. The objectives of this study are: to document daily and seasonal movements and home ranges of mountain quail, to collect information on productivity and survival rates, to document habitat-use patterns, to determine physical and vegetal characteristics of nesting and brood-rearing habitats, and to develop recommendations designed to maintain or enhance mountain quail habitat and populations. Field seasons will be January-August 1992 and 1993. To collect information to meet the objectives, we will trap mountain quail in January and February. Trapped quail will be banded and measured, and radios will be placed on 40 females. We will track radio-tagged quail to determine movements and the physical and vegetal characteristics of nest and brood-rearing sites.

areas. Key habitat components for masked bobwhite on the Buenos Aires NWR were interspersed of grass, grass-forb, and shrub vegetation types; diversity of grasses and forbs (10 or more species of each); 150 trees or shrubs/ha in the 0–5 m height class; 90% vertical cover by vegetation from 0 to 1 dm, 50% aerial, 30% basal grass cover, 15% forb cover, and 10% tree/shrub cover.

¹Present address: USDI Bureau of Land Management, Tucson Resource Area Office, 675 North Freeman Road, Tucson, AZ 85748.

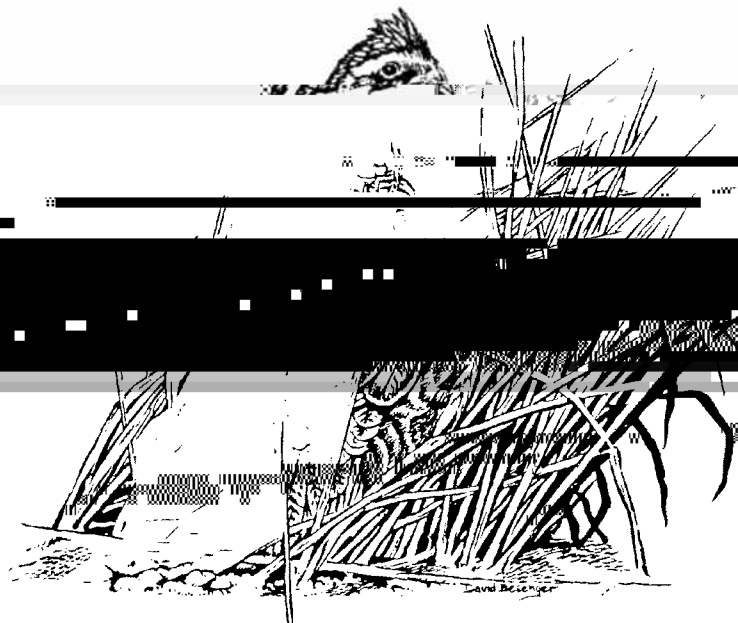
SEED AND INVERTEBRATE BIOMASS IN CENTRAL MISSOURI FOOD PLOTS

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Abstract: We measured biomass of seeds and invertebrates potentially available to northern bobwhite (*Colinus virginianus*) under 3 cultivation treatments in a Missouri forest-soil environment. Cultivation treatments included (1) sorghum, soybean, and German millet mixture; (2) sorghum and soybean mixture; and (3) single spring disking. We found no differences ($P > 0.05$) in biomass of seeds and invertebrates among these treatments. Invertebrate biomass from ground and aerial samples increased substantially from June to August. Biomass of seeds captured in seed traps decreased 96% from early October to mid-December. Sorghum and pigweed (*Amaranthus* spp.) seeds dominated above-ground samples collected in January; these and other seeds considered to be acceptable quail food made up 75% of the biomass and thus would be the main sustenance for quail when deep snow covers the ground. Of the 3 cultivated plants, only sorghum was available in amounts adequate to sustain quail through periods of deep snow coverage. Native plants, especially pigweed, accounted for 49% of select quail food found in above-ground samples.

We estimated the amount of emergency food-energy available to quail using published metabolizable energy values. We estimated energy needs of a covey of 10 bobwhite from Burger (unpubl. data); we assumed free-living quail need 50% more energy than Burger's fasted, resting quail. If bobwhite were the only source of seed loss or consumption, food-energy in a 0.1-ha milo/soybean/millet food plot would sustain a covey for 36 days at 0°C and 25 days at -15°C





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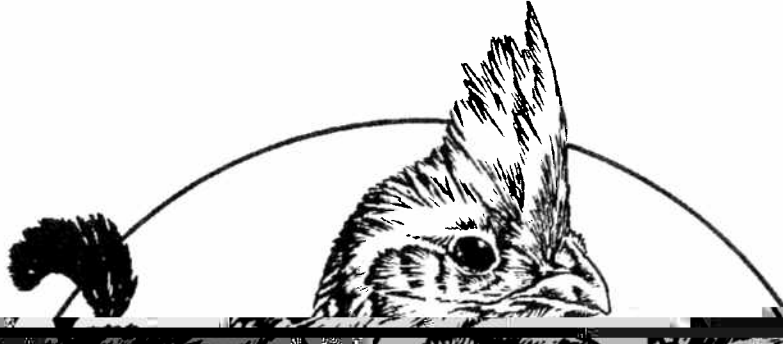
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