SOME ASPECTS OF THE FIRE ECOLOGY OF THE BOBWHITE QUAIL (*Colinus virginianus*)

by

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INTRODUCTION

The notion that fire is a destructive agency is largely the product of modern civilized man (Sauer, 1956). It probably had its origins when man first began to lose the products of his own ingenuity, such as planted crops and shelters, to the ravages of fire. From such destruction arose the idea of fire prevention in defense of human endeavor. In light of heavy economic losses to fire, it was not difficult for early civilized man to apply that thinking to his natural surroundings. All that was needed was the technology with which to suppress fire on a large scale.

That attitude toward fire was probably developed in the Old World and transported to North America by the early settlers (Sauer, 1944), and is still the attitude of most Americans today. It is fostered by the mass media, which frequently broadcasts or distributes news of catastrophic fires in the western United States or the Florida Everglades. Pictures of the charred remains of forests are televised and published in newspapers with little or no explanation of the fire's real cause. It is almost always blamed on the careless fire users such as smokers, campers or arsonists who actually set the fire. Attention is seldom given to possible mismanagement of such areas, which allows fuels in the form of dead and dying plant materials to accumulate in unnatural amounts, waiting to be ignited by the first spark regardless of its origin. Such accumulations become the primary sources of energy to fuel catastrophic fires (Martin, 1972). Historically, those fuels were removed by fires, caused by lightning or primitive man, usually before they accumulated enough to carry a crown fire over vast forested areas. The suppression of fires by modern man has allowed those fuels to accumulate over many years resulting in cataclysmic fires which destroy whole forests (Sauer, 1956; Wilson and Dell, 1971).

The general public naturally concludes that fires which destroy forests also destroy wildlife. "Wildlife has strong public appeal and conservation campaigns, particularly those of forest interest, frequently use wild animals to capture public attention" (Komarek, 1963, p. 35). Slogans such as "Fire destroys forests and wildlife" have been widely circulated on posters and in advertising, and leave the impression that wildlife lives happily in the forest. Few people would suspect the developing forest of choking off the food supply of some wild animals associated with earlier successional stages (Komarek, 1963). But when fire is excluded, changes occur in the plant environment, the result of which has been the destruction of wildlife habitat leading to severe depletion of some wildlife species. Lehman and Mauermann (1963) blamed the decline of Attwater's prairie chicken (_Tympanuchus cupido attwateri_) populations in Texas and Louisiana, in part, on exclusion of controlled burning. Sharp (1963) noted a decline of ruffed grouse (_Bonasa umbellus_) in habitat which had been allowed to proceed through plant succession after cutting. Aldrich (1963) states, "One race, the extinct eastern prairie chicken (_T. c. cupido_) survived, before elimination by man, in what were probably fire created 'prairies' or blueberry barrens along the northern Atlantic seaboard."

Habitat destruction through natural plant succession may result in serious reduction of many species of wildlife. However, many species may also increase as succession advances. As old niches disappear, new ones are created. Grange (1949) outlined the relationship between wildlife populations and community succession. He pointed out that many animals can occupy land only so long as appropriate successional patterns persist. Many successional stages are short-lived. Therefore, the tenure of the wildlife species associated with them is equally short-lived.

Miller (1963, p. 19) pointed out:

> With only few minor exceptions, upland wildlife has a marked affinity for subclimax plant associations. This indicates that disturbance (whether wildfire, or other natural phenomena) has been a common occurrence throughout the vast reaches of evolutionary times. These creatures would never have survived the ages were this not so. If we wish to perpetuate these wildlife species we must maintain the particular subclimax vegetation which is their natural habitat.

There are several methods by which successional stages can be perpetuated, namely; plowing, grazing, spraying, cutting and burning. It is the purpose of this paper to review the use of fire in disturbing plant succession for developing and maintaining bobwhite quail (Colinus virginianus) habitat.

HISTORY OF FIRE IN NORTH AMERICA

Open woodlands, savannas, grasslands and prairies in regions of enough precipitation to support closed canopy, climax forest, will become such forest if plant succession is not interrupted by fire or other agencies. Kucei (1960) found that American elm (Ulmus americana) readily invaded tall-grass prairie in east central Missouri. He stated (Ibid., p. 640), "The stability of prairie under primeval conditions favorable to forests would indicate that, in addition to geological and edaphic influences, fire was probably ar important ecological factor in arresting tree invasion and maintaining vegetational equilibrium."

Bragg (1971) in Geary County, Kansas, found that woody species had increased in area covered from 5 percent in 1937 to 34 percent in 1970 on his unburned study areas, while the areas burned by management increased about one percent. He attributed this slight increase to grazing by cattle. Vogl (1967, p. 19) stated that "all prairie types in Wisconsin have undergone brush and tree invasion since the cessation of fires." Invasion by brush and trees is visible in the Flint Hills region of eastern Kansas. Many areas around Manhattan and Fort Riley, Kansas, are being invaded by brush and trees where fire has been withheld for many years. Rangelands in that area which have been subjected to periodic burning by stockmen or accidental ignition from artillery fire on Fort Riley are free of invasion. Sweeping prairie fires in the Kansas Flint Hills have probably occurred regularly as long as the grasslands have existed (Anderson et al., 1970).

Catlin (1842, p. 16-18) reported shooting 75 "prairie hens" (probably *T. c. pinnatus*) in one afternoon in front of an advancing prairie fire in the vicinity of Fort Leavenworth, Kansas. He also tells of escaping from a fire on horseback under the guidance of an Indian who stated:

> Over the beautiful plain dwells the spirit of fire. He rides yonder cloud - his face blackens with rage at the sound of trampling hoofs - the 'fire-bow' is in his hand - he draws it across the path of the Indian, and quicker than lightning, a thousand flames rise to destroy him; such is the talk of my fathers, and the ground is whitened with their bones.

In that statement he indicates such fires occurred and were common in the days of his ancestors.

The Indian further stated that a small party of hunters from his tribe had been annihilated by a fire in this same area only twelve moons (one year) ago; indicating that fire had occurred over the same area in two consecutive years. Lewis (1814) mentioned prairie fires 12 times during his journey from Council Bluffs, Iowa, to the Grand River in South Dakota (Kirsch and Kruse, 1972).

Any estimate of the frequency of prairie fires before the coming of white men can only be conjecture. Before the landscape of the prairies and savannas was interrupted by roads and agricultural fields, fires could burn for days over thousands of square miles before being extinguished by rain or stopped by a natural barrier such as a river (Jackson, 1965). Few points of ignition would be needed to provide annual burning over wide expanses of prairie. However, this was probably not the case. Many areas probably escaped fire from year to year, depending on location relative to natural barriers and wind direction. Bragg (1971) concluded that natural fires probably occurred more than once per decade over most of Geary County, Kansas, on the western edge of the Flint Hills.

Komarek (1966, 1967) concluded that lightning was the most frequent cause of wide spread fires before the coming of Europeans. Sauer (1944, 1950, 1956) believed the coming of primitive man to North America, at least 15 to 20 thousand years ago, drastically increased fire frequency over much of the continent. He states (1950, p. 20):

> For millennia, and tens of them, fires, for the most part set by man, have deformed the vegetation over the large plains of the world and their hill margins. The time of human disturbance is probably long enough even in the New World, to allow for the development of soils of characteristic profile and structure that are known as 'prairie soils', a secondary product rather than a cause of grassed surfaces.

Fire, as a tool of man, probably had its origins early in primitive man's existence as a hunter. His hunting weapons consisted of stone knives, axes and lances seemingly inadequate for killing the large animals which he hunted (Sauer, 1944). He discovered that those animals could be driven to their deaths over escarpments, or trapped and even killed by properly set fires. He also learned that they were attracted to new growth on burned areas. So important was fire to primitive people in many aspects of their daily lives and their survival that Sauer (1950, p. 19) called their societies "fire economies." Many fires in daily use of those people probably escaped or were turned loose on the landscape. Such fires along with those set naturally, played an important role in spreading the grasslands, savannas and open woodlands over large areas of North America.

The benefits of fire to wildlife did not escape notice by early settlers in North America. Jackson (1965, p. 243) related the following:

> During the 1930's I undertook to investigate in what ways the early settlers of Texas were influenced by the great abundance and variety of wildlife the state afforded. A considerable number of the early settlers of the western half of Texas were interviewed. In addition, journals, diaries, and books about early Texas were searched. The files of 88 early-day newspapers were scanned. Notes were made of references to prairie fires because of their close relation to wildlife habitat. The notes are far too numerous to cite in this paper and would be repetitious in any case. Suffice to say, the picture which emerged was one of incredibly abundant wildlife in an environment which seemed to be on fire, somewhere, all of the time.

Anderson et al. (1970, p. 81) stated:

> Together with grazing by the abundant wild fauna, fire periodically removed dead plant tops that otherwise would accumulate to rather substantial depths. Indeed it is unlikely that prairies could exist as such without repeated removal of tops...
>
> Fire not only has prevented excessive and, therefore, harmful buildup of mulch, but it also has helped maintain the prairie by killing, or at least suppressing, species with growing points above the ground. Fires favor grassland, as grass and grassland climaces favor fire.

Thus grasslands, savannas and woodland - grassland complexes from the Flint Hills of Kansas east to the Atlantic Ocean and south to the Gulf of Mexico are probably the result of frequent widespread fires. Those plant communities may be described as fire dependent.

Mutch (1970, p. 1046) hypothesized:

> If species have developed reproductive mechanisms (underground rhizomes, root sprouting, serotinous cones) and anotomical mechanisms (thick bark, epicormic sprouting) to survive periodic fires, then fire-dependent plants might also possess characteristics obtained through natural selection that actually enhance the flammability of these communities. Although plant communities may be ignited accidently or randomly, the character of burning is not random. The following hypothesis treats this interaction between fire and the ecosystem. Fire dependent plant communities burn more readily than non fire dependent communities because natural selection has favored development of characteristics that make them more flammable.

He does not offer his limited experiments as proof of his hypothesis, but proposes more research on the subject. His hypothesis, if substantiated, could explain the existence of grasslands, savannas and open woodlands in regions of enough precipitation to support closed canopy forest.

Foresters and plant ecologists have become increasingly aware of fire's role in the ecology of a variety of grassland, savanna and transitional communities in which the bobwhite is found (Shelford, 1963). Those communities are subclimaxes created and maintained by periodic burning over long periods of geologic time (Ahlgren and Ahlgren, 1960). The frequency and intensity of fires in the various plant associations of North America prior to the arrival of European Man is unclear. However, our present knowledge of plant ecology, plus descriptions of vegetation and the use of fire by Indians as reported in the diaries of early explorers, indicate that extensive areas of this continent burned regularly (Sauer, 1944; Komarek, 1964, 1965, 1966, 1967; Arnold, 1964; Kirsh and Kruse, 1972). In those plant associations, created and maintained by fire and other disturbances, the bobwhite was able to expand its range northward and eastward from probable origins in Middle America (Johnsgard, 1973).

EVOLUTION OF THE BOBWHITE

The origin of bobwhite is apparently closely linked with origins of all other quail species native to the New World. Johnsgard (1973, p. 5) states:

> Central and South America exhibit the largest total species, number of species as well as the largest number of endemic quail species (nearly all of which are in the large genus Odontophorus), whereas North America exhibits the largest number of genera and endemic genera. Since the apparently most primitime genera (Dendrortyx and Odontophorus) are of Mexican or more southerly distribution it seems apparent that the center of origin of this group must be regarded as Middle American.

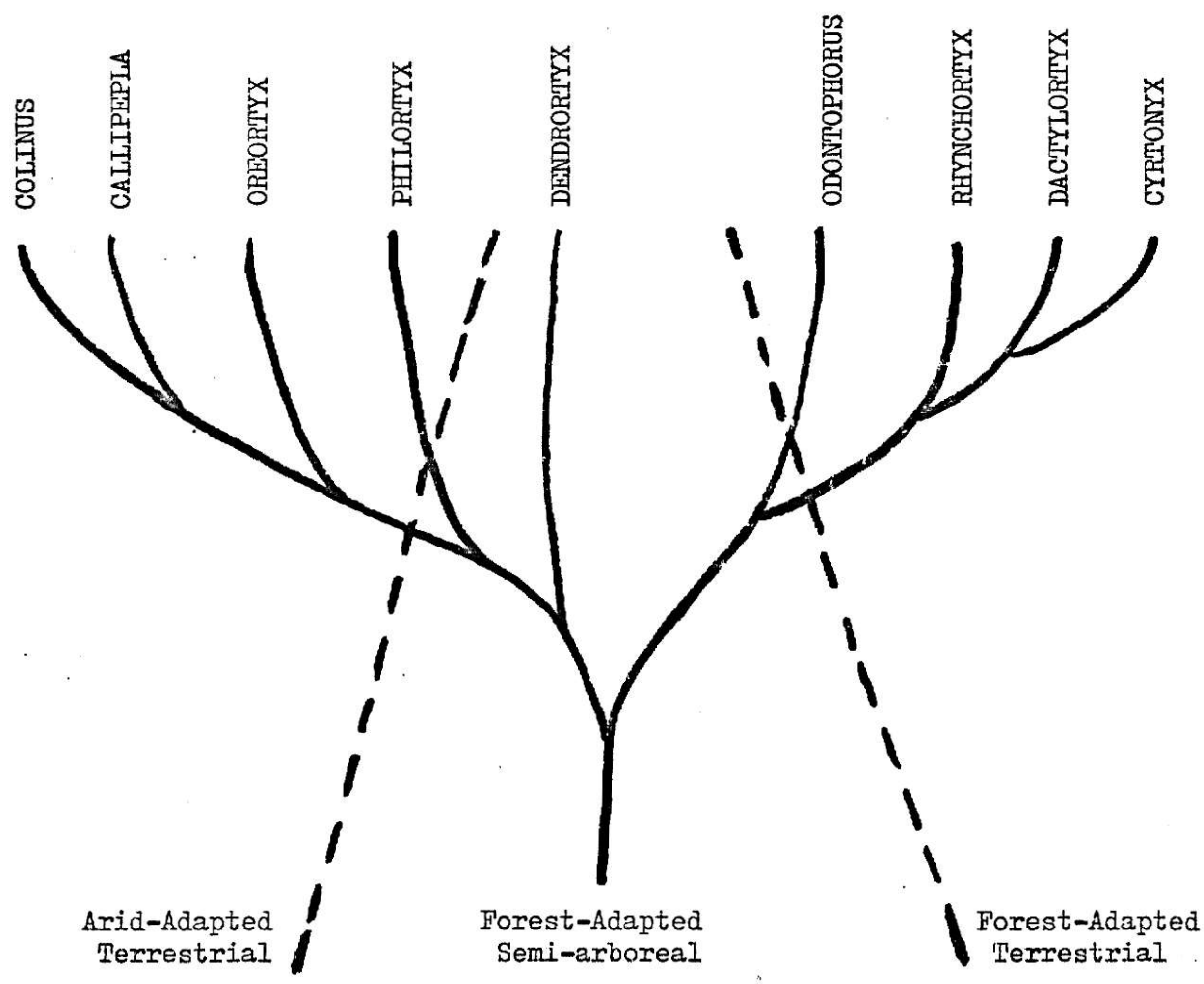
Both Dendrortyx (tree quail) and Odontophorus (spotted wood quail) are indiginous to heavy damp forests of Mexico and Central America (Leopold, 1959).

Holman (1961, 1964) reported that the genus Dendrortyx exhibits many skeletal characteristics suggestive of those found in more primitive gallinaceous families.

Johnsgard (1973) draws two evolutionary lines (Fig. 1) representing the evolution of New World quails. He includes in the seed-eating "xeric-adapted" quail genera, Philortyx (barred quail), Oreortyx (mountain quail), Callipepla (elegant quail and scaled quail) and Colinus (bobwhite quail). It is interesting to note, Colinus is the only genus in this "xeric-adapted" group with representative species in South America (Blair et al., 1968; Johnsgard, 1973). The other evolutionary line consists of primarily Middle American forest dwellers which feed mostly on bulbs, rootlets and tubers, and include the genera; Dactylortyx, Cyrtonyx and Rhynchortyx (Johnsgard, 1973). Only one genus of that group occurs in the United States. Harlequin quail (Cyrtonyx montezumae) occurs in the Pine-Oak association of the southwestern United States (Blair et al., 1968).

If Middle America is accepted as the place of origin of Colinus, it must have inhabited grasslands and savannas, and the associated riparian, woody habitats of Texas, Oklahoma and Kansas prior to inhabiting the eastern seaboard. There is evidence of its early habitation in Kansas. Wetmore (1944) attributed fossil bones of the Upper Pliocene, from Meade County, Kansas, to this genus. He speculated that it (Colinus hibbardi) was probably a resident of "forests, or regions where thickets and groves grow amid plains, prairies or savannas" (Ibid., 1944, p. 96). Another fossil species of this genus was reported from the Pleistocene Epoch. Those remains (C. suilium) were found in Florida and Texas (Holman, 1961). That species is thought to have existed concurrently with C. virginianus and has since become extinct. Rosene (1969) speculated that C. hibbardi may be the ancestor of the eastern bobwhite (C.

Figure 1. Evolutionary tree of extent genera of Quails. Adapted from Johnsgard, 1973, p. 7.


COLINUS
CALLIPEPLA
OREORTYX
PHILORTYX
DENDRORTYX
ODONTOPHORUS
RHYNCHORTYX
DACTYLORTYX
CYRTONYX
Arid-Adapted Terrestrial
Forest-Adapted Semi-arboreal
Forest-Adapted Terrestrial

virginianus).

The ability of the bobwhite, as demonstrated by its western subspecies (C. v. texanus, C. v. taylori, C. v. ridgwayi), to inhabit arid and semi-arid grassland and prairie regions, was probably instrumental in its range expansion eastward into more humid environments. Since it is primarily a seed eater, (considered to be a xeric adaption by Johnsgard, 1973) it was able to invade grassland and savanna plant associations where many grasses and forbs provided an abundant food supply. In all parts of its range today, even in the humid forest regions of the eastern United States, it is dependent primarily on seeds of grasses, forbs and shrubs for its food supply (Stoddard, 1931). This characteristic makes it a resident primarily of grassland, savanna, and transitions zones up to woodland edge, and not of the deep forest where such plants are not abundant because of shading by the tree canopy. The bobwhite meets its nutritional needs almost entirely from the soil surface to a height of eight inches (Rosene, 1969), and probably could not survive where low ground cover vegetation is not plentiful.

The habitats of the bobwhite in the more humid parts of its range are those which, if left undisturbed, would succeed to closed canopy forest, a condition which it can not tolerate (Stoddard, 1931).

The coming of the early pioneering settlers, with their clearcut, burn, farm and move agriculture, especially to states east of the Mississippi River, no doubt contributed greatly to increased abundance of bobwhites in those states. Farming land until fertility was lost and abandoning it to clear new land resulted in many stages of succession on any large acreage. This was a condition preferred by the bobwhite and resulted in remarkable population increases. Kabat and Thompson (1963) attributed the vast abundance of bobwhites in Wisconsin during the mid 1800's (Schorger, 1944; Leopold, 1931) to the settlement of land by farmers. Their road building activites and farming practices created extensive edges and field borders preferred by quail. Kabat and Thompson (1963) attributed the later decline of bobwhite populations in Wisconsin to clean farming practices and hedgerow removal by farmers seeking increased crop production. Those edges and hedgerows were subclimax communities with which the bobwhite is almost exclusively associated.

> The role of fire in pre- and post-settlement periods in creating and reducing the value of quail habitat is difficult to appraise. We don't believe pre-settlement fires which greatly contributed to the maintenance of the grassy prairies and oak savannas (Curtis, 1959) contributed equally to creating and destroying quail habitat (Ibid., 1963, p. 60).

Fire, by suppressing climax, may have been responsible for the bobwhite's presence in Wisconsin and other states in pre-settlement days, though not in the peak abundance later experienced.

We will never know precisely, the role of fire in the evolution and range expansion of the bobwhite. Whether the term "fire-adapted" (Komarek, 1967, p. 143) applies to the bobwhite can only be conjecture on a basis of research to date. A distinction should be made between the bird's response to fire and its response to fire created habitat. Fire has played an important role in development and maintenance of virtually all non-agricultural plant associations in which the bobwhite resides.

BOBWHITES AND NEW BURNS

Although quail, quail habitat and effects of fire are interrelated, the proof of Komarek's (Ibid., 1967) hypothesis that "certain of our wild fauna are fire-adapted' should be restricted to research done on behavioral aspects of the bird during and after the fire until its immediate effects are again covered by vegetation. After a short period of time, the bird is responding to the new vegetation and other environmental factors, and not directly to the fire. I once witnessed prairie chickens performing their annual booming rituals on hilltops in the Kansas Flint Hills, which had been burned only two or three days earlier. On that occasion our party of about 35 people approached within 75 to 100 yards of approximately 10 cocks booming on the blackened hilltop. They seemed oblivious to our approach even in the absence of cover.

Bigham et al. (1964) reported finding two coveys, one of five and one of eight bobwhites on a 400 acre burn in Oklahoma the day following a fire. They attributed the low population to an extended drought and not necessarily to the fire. Jackson (1965) found six bobwhites in a pasture 16 days after a March 3, burn in Texas. There was a complete absence of ground cover and no visable source of food. Edwards and Ellis (1969) observed quail and fire in Illinois and reported the following:

> Three bobwhites were heard giving covey calls, one east, one south and one northwest, within 200-300 yards of the burning field. Two single and one pair of quail were observed to fly directly to the burning field and land within a few feet of the flames.
>
> Earlier in the afternoon, on a different part of the study area, a covey of about 16 quail had been observed to flush less than 6 feet ahead of the fire. When flushed, they flew approximately 80 yards and landed as a covey. There was neither covey disorganization nor calling behavior to indicate either alarm or fright exhibited by these birds. The following morning a covey, presumably the same one, again flushed from this earlier burn; three more coveys were flushed from other new burns that morning.
>
> From these and other observations we conclude that bobwhites typically respond very quickly to burning and newly burned fields...
>
> The significance of these observations is that quail respond positively rather than negatively to fire in their environment. These observations are in agreement with Komarek's (1967) hypothesis that certain of our fauna may be fire adapted.

"So important is fire in bobwhite management that this bird might be called the 'fire-bird'. Quail are attracted by burning in their pineland habitat, and may flock to burns almost before they stop smoking" (Stoddard, 1963, p. 166).

Availability of food is probably the most powerful attraction to new burns. Mulch and litter serves as a sieve through which seeds may fall beyond the reach of quail. It also serves as a hiding place for over-wintering insects. Removal of this accumulation by fire in the spring uncovers many seeds and probably kills many hiding insects leaving their scorched carcasses in the ashes. The black ashes serve to warm the soil (Kucera and Ehrenreich, 1962) earlier in the spring, and possibly stimulates early emergence of many surviving insects into an environment of little cover and few hiding places. Seeds and insects are then readily available to quail. Crops can be filled quickly. Feeding time is danger time because birds have to move around to feed. This motion may attract predators (Jackson, 1947). By minimizing feeding time bobwhites can reduce exposure to predation.

If there is adequate brushy cover interspersed in the burned area, quail will probably remain. "Quail, however, are very timid and fear to feed far from thicket cover, in spite of being color protected" (Stoddard, 1963, p. 167).

MULCH AND ROUGH

Probably the most important function of fire is the removal of mulch and litter which accumulates during years of no burning. The implications against litter and mulch as being detrimental to quail and quail habitat are many.

Accumulation of mulch and litter is important in preparing the environment for advanced woody stages of succession. The open grassland and savanna communities which developed under repeated fires typically have little mulch and litter accumulation and thrive in that open environment. But when fire is withheld, mulch accumulates. The environment is no longer the same. The grasses and forbs adapted to fire lose some competitive advantage. Weaver and Rowland (1952) reported 53 percent less production (air dry) of big bluestem (*Andropogon gerardi*), and 57 percent less production of switchgrass (*Panicum virgatum*) on mulched plots, opposed to plots on which mulch had been mechanically removed. They stated (Ibid., p. 13), "That the effects of the mulch had greatly thinned the stand was shown both by stem counts and measurement of basal area." Anderson et al. (1970) reported increases in basal cover of all the key decreaser species, big bluestem, little bluestem (*A. scoparius*), indiangrass (*Sorghastrum nutans*) and switchgrass with mulch removal by burning in the Kansas Flint Hills. Kucera and Ehrenreich (1962) observed a marked increase in dry matter and seed production of prairie grasses in Missouri with annual mulch removal by fire.

Mulch suppresses species from which it develops and enhances invasion by mulch tolerant, non-fire adapted shrubs such as buckbrush (*Symphoricarpos orbiculatus*) and roughleafed dogwood (*Cornus asperifolia*), and trees such as osage orange (*Maclura pomifera*), eastern redcedar (*Juniprous virginiana*) and American elm. The next stage of plant succession is at hand. The open habitat which supports large quail populations will diminish as woody species become dominant plants. Quail populations will also decline (Rosene, 1954) until the next fire or other disturbance occurs and reopens the ground cover.

Mulch accumulation also has a direct effect on bobwhites. If present over large areas, it renders much of the quail's food supply unavailable. The bobwhite is a "weak scratcher and can not obtain food from heavy litter" (Komarek, 1965, p. 189). Stoddard (1931, p. 406) states:

> Cover for the birds at their level should be open enough for them to run about easily and find their food without having to dig down in a mat of surface litter. So great is their aversion for unbroken areas of old broomsedge or wiregrass, or for areas covered with an accumulated mat of pine needles, that they avoid them except for temporary shelter when persued by enemies. "Rough" is not necessary even for shelter, for quail are equally safe in thickets and in cover of the more open type that they prefer.

Nesting and roosting are also activities of the bobwhite which require open habitat with the absence of heavy litter accumulation. Although fire is an effective litter remover, its effect on quail nesting can be harmful or beneficial. Bobwhites use dead plant materials from previous years' growth almost exclusively, for nest construction (Stoddard, 1931; Rosene, 1969; Klimstra and Scott, 1957; Lehman, 1946; Parmalee, 1955). Dimmick (1971) reported, of 534 in use nests, only 107 were in areas burned the previous season. Of 600 nests studied by Stoddard (1931), 89 percent were in unburned growth of the preceding season, 82 percent in growth open enough at the birds' level for them to run about freely and 75 percent were within 50 feet of open grassy edge. Klimstra (1950, p. 389) noted, "Areas of dense plant growth, such as idle fields and grassed waterways, were never found to be used for nesting or rearing the young except at the edges." Klimstra and Scott (1957) observed, open cover at ground level seemed to be important to nesting quail.

Either too little or too much dead plant material can be detrimental to quail nest site selection. Annual burning of an entire management area might impose severe limitations on quail nesting, but heavy litter accumulation as a result of complete fire suppression could be just as severe. This problem might be solved by using one or more of the following burning methods.

1. Backfire when litter is damp for litter reduction rather than litter elimination.
2. Prevent areas from burning each year so they may be used for nesting, i.e., patch burn (Vogl, 1967).
3. Burn any area no more than every three or four years, i.e., rotation burn (Dimmick, 1971).

Periodic disking, plowing and cropping may be suitable alternatives to burning on small areas, for maintenance of subclimax vegetation.

Klimstra and Ziccardi (1963) found wintering quail in southern Illinois intolerant of heavy litter accumulation in roosting site selection. They reported that 60.4 percent of the roosting sites found occurred on bare ground, 31.0 percent on duff and only 8.6 percent on vegetation. Ellis et al. (1969) noted that relative sparseness of vegetation seemed characteristic of roost sites. Most sites were on bare ground or on light duff. Only five of 23 were on matted grasses or low forbs.

Management practices for bobwhites should include litter suppression by grazing and burning or mechanical removal.

BURNING AND QUAIL FOOD PLANTS

Withholding fire from naturally succeeding plant communities for excessive periods of time interferes with quail production by permitting a shift in botanical composition away from abundant quail food plants including legumes and composites to heavy stands of broomsedge (Andropogon spp.), wiregrass (Aristida spp.) or other non-food types (Ellis et al., 1969). Most legumes, other dicots and some grasses, the seeds of which are a large part of the bobwhite's diet, are typically early successional species. They become most abundant when they are allowed to pioneer on bare ground.

Robinson (1957) reported that smoothseed wildbean (Strophostyles leiosperma) grew in profusion on cultivated ground in south central Kansas. He found this legume provided a major winter food for bobwhites in his study area. Korschgen (1948) found common ragweed (Ambrosia artemisiifolia) to be the third most important late fall and early winter food of bobwhites in Missouri and is abundant in the aftermath of small grain crops throughout that state. Common ragweed, jerusalemartichoke (Helianthus tuberosus) and sensitive partridge-pea (Cassia nictitans) were all found to be important natural fall and winter foods of bobwhites by Robel (1964) in eastern Kansas. The above mentioned quail food plants are typically associated with repeated soil disturbance and pioneer on barren ground. A mulch free environment may also be created by burning. Anderson and Schwegman (1971) found that showy partridgepea (C. fasciculata), sensitive partridgepea, smoothseed wildbean, pencilflower (Stylosanthes biflora) and common ragweed all increased after the first spring burn of native vegetation in southern Illinois. Morse (1963) compared two-year trends in the vegetation on burned areas and adjacent unburned areas in Texas. The number of perennial grass plants decreased 13 percent on burned areas and 6 percent on unburned areas, while a group of plants rated as key winter food sources of quail averaged a 15 percent increase on burned areas and decreased 30 percent on unburned areas. Of these, he found fringeleaf paspalum (Paspalum ciliatifolium) increased 16 percent in frequency on burned areas but decreased 24 percent on unburned areas. Erect dayflower (Commelina erecta) increased 58 percent on burned areas and decreased 14 percent on unburned areas. Western ragweed (A. psilostachya) was unchanged from the previous year on burned areas, but decreased 35 percent on unburned areas. Texas croton (Croton texensis) increased on both areas, but rate of increase was double on the burned area.

An analysis of vegetation on burn and check areas in Alabama Piedmont conducted by Speake (1966) revealed a much higher coverage of important quail food plants on the burned area compared to those on the check area. He found that percent coverage by those plants on the burned area was similar to that found occurring naturally on old fields in the most favorable stage of plant succession. Speake (1960) concluded that attractiveness of old fields in the Piedmont to quail is associated with wild legume abundance largely determined by plant succession. Cushwa and Brender (1966) found legumes significantly more abundant on burned plots than on unburned controls in a Georgia Piedmont study area.

The specific composition of plant communities, resulting from burning, is dependent in large part on edaphic factors associated with the region. But, shift in composition has been documented over most of the bobwhite's range; in the southeastern United States by Stoddard, (1931); Speake, (1960, 1966); Cushwa and Brender, (1966); in Texas by Morse, (1963); in Illinois by Ellis et al., (1969); Anderson and Schwegman, (1971); and in Kansas by Anderson et al., (1970). By properly timing the burn, succession can be forced back, the vegetation opened up and a high density of seed bearing dicot plants attained.

Not only are food plant densities increased by properly timed burning, but Lemon (1967) suggested that their fruit and seed production might also be stimulated. Stimulation of legume growth noticed after fires may be due to the removal of dead plant parts of the competing grass, to plant food released in the ash or to increased germination of hard seeds by fire (Stoddard, 1931).

Kucera and Ehrenreich (1962) found three species of native grass, big bluestem, little bluestem and indiangrass increased flowering stalk production by 270, 1200, and 400 percent respectively after burning. During the three years of their experiments, resumption of growth by these grasses in the spring was seven to ten days earlier on the burned than on the unburned plots. They attributed this primarily to higher soil temperatures resulting from the removal of mulch and greater heat absorption by ash blackened soil.

Those grasses do not produce primary quail foods, but they are fire tolerant, dominant, perennial grasses. Fire tolerant, perennial legumes and composites might respond similarly to maintain their stature in fire-disturbed subclimax communities. More quantitative research is needed to study the fruiting and seed production response of quail food plants to burning.

FIRE AND THE ANIMAL FOODS OF QUAIL

The role of insects in food habits of the bobwhite has not been adequately researched. Insects are taken in greatest numbers during late spring to early fall (Cottam, 1931). There is great reluctance among researchers to kill quail during the reproductive season to accomplish such research (Robinson, 1957). A few studies of the spring and summer food habits have been undertaken in conjunction with larger projects by Cottam (1931), Handly (1931), Frye (1954, 1956), Jackson and Green (1964, 1965) and Hurst (1970). Those studies have indicated, animal matter may not be critical in the diet of adult quail, but is taken as the opportunity arises.

Data from Handly (1931), however, leads one to the opposite conclusion in the case of young birds:

> During the first two weeks of existence, young bobwhites, as with young of practically all birds, consume a much greater proportion of animal food than do their parents. Of the food of 20 chicks under two weeks of age, 83.7 percent consisted of animal matter, compared with 22 percent in 154 adults collected during the same period. The animal matter taken by chicks was composed of beetles, 31.7 percent; grasshoppers and their allies, 26.7 percent; spiders, 8 percent; caterpillers and moths, 7.9 percent; bugs, 7.1 percent; miscellaneous insects, 1.8 percent; slugs and snails, 0.5 percent. All the 20 birds had eaten beetles; 17 had taken grasshoppers and their allies; 16 of them spiders; 11, caterpillers and moths; 18, bugs; and three had taken slugs and snails. The kinds of insects and other animal matter eaten, although of smaller size, were just as varied and of the same character as those eaten by adults.

Southwood and Gross (1969) concluded from their studies of partridge (*Perdix perdix*) chicks in the British Isles, that insect availability was more important than mean daily sunshine or mean temperature in successful rearing of young.

Dependence of gallinaceous chicks on insects is probably related to protein requirements. Nestler et al. (1942) found the optimum diet of pen reared bobwhites under ten weeks of age, contained 28 percent protein while 22 percent was optimum for adults. Adult wild quail probably can survive without large amounts of insect matter in their diet. But insects provide a readily available source of protein, essential amino acids and trace nutrients in the quail's natural environment. This is especially true in rearing young birds, which would be hard pressed to find and ingest enough vegetable protein and amino acids during a time of rapid growth and development.

If insects are ever essential to quail, it is during the first two or three weeks after hatching (Stoddard, 1931). Quail chicks likely are not as dependent on a high biomass as on a highly available biomass of insects. Burning could decrease insect biomass and still increase availability by removing litter and opening the vegetation.

There is evidence, however, that some insects respond positively to burned-over habitat. Three important findings by Rice (1932) were (1) soil temperatures at time of burning were not high enough to kill all animals hiding beneath the soil surface, (2) animals surviving the burn sought shelter in safe cover, and (3) many phytophagus insects and herbivores soon returned to the burned area because of the rapidly growing vegetation.

Komarek (1965) noted that populations of red-legged grasshoppers (<u>Melanopus femurrubrum</u>) moved from unburned patches of grass to interspersed burned grass within one week of burning and were apparently feeding upon fresh nutritious young grass.

Cancelado and Yonke (1970) captured significantly greater numbers of Homoptera, Hemiptera, Cicadellidae and Lygaedae in Malaise traps on burned than on unburned areas. Two sweep samples they took on burned areas produced as many Miridae as ten other samples combined.

Hurst (1970) found that total biomass of arthropods on burned plots was nearly double that on unburned plots. He found this true in both D-vac and sweep samples (Table 1). He collected further data on 126 quail chicks, aged two days to two weeks, which were turned out to forage with bantam hens on the burned plots. All the insects eaten by the chicks were also identified in D-vac and sweep samples. He found that beetles (Curculionidae and Chrysomelidae) were most frequently eaten by the chicks, followed by Hemiptera, Homoptera, Orthoptera and various other groups, respectively.

Southwood and Gross (1969) indicated that partridge chicks feed most heavily on insects most available. Whether this is true of bobwhites remains to be learned. If insects which tend to increase with burning are also preferred by quail chicks, chick survival, as it depends on insect availability, would be enhanced as a result of periodic burning. The relationship between quail chicks and insects as affected by burning, needs further study.

BURNING AND QUAIL-RODENT COMPETITION

Although research concerning direct competition between bobwhites and small rodents is lacking, food habit studies of each group are available. Comparisons of those studies indicate that such competition might be severe during the winter and early spring months. Both quail and small rodents sustain themselves predominantly on seeds, but they also eat large numbers of insects and some green vegetation during the warmer months.

Williams (1959) analized the stomach contents of 122 deer mice (*Peromyscus maniculatus*) trapped in Wyoming and Colorado. He found starchy interiors of seed integuments comprised roughly two-thirds to three-fourths of the material found in the stomachs. One-tenth to one-fifth of the material identified was arthropod remains. Grubs and caterpillers were frequently

Table 1. Means and statistical significance of the multiple sample analysis of the four sweep net and three D-vac samples. Adapted from Hurst, 1970, p. 196.

Category	Treatment	Mean number		Dry Wt. (g)	
		D-vac	Sweep net	D-vac	Sweep net
Araneida	B	107	62**	.184	.246**
	U	100	47	.164	.146
Formicidae	B	112**	42**	.042*	.018*
	U	41	17	.017	.008
Diptera	B	79*	20	.030	.025
	U	62	26	.036	.031
Tettigoniidae	B	42**	40**	.160**	.376**
	U	18	21	.050	.183
Gryllidae	B	8.4**	6.3**	.028*	.028*
	U	3.6	2.6	.013	.015
Tetrigidae	B	7.9**	2.6**	.051**	.043**
	U	0.3	0.2	.002	.002
Acrididae	B	27.5**	55.9**	.165**	.990**
	U	10.6	25.5	.069	.419
Homoptera	B	162**	130**	.166**	.205**
	U	87	61	.096	.101
Hemiptera	B	82**	100**	.159**	.263
	U	56	65	.100	.214
Coleoptera	B	87**	124**	.106**	.198**
	U	51	64	.066	.132
Total Sample Weight	B			1.222**	2.657**
	U			0.660	1.356

* 5% confidence level
** 1% confidence level

B Burned
U Unburned

represented. Fruits, fungi, annelids and green vegetation comprised the other foods eaten.

The more important foods of the house mouse (Mus musculus) in studies conducted by Whitaker (1966) were Setaria seeds, lepidoptera larvae, various weed seeds, various animal materials and cultivated crops including corn (Zea mays), wheat (Triticum aestivum), soybeans (Glycine max) and Sorghum. Among the more important foods of P. maniculatus bairdi, he found lepidoptera larvae, weed seeds, animal materials and cultivated foods, especially wheat and soybeans. The more important foods of P. leucopus were various kinds of seeds, lepidoptera larvae and mast.

Small populations of rodents are probably not detrimental to quail, but large populations could be a serious problem, on a basis of competition for food (Scott, 1958). Competition is probably most intense during the winter and early spring months when both populations are competing for a diminishing food supply (Robel, 1964).

Hamilton (1941) calculated food consumption per acre per day for a mixed population of small rodents as follows:

> The amount of food eaten by these small mammals is considerable. We can determine this by weighing the contents of a series of full stomachs for the various species. It is known that the stomach is filled at least twice a day (a conservative estimate based on the feeding habits of captive species). From this may be judged the total amount eaten by a mixed population of small mammals in a forest region. Under natural conditions, adult deer mice eat about thirty percent of their weight daily, or 6 grams of food; jumping mice and red-back mice a similar amount; lemming mice considerably more than this; short-tailed shrews 2 to 4 grams of food daily. If we have a mixed population from 60 to 100 mammals per acre, we thus find that the small mammal population is consuming from .85 to 1.2 pounds of food daily. In addition to the food actually eaten, much is stored, a proportion of which is never eaten.

When abundant, mice may efficiently consume and gather so much food that they seriously deplete the food supply of quail. Some measure of rodent control may be necessary if abundant winter food is to be maintained. Limited research indicates that fire may be used for rodent control.

Clubine (1971) concluded that the white-footed deer mouse (P. maniculatus) was the only species in the Flint Hills to succeed under burning. Three other species, white-footed mice (P. leucopus), meadow voles (Microtus ochragaster) and least shrews (Cryptotis parva) were almost non-existent on burned plots but were common on unburned plots. He assumed burning to be a hazard to their existence and grazing a mild deterrent since both retard shrub invasion.

Eadie (1953) noted a direct response of Microtus to measurable differences in amount of vegetative cover. The area of high Microtus density had almost twice as much vegetative cover as the area of low density. In central Kansas, Frydendall (1969) found the largest concentrations of rodents in the relic habitat, on his study area of four habitat types. That habitat had been relatively undisturbed for 60 years, while the other types had periodic disturbance by grazing and farming. Cooksey (1970) concluded that disturbance of any kind, grazing, farming or burning, was detrimental to Microtus habitat in the Manhattan, Kansas, area.

Springer and Schramm (1972) concluded:

> Burning has a temporary adverse effect on nearly all small mammal species found in the restored prairie. Exceptions are the white-footed mouse (P. leucopus), which invades from wooded areas, and possibly the jumping mouse (Zapus hudsonius). It is evident that the population density of the short-tailed shrew (Blarina brevicauda), is substantually reduced the summer following a spring burn, taking two full years, plus one growing season, for the population to recover to the maximum density.

Clubine (1971) further concluded that burning in the Kansas Flint Hills did not necessarily reduce the biomass of small rodents, but that P. maniculatus was able to increase under burning and replace, at least in part, the biomass lost with the disappearance of other species. That increase in P. maniculatus could still represent serious competition for quail.

Quail-rodent competition likely can only become a problem in marginal quail habitat. Optimum habitat conditions for quail are not optimum for most small rodents. Many rodents have a preference for heavily mulched and littered habitats while quail prefer the opposite. Perhaps increasing populations of certain small rodents such as Microtus are indicators of declining quail habitat. Additional research on quail-rodent-habitat relationships might uncover valuable quail management possibilities. Fire appears capable of manipulating habitat in favor of bobwhites.

QUAIL RESPONSE TO BURNED HABITATS

In any wildlife management program, the best indicator of success is response of the managed species. There is evidence in the literature of the positive response by quail populations to burned habitats.

Ellis et al. (1969) in managing historically timbered, previously farmed, go-back land, in Illinois, increased quail populations with a combination of sharecropping and burning, and by burning alone. Over a six year period (1963-1968) quail populations on burned and sharecropped lands increased by 140 percent. Where burning was the principle tool, populations increased by 91.4 percent. On the area where sharecropping and food plantings were used, the quail population increased by only 57 percent, and where only food plantings were used the population declined by 14 percent.

Jackson (1965) studied effects of a wildfire (March 3, 1962) on bobwhite populations in the Texas sandhills. He observed the following:

> During September, roost call-counts were carried out in the sandhills burn area. A total of ten stations at one mile intervals were manned at dawn on two successive days. Thirty-one coveys were counted, of which seven were in the 576 acre Persimmon Pasture. Rechecks of Persimmon Pasture with dogs on the same dates resulted in locating nine coveys, or approximately 150 bobwhites. A surprising density of one bobwhite per 3.8 acres had been attained in six months following a sweeping grass fire which had erased all semblance of quail habitat.

> During the December-January hunting season, a series of controlled hunts were permitted on the Gene Howe Area for research purposes. The hunters found quail most abundant in those pastures which had been burned off in the March fire. The previous season, bobwhites had been few in the sandhills, but concentrated in bottomland habitats. In the case of privately owned ranches which had been involved in the grass fire, hunters reported finding the most coveys in those areas which had been burned off.

Kellogg et al. (1970) reported a fall quail population density, of 1.5 birds per acre on 1118 acres, 90 percent of which is burned annually in February and March. Speake (1966) reporting on burning in the Alabama Piedmont stated:

> The fall quail population on the burn area greatly increased during the years of intensified burning (1960-1965). During this six year period, the fall quail population averaged 50.1 birds per 100 acres on the burn area, and for three of these years (1960-1962) the check-area population averaged 27.5 birds per 100 acres.

The highest population he measured was 66 birds per 100 acres on the burned area, and was considerably higher than 40.8 per 100 acres, the highest population when the area was considered to be in the most favorable stage of plant succession.

Quail populations in several areas have been increased by applying current knowledge of fire ecology to management. But many aspects of burning on quail populations are poorly understood and remain to be explored. The answers to the following questions are still lacking:

1. How does burning affect parasitism of quail by internal and external parasites?
2. How does burning affect predation on quail, quail nests and broods?
3. What is the real effect of litter accumulation on the ground movements of quail?
4. With what intensity and under what weather conditions should prescribed burning be carried out to attain the maximum benefit?

Stoddard (1931) and other workers have made observations concerning these problems, but hard data from which to draw conclusions is still needed. Perhaps with the answers to the above questions, and others, it will be possible to refine quail management so populations of 1.5 birds per acre as reported by Kellogg et al. (1970) will be a matter of course rather than isolated occurrences.

BURNING AS A TOOL FOR QUAIL MANAGEMENT

As Grange (1949) and Howard et al. (1959) have pointed out; fire, in its ability to alter plant communities and succession, also has indirect ability to alter animal communities to the benefit of some and detriment of others. Burning tends to suppress plant succession while withholding fire and other disturbances allows succession to advance to climax. Each successional plant community, including climax, has its characteristic wild fauna. Fire alters type and abundance of niche of any species resident to the burned area.

Since most wildlife management techniques are based on habitat manipulation to provide maximum niche availability for the managed species, it is not possible to manage an area for maximum production of two or more species whose optimum niche requirements do not normally occur in the same successional plant community. For example, one could not maximize both Microtus and bobwhite populations in the same area. Management for one would be at the expense of the other.

Bobwhites are usually a more desired product of the habitat than Microtus, therefore, it is the species for which the management plan is formulated, and Microtus is forced to do with the conditions provided by management. Species which do well in habitat managed for quail will flourish. Whether burning in quail management is beneficial or detrimental to other forms of wildlife is dependent on whether they are adapted to cohabiting the same environment as quail. If fire is to be used in quail management, it should be done with the expectation that some of the resident wildlife species will decline and others will increase. In this respect, fire is like any other tool used in wildlife management. If it can be properly implemented and will aid in fulfilling management's goal without undue destruction to other entities considered valuable to the public good, it should be used.

Biswell (1969) proposed the following definition for prescribed burning:

> Prescribed burning, also known as control burning, is the judicious use of fire for a constructive purpose and according to a management plan. Its objective is to employ fire scientifically for maximum net benefits at minimum damage and acceptable cost.

When burning occurs in departure from this definition, it can become detrimental to wildlife and man. This most often occurs in the case of wildfires. Wildfires, although sometimes beneficial to quail (Jackson, 1965) and other wildlife, should be prevented. Man has left little to be accomplished by wildfire in his creation of an artificial environment suitable to his needs. This does not mean that man with his technology has nothing to learn from the ecological impact of naturally occurring wildfires. It is for him to understand this impact and convert its benefits to his own use. Fire thus becomes a habitat management tool, which when properly used has no greater impact than properly used plow, disk, harrow or ax.

The temptation to abuse or overuse burning in habitat management is easily understood. Fire is so easily applied that the careless or unskilled manager may be tempted to drop a few matches in areas where other tools might be more appropriate.

For maximum benefits from use of fire, a plan of prescribed burning, based on experimentally produced predictable results, must be incorporated into the management plan for an area.

The most important benefits of burning in quail management are probably control of plant succession and reduction of mulch and litter. That can be accomplished by burning at any time of the year, whenever litter is in heavy enough accumulation and dry enough to burn. Burning in this fashion, however, would be a non-judicious use of fire in terms of the definition. Control of succession and litter reduction are not the only criteria on which to formulate a burning prescription. Poorly timed burning could have disastrous effects on quail populations. Burning in late summer or fall, for example, would remove most of the birds winter food supply. At that time much of the food supply is still hanging in seedheads and is subject to destruction by fire. Fall fires also remove much of the vegetation which quail need for winter cover and protection from predators.

Late spring and early summer fires can be harmful to nesting success. Nests and flightless broods may be destroyed by improperly timed burns. Stoddard (1931) observed that such fires might be useful in isolated instances to discourage quail nesting in low-lying, frequently flooded areas. That might force nesting pairs to select nest sites in well-drained areas.

Prescribed burning is used for a variety of purposes other than quail management. Fire, as with any other tool, is subject to the planned benefit it offers to the major product of the land. In livestock producing areas it is used to maximize forage production and quality. In timber producing regions it is used to control tree diseases, destroy undesirable shrubs and trees, and reduce threat of wildfire (Zontek, 1966).

Bobwhites sometimes benefit even when burning is carried out for other purposes. Owensby (personal communication, 1971) has observed that quail are abundant on late-spring (May 1) burned pastures, but almost non-existent on unburned pastures in the Range Research Unit at Kansas State University, Manhattan, Kansas. Those pastures are used for research in maximizing beef production, and are burned without consideration for quail. Late spring burning is not considered, by most quail biologists, optimal for quail production.

The International Paper Company, Bainbridge, Georgia, uses prescribed burning in management for maximum timber production. They have been able to fit quail management into their burning program by adjusting time of fire and rotation burning to benefit quail while accomplishing management purposes (Perkins, 1967).

Peak quail production likely cannot be attained on land managed for other purposes, but in some cases they respond positively to burning practices even if the fires do not occur at optimum times or with optimum frequency.

Fire prescriptions can be formulated to optimize quail habitat where peak quail production is the primary land use. On shooting preserves and public hunting areas, other production is secondary but may help pay for implementation and maintenance of quail management programs.

Probably the two most important questions the quail manager must answer correctly in formulating a successful prescribed burning program are:

1. At what time of the year should the burning be done?
2. How frequently should the vegetation be burned?

Answers to those questions appear regularly in the literature. Scott (1958) suggested that burning dates ranged from November 1, to April 1. Stoddard, (1931) suggested that exceptions might range to mid-summer. Answers to the second question range from not at all to annually depending on the rate of litter accumulation (Devet and Hopkins, 1967; Kellogg et al., 1970).

The best answers to both questions probably lie between the extremes in both cases. No two quail management units are alike. Therefore, the same fire prescription will not apply over the entire bobwhite range. The manager must formulate his plan from the research and experience of workers in other areas and experiment with it. It may be successful and increase the quail population the first year after the burn (Jackson, 1965). But it is not likely to produce a peak population. Peak populations probably cannot be produced from low populations in just one year. Such increases may be limited by reproductive potential. Peak populations are most likely to occur when the manager after several years of observation has modified and tailored his burning prescription and other practices to his particular area. It will take many years, and a vast amount of research and experimentation, to provide all the right answers and to refine prescribed burning for quail management.

The overriding effect of fire to be considered in properly timing the burn is the shift in botanical composition. Anderson and Owensby (1966) and Anderson et al. (1970) indicated that late-spring burning shifts botanical composition in favor of warm-season grasses and against perennial forbs, shrubs and cool-season grasses in the Flint Hills. Burning at that time favors warm-season grasses because their meristems are at or below the soil surface where damage by fire is minimal. At the time of a late-spring burn they are just emerging and still have energy reserves stored in their roots. Fire removes most old growth, warms and fertilizes the soil, and removes cool-season grass and forb competition when the warm-season grasses are ready to take advantage of those conditions. Late-spring burning does not remove all cool-season grasses and forbs from the True Prairie plant community. Many species including common ragweed, goldenrods (Solidago spp.), Louisiana sagewart (Artemesia ludoviciana) and many legumes remain in substantial numbers.

High production of legumes and other forbs is imperative for production of large quail populations (Stoddard, 1931; Moore, 1957; Morse, 1963; Jackson and Green, 1964). Therefore, timing the burn to favor legumes is important. Anderson et al. (1970) have demonstrated that early-spring (March 20) burning causes such a shift in the Flint Hills.

Mary quail investigators researching in other regions have arrived at approximately the same conclusion (Scott, 1958; Speake, 1966; Ellis et al., 1969). They have timed burning to least interfere with the quail's life cycle. Early-spring burning allows for adequate revegetation before onset of nesting. It clears old vegetation, fertilizes the soil and results in a warm, blackened soil surface when legumes and other forbs can best gain advantage over warm-season species. Forbs have not yet sprouted, and early-spring burning represents no hazard to their growing points. They gain their advantage by emerging a few days ahead of the warm-season species and exploiting the conditions made available by the early-spring burn (Anderson et al., 1970).

Complete coverage of the land by fire is not needed. Stoddard (1963) tried to leave small areas of "rough" of two to four years exclusion from fire. That provides refuge for insects which are important summer foods, and also small brushy coverts, or refuges to assist quails' escape from predators.

Vogl (1967) commented on fire's feel for the land:

> On occasion, the fire destruction of habitat may indirectly destroy the wildlife dependent on that habitat. Extremely large burns may reduce protective cover to a minimum. In this connection, I have heard managers speak with dismay of a particular area which was not uniformly burned because the fire missed here and there or didn't burn hot enough in places. Perhaps this is a carry-over from plowing straight furrows or planting trees in rows. The variety of intensities and the spotty effects of fire on a given piece of terrain is to be desired, since this provides the greatest variety in plant succession and edges. Fire has a little better "feel for the land" than man with a spray gun, brush saw or bulldozer, and leaves or skips the proper amounts and kinds of cover.

In answer to how frequently to burn, several questions must be answered concerning the area to be burned.

1. Has plant succession advanced past the stage considered optimum for

bobwhites?

2. Will litter accumulation, with the addition of next season's growth, become great enough to retard ground movement and feeding by quail?

3. Has quail food production decreased since the last fire or other disturbance?

4. Has the quail population declined as a result of any of the above conditions?

Quail habitat is a condition comprised of several important factors, and not just a matter of cover and food supply. There is no pat answer to the question of how often to burn. If any of the above questions can be answered "yes", the habitat cannot produce a peak quail population and would probably benefit from a timely burn.

In areas of high soil fertility and rainfall, the answer to the second question might be "yes" after one growing season, and annual burning might be recommended at least over most of the area. In areas of lower fertility or rainfall, vegetative recovery after a burn would be slower (Launchbaugh, 1972) and fire should be withheld up to three or four years depending on the advancement of succession, litter accumulation and the condition of the quail population.

COST OF PRESCRIBED BURNING FOR QUAIL PRODUCTION

Fire is one of the least expensive management tools available to the wildlife manager. It can be applied in many cases for a few cents per acre (Ellis et al., 1969). Vogl (1967) reported burning 200 acres in Wisconsin, in 1941, for about $0.30 per acre. Concerning other burns, he stated (Ibid., p. 89):

> The average cost for 8,783 acres burned in northwestern Wisconsin was $0.68 per acre. Costs ranged from a high of $8.30 per acre on a 3.7 acre burn to $0.05 per acre on a 1,940 acre fire on sandy soils. Preliminary results indicate that costs for heavier soils will average between $1.00 to $1.20 per acre....Burning costs on the Mead Area from 1960 through 1962 ranged from $0.05 per acre on 920 acres to $1.06 on 50 acres, with an average of $0.41 per acre for 5,905 acres. Costs included labor, equipment and supplies.

The direct expense of using fire varies, depending on how large an area is to be burned, how difficult the fire will be to control, type and amount of equipment needed to control it, number and experience of the men doing the burning, topography and vegetation.

If large continuous areas can be burned using a minimum of equipment, and with an experienced crew, the cost will be small. As the area to be burned decreases in size or the amount of equipment and number of men needed increases, cost per acre increases.

On the public hunting areas in eastern Kansas, the sharecropping farmers and the range leasing stockmen do the burning on their leases as prescribed by the Kansas Fish and Game Commission (R. E. McWhorter, personal communication, 1973). Since most of them either own or have access to tractor mounted spray rigs suitable for controlling fire, equipment expense is small. In early spring they also have spare time in which to complete the job with the aid of biologists and hunting area managers.

One way to evaluate the cost of a game management program is on a cost of management per animal harvested or bag limit bagged. Ellis et al. (1969) prepared such an evaluation (Table 2) for one of his management areas in Illinois.

In using fire as a management tool, there may be some additional, not so obvious costs resulting from burning. Presently, inadequate data is available to assess the following costs suggested by Zivnuska (1972):

Table 2. Approximate costs of producing harvested quail under three management systems in Illinois. Adapted from Ellis et al., 1969, p. 757.

Management system	Food patch	Sharecrop and burn	Burn only
Quail/100 acres	37	96	67
Harvest/100 acres	20	50	33
Acres/quail bagged	5	2	3
Mgmt. cost/acre	$4.57	$0.16	$0.22
Cost/quail	$22.85	$0.32	$0.66
Acres/limit (8)	40	16	22
Cost/limit (8)	$182.80	$2.56	$5.28

1. Cost of keeping men and equipment available while waiting for proper meteorological conditions for burning.
2. Probability that the fire might escape and become a wildfire doing unintended damage.
3. Contribution of the smoke of prescribed fire to air pollution.
4. Effects of accelerated water runoff on down stream aquatic systems.

A detailed discussion of these and other indirect costs of prescribed burning is outside the purpose of this paper. However, such costs do exist and have to be considered in the decision of whether to use prescribed fire and in the formulation of the burning prescription. Such costs, once calculated, could render prescribed burning less efficient than other methods of succession manipulation and litter control. But, based on direct costs, prescribed burning is still the least expensive and probably the most natural method of quail habitat development and maintenance available to the game manager. Methods for calculating indirect or spillover costs and benefits of prescribed burning are still needed.

SUMMARY

Historically, fire has been an important ecological factor in controlling the evolution and maintenance of grasslands, savannas and transition plant communities in the eastern half of the United States. The bobwhite, with its evolutionary origins in Middle America, had to adapt to living in arid grasslands in order to expand its range to the forested regions of the eastern seaboard. It was probably able to inhabit those humid forest regions only so far as it could survive in early stages of plant succession, which were the result of fires or other disturbing agencies. Those plant communities were similar to many communities of the grassland to which the bird had become adapted in its range expansion through what are now the prairie states.

Quail populations decline in most areas of native vegetation in those regions when fire is withheld and succession is allowed to proceed to a condition of dominantly woody species over an extended period of years. Prescribed burning may be favorable alternative to mechanical or grazing methods for manipulating succession so that large quail populations can be maintained.

The benefits of fire from a quail management standpoint, include litter removal, increased ground mobility for the birds, increased food availability, control of botanical composition and maintenance of favorable stages of plant succession.

Prescribed burning has been applied for increased quail production in several management areas with excellent success. It is probably the least expensive management tool, at least on a direct cost basis, available to quail managers, and has produced results which far outweigh direct cost of application.

Prescribed fire is potentially a very powerful tool for quail management, but its use must be weighed against indirect costs such as contribution to air pollution, chance of fire escaping and doing unintended damage, and the effects of increased run-off on down stream aquatic systems. Prescribed burning is certainly worthy of trial on an experimental basis over much greater portions of the bird's range than it is currently being used.

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SOME ASPECTS OF THE FIRE ECOLOGY
OF THE BOBWHITE QUAIL
(*Colinus virginianus*)

by

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AN ABSTRACT OF A MASTER'S REPORT

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Historically, fire has been an important ecological factor in controlling the evolution and maintenance of grasslands, savannas and transition plant communities in the eastern half of the United states. The bobwhite, with its evolutionary origins in Middle America, had to adapt to living in arid grasslands in order to expand its range to the forested regions of the eastern seaboard. It was probably able to inhabit those humid forest regions only so far as it could survive in early stages of plant succession, which were the result of fires or other disturbing agencies. Those plant communities were similar to many communities of the grassland to which the bird had become adapted in its range expansion through what are now the prairie states.

Quail populations decline in most areas of native vegetation in those regions when fire is withheld and succession is allowed to proceed to a condition of dominantly woody species over an extended period of years. Prescribed burning may be favorable alternative to mechanical or grazing methods for manipulating succession so that large quail populations can be maintained.

The benefits of fire from a quail management standpoint, include litter removal, increased ground mobility for the birds, increased food availability, control of botanical composition and maintenance of favorable stages of plant succession.

Prescribed burning has been applied for increased quail production in several management areas with excellent success. It is probably the least expensive management tool, at least on a direct cost basis, available to quail managers, and has produced results which far outweigh direct cost of application.

Prescribed fire is potentially a very powerful tool for quail management, but its use must be weighed against indirect costs such as contribution to air pollution, chance of fire escaping and doing unintended damage and the effects of increased run-off on down stream aquatic systems. Prescribed burning is certainly worthy of trial on an experimental basis over much greater portions of the bird's range than it is currently being used.