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Construction Engineering
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**US Army Corps
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Engineer Research and
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Effects of Prescribed Burning on Game Species in the Southeastern United States

A Literature Review

Deborah S. Maas, Robin L. Musson, and Timothy J. Hayden

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Foreword

This study was conducted for the Department of the Army, Office of the Director of Environmental Programs under A896, "Environmental Quality Technology," Work Unit CNN-T013, "Mitigation and Management Strategies for Endangered Species." The technical monitor was Dr. Vic Diersing DAIM-ED-N.

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1 Introduction

Background

Prescribed burning has become an increasingly common management tool to modify habitats for many species in the southeastern United States. On military installations in the southeast, prescribed burning is used frequently and is used on a landscape scale to control midstory encroachment in habitats of the endangered red-cockaded woodpecker (RCW, *Picoides borealis*). On Army installations, as much as one-third of RCW habitat is scheduled for prescribed burning annually under installations' Endangered Species Management Plans. Such a wide-scale use of prescribed burning to achieve management objectives focused on one species raises valid concerns of ancillary effects to other biological resources on military installations.

This concern has been raised on military installations in the southeast, particularly in the context of effects of prescribed burns on populations of popular game species. Installations provide significant recreational hunting opportunities to both resident civilian and military personnel as well as to the general public in surrounding communities. Recreational hunting programs on military installations provide high public visibility for prescribed burning activities and the perceived effects of prescribed burning on game species. The obvious short-term effects of burning have often lead to a strongly negative public perception that prescribed burning on a landscape scale is detrimental to game species.

Military land managers need a current scientific perspective on the effects of prescribed burning on the three most popular terrestrial game species in the southeast: bobwhite quail (*Colinus virginianus* L.), eastern wild turkey (*Meleagris gallopavo silvestris* Vieillot), and white-tailed deer (*Odocoileus virginianus*). This literature review provides land managers useful information for planning and implementing a balanced burning program as well as information useful for educating the public on the effects of prescribed burn programs on installations.

This document reviews pertinent literature and data to evaluate the effects of fire on the viability of bobwhite quail, eastern wild turkey, and white-tailed deer populations. It includes both direct and indirect effects of fire on the habitats, behaviors, and diets of the species. This review also discusses the advisability of

using prescribed burning as a management tool in habitats occupied by each of these species, and suggests guidelines for the optimum season of burning, frequency of burning, the amount of habitat consumed, and specific precautions to ensure proper application of fire for game species considered in this review.

Objective

The objective of this report is to provide the information necessary for wildlife managers throughout the southeastern United States to make sound management decisions relative to employing a burning regime in habitat occupied by bobwhite quail, wild turkey and white-tailed deer.

Approach

For this project, researchers conducted extensive searches of appropriate databases and library holdings to identify both contemporary and historic/fundamental research.

Scope

This report is limited to information on the habitat requirements, behaviors, and diets of bobwhite quail, wild turkey, and white-tailed deer and the effects of fire on each of these aspects of each species' biology and ecology in the southeast United States. It focuses on the impact of fire on herbaceous and woody vegetation used by the species in question, on fauna of interest to the species in question, and direct impacts on the three target species. The information may not apply to other species or other geographical areas.

Mode of Technology Transfer

The information in this report will be distribute to military land managers in the southeastern United States for incorporation in installation Endangered Species Management Plans by reference or addendum.

This report will be made accessible through the World Wide Web (WWW) at URL:

<http://www.cecer.army.mil>

Units of Weight and Measure

U.S. standard units of measure are used throughout this report. A table of conversion factors for Standard International (SI) units is provided below.

SI conversion factors		
1 in.	=	2.54 cm
1 ft	=	0.305 m
1 acre	=	0.405 hectare

2 Bobwhite Quail (*Colinus virginianus* L.)

Introduction

Typical quail habitat in the southeastern United States consists of open pine forest interspersed with thickets. This habitat is capable of producing an abundance of seeds and fruits and supporting a large insect population (Stoddard 1931; Landers 1981; Wade and Lunsford 1989). Such diversity of habitat is necessary to create productive wildlife habitat (Speake, Hill, and Carter 1975; Wilson, Masters, and Bukenhofer 1995), and is important to quail for seasonal nesting and for conducting the daily activities of foraging, dust bathing, and roosting. According to Stoddard (1931), some productive quail preserves consist of 50 to 70 percent open woodlands with various oaks, gums, flowering dogwoods, cherry, and shrubby undergrowth. When woods become too dense, ground vegetation will not grow (Speake, Hill, and Carter 1975; Dunning 1993), or when the leaf litter is too thick, it becomes impossible for the bobwhite to find food (Stoddard 1931). Under these circumstances, bobwhite quail will "starve in a land of plenty" and are usually absent from or purposely avoid such areas (Stoddard 1931; Rosene 1969). Therefore, to manage for quail in the sandhills, flatwoods, or other regions of the southeastern United States, one needs to diversify vegetation as much as possible by providing a balance of open woodlands, weedy fields, thickets, and scattered grasses through the use of prescribed burning (Stoddard 1931; McRae, Landers, and Buckner 1979; Landers and Mueller 1986; Wade and Lunsford 1989; Landers 1990; Wilson, Masters, and Bukenhofer 1995). Rosene (1969) is also in agreement with this habitat characterization and states that a combination of burned and unburned vegetation and bare soil provides ideal quail habitat.

Direct Effects of Fire on Quail Populations

Direct effects of fire on quail include destruction of quail nests, and uncovering hidden food reserves (Wilson, Masters, and Bukenhofer 1995). Quail usually respond to recently burned sites by being attracted to the newly available food resources, such as insects and seeds (Stoddard 1963). Stribling and Speake (1991) conducted spring and fall bird counts on annual and biennial burned plots and an unburned control area. Although no significant differences between biennial

and annual burned plots were found, biennially burned plots averaged twice as many quail as annually burned plots. In addition, of the nine census periods conducted over 5 years, quail were detected on unburned plots only twice. Wilson, Masters, and Bukenhofer (1995) show similar findings in open pine-grassland communities with quail found most frequently in the first year post-burn with declining predominance in subsequent years. Emlen (1970) conducted bird counts 1 to 5 months after a burn in the Florida Everglades. He reported that quail had no preference for either burned or unburned plots. Lack of response to burning suggests that food and shelter resources were not critically disrupted by fire or may be attributed to individual home range attachments. This may also be associated with the relatively brief duration of such a severe habitat disturbance in an ecosystem that is fire adapted (Emlen 1970).

Insufficient data exists on the effects of fire on bobwhite quail population dynamics. A quail census may not represent the true consequence of prescribed burning on quail populations because census areas and number of animals observed are too small, studies may not be long enough to detect a response (Bendell 1974), and treatment replication or pretreatment sampling is inadequate or altogether lacking. The most articulate study in the southeast on how fire affects quail populations was conducted by Speake (1966) in the Alabama Piedmont. When habitat was burned on a 4-year rotation, quail populations were similar on burned and unburned sites. When burning occurred every 2 years, quail populations on burned plots were less than those on unburned plots. However, when the burning regime changed to annual winter burns, quail populations on burned plots were almost twice as high as populations on unburned plots. Note though that inadequate sampling of unburned plots and an uncontrolled burning treatment confounds the latter results. Additional data from Wilson, Masters, and Bukenhofer (1995) indicate greater frequency of quail in the first growing season following a prescribed burn, with declines in density in years 2 and 3 post-burn.

Indirect Effects of Fire on Quail Populations

Fire indirectly affects quail through its impact on habitat. Fire has the negative effect of removing areas of cover provided by thickets and loss of some hardwoods that provide important fall foods. Fire can be helpful, however, in reducing the litter layer, thereby creating needed bare patches of soil, providing important herbaceous summer foods by stimulating seed germination and plant growth, and attracting insects with new growth of vegetation on burned lands.

Understory Vegetation

Predation

Dense understory vegetation, or thickets, in quail habitat are important for three reasons. The first is protection from predators. In a 2-year study conducted in Georgia, Mueller, Atkinson, and DeVos (1989), measured pre- and post-fire mortality of bobwhite quail following a clean burn vs. a patchy burn. Cover provided in the patchy burned plot (20 ha cover / 100 ha plot) was twice as much as that of the clean-burned plot (8.7 ha cover / 190 ha plot) in 1985, and 1.7 times as much in 1986 (51.2 ha cover/100 ha plot and 30.6 ha cover/190 ha plot). Results indicated that both pre- and post-fire mortality was greater on the clean burn site than the patchy burn site. Furthermore, quail ranges on the clean burn site were larger than those on the patchy burn site. Apparently, quail used whatever cover was available on the clean burn site, even if it was outside their normal range. The authors caution that populations of resident raptors are augmented in March and April with the arrival of migrating hawks. This increased predator base often coincides with the time of the prescribed burning, creating conditions under which higher mortality was possible. They recommend a delay in burning until after the peak of influx, unfortunately the peak migration point is unknown. Landers and Mueller (1986) have also noted high mortality of bobwhites in the spring due to increased movement of the birds at this time, reduction of cover due to burning, and an increase in avian predators. Cause for concern about predation levels also occurs when late winter burning is conducted over large areas where few, if any, patches of cover remain (Landers 1981). Results reported by Bowman and Harris (1980) indicate that spatial heterogeneity is more important than nest concealment in reducing nest depredation. Thus, local habitat heterogeneity is an important factor for quail survival and patchy burns may contribute toward the creation of such habitats.

Nesting

Thickets are also important for nesting. Quail most often nest in "roughs," areas that have been unburned for 1 year or more (Rosene 1969; Simpson 1972b), and that are within 50 ft of an opening (e.g., field, disked strip, roadway, path; Rosene 1969; Harshbarger and Simpson 1970. Stoddard (1931) found 74 percent of nests (447 nests) within 50 ft or less of an opening and 82 percent of nests (497 nests) in growths sufficiently open at the birds' height for them to run freely. Harshbarger and Simpson (1970) reported the occurrence of bare ground around 65 percent of nest sites studied. Simpson (1972b) contends that prescribed burning benefits nesting activities by creating suitable cover conditions 1 and 2 years post-burn. A dense plant community or a deep litter layer is considered unfit

brood habitat (Hurst 1972). This observation is further supported by Stoddard (1931) who found only 7 percent of nests (42 out of 539 nests) in dense growth, with most being near its edge. Prescribed burning thus fills an important role in maintaining quail brood habitat by removing litter (Landers and Mueller 1986) and controlling the density of understory vegetation (Rosene 1969; Waldrop et al. 1987).

Roosting

The third reason for which thickets are necessary is to create a proper roosting environment. Yoho and Dimmick (1972) indicated that honeysuckle or other dense understory covering provide attractive quail habitat, with honeysuckle being the preferred ground cover for roosting. Stoddard (1931) noted that quail avoided dense tangles of broomsedge or wiregrass for roosting, and preferred to roost in chinquapin or stubby oak sprouts, huckleberry, dewberry, or blackberry. In west Texas, quail preferred lotebush or honey mesquite for cover (Renwald, Wright, and Flinders 1978). In contrast, Rosene (1969) reported that quail roost on bare soil, between clumps of grass or weeds, or on soil with a small amount of matted-down vegetation. The type of roosting cover used at different locations is probably dependent on such factors as severity of winter, habitat composition, and the intensity and kind of predation (Landers 1981).

Effects of fire on understory vegetation

The effects of various burning regimes on thickets are best illustrated by a 30-year study conducted at the Santee and Westvaco Experimental Forests in South Carolina. Annual winter, periodic winter (3 to 7 yrs) and periodic summer (2 to 7 yrs) burns resulted in an increase in the number and density of hardwood stems (Langdon 1981). This phenomenon has been reported by others (Lotti, Klawitter, and LeGrande 1960; Ferguson 1961; Grano 1970; Springer 1977; Grelen 1978; McGee, Leopold, and Nyland 1995; Brose, Van Lear, and Cooper 1999), and is explained by Waldrop et al. (1987). They state that the aboveground portions of hardwoods less than 5 cm diameter at breast height (dbh) are too small to survive most fires, but their root systems do, and as a result, produce sprouts after each fire. This is supported by the work of Brose, Van Lear, and Cooper (1999) who state that since oak species have hypogeal germination, their root collar and dormant buds remain subsurface. This gives them a great deal more protection from surface fires, which allows sprouting to occur post-burn. In contrast, Langdon (1981) asserts that annual summer burning dramatically decreased all hardwood species. Other researchers have concluded that summer burns better eradicate understory vegetation (Ferguson 1957; Ferguson 1961; Brender and Copper 1968; Grano 1970), and that annual summer burns are

more effective (Waldrop et al. 1987) and faster (Grano 1970) than biennial summer burns.

Management recommendations for understory vegetation

In bobwhite quail management, some removal of understory vegetation by fire is desirable to produce open areas, but unburned thickets are needed for escape cover and nesting and roosting sites. Landers and Mueller (1986) recommended leaving shrubs unburned for 2 to 4 years, as these areas provide escape cover and nesting and roosting sites. Others encourage leaving unburned areas along stream bottoms or small upland thickets scattered throughout the habitat (Hurst 1970; Speake, Hill, and Carter 1975; Wade and Lunsford 1989). In managing wet flatwoods, small areas (1 to 10 acres) were left unburned to provide escape cover (Campbell 1988). Renwald, Wright, and Flinders (1978), in managing the rolling plains of Texas for quail, recommend providing at least ten large honey mesquite and four large lotebushes per hectare to ensure adequate cover. Mueller, Atkinson, and DeVos (1989) emphasized that cover areas be an integral part of quail management plans. These patches are also potential food sources, and for this reason, many researchers have advocated protecting them from fire (Stoddard 1931; Rosene 1969; Sharpe and Curtis 1988). Although some fire exclusion from these areas is needed, periodic burning will maintain them at the appropriate density for use by the bobwhite quail (Rosene 1969).

Nesting activity

Although fire serves an important function in the removal of vegetation to create ideal brood habitat (Hurst 1972), the timing of fire is just as critical. The most important nesting months for quail in the southeastern United States are May through August (Stoddard 1931). Breeding activity, which starts with the first bobwhite call in the spring and ends with the last hatching date in the fall, would also include April and September (Rosene 1969). Earlier nesting activity in Georgia and Florida in late January or early February has been noted (Rosene 1969; Moore 1972; Campbell 1988), and nesting may extend into October (Stoddard 1931; Landers and Mueller 1986; Campbell 1988). Peak nesting usually occurs in May and June (Rosene 1969; Moore 1972; Simpson 1972a; Campbell 1988), but later peaks may also occur in July (Rosene 1969; Devos 1986; Landers and Mueller 1986). Campbell (1988) noted peaks as late as September and mid-October due to drought conditions and late-nesting birds, respectively. It should not be forgotten, too, that second broods do occur, and thus in Missouri, the peak hatching date is 15 August (Stanford 1972). In Alabama, incubation of second broods began mid-August or early September with hatching occurring in late September (Sermons and Speake 1987).

Due to nesting activity in spring and summer months, winter or early spring burning (before April) is usually practiced and recommended for quail management (Stoddard 1931; Stoddard 1963; Rosene 1969; Moore 1972; Speake, Hill, and Carter 1975; Landers and Mueller 1986; Wade and Lunsford 1989). Six months after spring burning in Georgia, and 4 months after spring burning in Florida, the regrowth of herbaceous cover is apparently sufficient for use by quail. Harshbarger and Simpson (1970) found 58 percent of late summer nests (44/76) in areas burned the previous March or April, and Simpson (1972b) reported that the use of unburned sites for nesting decreased after mid-June while the use of burned sites for nesting increased. Burning after February has been characterized not only as hazardous and difficult to control (Moore 1972), but also as detrimental to quail's food supply (Stoddard 1931; Rosene 1969). Summer fires are more problematic because of the risk of destruction of quail nests and nesting sites (Stoddard 1931; Rosene 1969; Wade and Lunsford 1989). Kruse and Piehl (1986) found that 31 percent of ground-nesting bird nests (21/68) were destroyed by June fires and 4 percent (3/68) were deserted due to the fires. Robbins and Myers (1992) documented no deleterious effects on quail nest success by summer fires in the southeast. A study of quail nesting habits in southwest Georgia found that nest initiation peaked before 16 June and accounted for 56 percent of all nests. Although nests initiated after 15 June composed only 44 percent of all nests, they constituted 77 percent of successful nests (nests that hatched, Simpson 1972a). One may easily reach the conclusion that a summer fire after 15 June would have detrimental, possibly catastrophic, effects in terms of nest success on quail populations. Simpson (1972a) attributes low nesting success of early-season nests to a high incidence of predation, brought about by a poorly planned spring burn that left too little cover. Winter burns were conducted by Wilson, Masters, and Bukenhofer (1995). This research showed that quail densities increased in the first summer post-burn though no nesting numbers were included in this research. Choosing the best season to conduct a prescribed burn to avoid detrimental effects on nesting is difficult to determine from existing data, although the importance of maintaining cover in quail habitat has been verified (Mueller, Atkinson, and DeVos 1989; Landers and Mueller 1986).

The importance of bare ground for quail

Controlled burning serves not only to maintain thickets, but also to create bare patches of soil and ash. These areas, occurring in open situations with sparse vegetation, are where dusting takes place (Stoddard 1931; Rosene 1969). Dusting is a habit of bobwhite quail through which dust is worked into the feathers to keep them in good condition and to control lice. Fire creates these needed areas. Without fire the litter layer would continue to build from year to year forming a

solid mat (Rosene 1969) and thus preventing dusting. In addition, ashes from old burned logs mixed with dirt appears to be attractive to quail for dusting (Stoddard 1931).

Woody food items eaten by quail

A great variety of foods make up the average bobwhite quail diet as illustrated in a study that found 45 prominent seed foods used. Thirty-three other plant foods have also been identified in quail diet (Landers and Johnson 1976). Important woody species include various oaks, sumacs, pines, and dogwoods, as well as sweet gum, black gum, black locust, sassafras, black cherry, persimmon, *Myrica* spp, honeysuckle, grape, blackberry, blueberry, and huckleberry (Landers and Johnson 1976). Stoddard (1931) found that fruits formed more than half the total food intake during June and July. In another study, blackberries comprised 75 percent of the June diet, while black cherry was the most important food in July (McRae, Landers, and Buckner 1979). Landers (1990) found blackberry to be the most important food item during summer months, especially as a source of moisture during dry periods. Fruits of sassafras, dwarf sumac, black cherry, and poison ivy were extensively used, even after the fruit dried (Stoddard 1931). Acorns, the preferred and most widely utilized fall food source (Sweeney, Wenger, and Yoho 1981; Landers 1990), alone contributed the most to the quail diet in the months of October, December, and January. Acorns in combination with pine mast constituted over 70 percent of the diet from November through January, and nearly 60 percent in February and March (McRae, Landers, and Buckner 1979). Reid and Goodrum (1979) found that longleaf pine seeds constituted 73 percent of the total food intake for November. Red bay fruits are taken from November to February, although usage peaked in January and February (Reid and Goodrum 1979). Oaks have served as buffer food sources in times of drought (McRae, Landers, and Buckner 1979) and red bay in times of little to no pine mast availability (Weber 1975). In late winter, after preferred food sources have become depleted, holly, wax myrtle, and sumac are eaten (Landers 1990).

Effects of fire on woody vegetation

Fire affects important woody food species differently, and the season of fire may have different results. Spring fires (April or May) may be beneficial to longleaf pine by stimulating growth (Grelen 1975; Boyer 1990), but summer or autumn fires may be detrimental to longleaf pine by increasing mortality (Grelen 1975; Wade and Johansen 1986a,b; Wiese et al. 1989; Boyer 1990; Robbins and Myers 1992). In contrast, Glitzenstein, Streng, and Platt (1990) reported that longleaf pine mortality, growth, and recruitment each did not differ significantly between plots burned in the growing season (April-August) and plots burned in the dor-

mant season (October-February). Glitzenstein, Platt, and Streng (1995) gave supporting evidence that season of burn does not influence longleaf pine populations. Brockway and Lewis (1997) reported the lengthiest study of the effects of fire on longleaf pine. In that study, longleaf pine on the southern Georgia Coastal Plain were subjected to periodic burns over a 40-year span. The findings indicate that longleaf pine populations are maintained by periodic summer or winter burns.

Growing season fires may also stimulate growth and fruiting of dwarf live oak (Williams 1977a) and running oak (Williams 1977b). Brose, Van Lear, and Cooper (1999) found high intensity spring burns or medium intensity summer burns to work best for regeneration and stocking of oaks when applied at periodic intervals, whereas low intensity fires in all seasons were shown to be detrimental to oak densities. Brose and Van Lear (1998) found that the density of oaks was positively influenced by both spring and winter burns, but growth rates were greater following winter burns. Glitzenstein, Streng, and Platt (1990) and Glitzenstein, Platt, and Streng (1995) found, however, that oak mortality was significantly greater after spring burns (April, May) than burns in any other season. Oak recruitment was not affected by the season or frequency of burning, but growth was affected (Glitzenstein, Streng, and Platt 1990). Annually burned trees grew faster in the dormant season than the growing season, while the opposite result was found for biennially burned trees (Glitzenstein, Streng, and Platt 1990).

Fire, in any season, damages or decreases yields after the first year of burning in sweet gum (Grelen 1975; Hooper 1977), sassafras (Leonard 1977), black gum, black cherry (Halls 1977c), blackberry (Lay 1977), ground oak, chinquapin (Stoddard 1963), gallberry (Brockway and Lewis 1997) and live oak (Springer 1977). Fruiting by huckleberry, running oak, dangleberry, dwarf blueberry, gallberry, dewberry, chokeberry and blackberry was inhibited the first year after prescribed burning, but peaked, depending on species, 2, 3, or 4 years after burning (Johnson and Landers 1978). Stoddard (1963) also found similar responses in fruiting behavior in huckleberry, blueberry, blackberry, dewberry, gooseberry, and gallberry, while Waldrop, White, and Jones (1992) noted prolific growth of huckleberry and blueberry after burning. Although burning injures the fruit supply for the following year, occasional pruning of fruiting shrubs by fire is beneficial for fruit production 2 to 4 years later (Stoddard 1962; Stoddard 1963). Annual burning is not recommended over extensive areas inhabited by quail due to the potential injury to the fruit supply (Stoddard 1931; McRae, Landers, and Buckner 1979). Annual fires would likely result in fruits confined solely to spots skipped by the fires of previous years, and these spots may be few and far between (Stoddard 1931). Furthermore, the eradication of important woody, food-

bearing species is a detrimental practice, and even though woodlands must be kept in an open condition for quail, it is important to leave a few of each kind of fruit producing woody species (Stoddard 1931; Weber 1975; McRae, Landers, and Buckner 1979; Sharpe and Curtis 1988).

Herbaceous food items eaten by quail

Legumes (Fabaceae) and grasses (Poaceae), the herbaceous components of the bobwhite quail diet, are eaten year-round by quail (McRae, Landers, and Buckner 1979), but the utilization of a species varies with season and availability (Weber 1975). Various studies report lespedeza (Fabaceae), beggarweed (Fabaceae), Korean clover (Fabaceae), partridge peas (Fabaceae), milk peas (Fabaceae), bush clovers (Fabaceae), Panicum spp (Poaceae), rye (Poaceae), millet (Poaceae), corn (Poaceae), Paspalum spp (Poaceae), and ragweed (Asteraceae) as major food items of the bobwhite quail (Speake 1966; Hurst 1970; Weber 1975; Landers and Johnson 1976; Reid and Goodrum 1979; Sharpe and Curtis 1988; Landers 1990). The role legumes play in the quail's diet is not as important in south Florida or the western portion of the bobwhite's distribution. In Florida, slough grass and wax myrtle are major food items (Rosene 1969; Campbell 1988), and in the West, spurges (Euphorbiaceae) and composites (Asteraceae) are most important (Rosene 1969). A study in Georgia of seasonal food usage by the bobwhite quail found that green vegetation and legume seeds provided nourishment in April, with grass seeds becoming more important in late spring. Panic grass was the major food source in May, and side-seed grass was an important constituent in August and September (McRae, Landers, and Buckner 1979). From November to February, lespedezas, downy milk pea, partridge peas, butterfly-pea (Fabaceae), ragweed, and rye were heavily consumed (Stoddard 1931; Speake 1966; Weber 1975).

Effects of fire on herbaceous food items

The research of Brockway and Lewis (1997) has shown that grasses exhibit the greatest overall benefit of a recurrent burning regime. This has historically been a well-supported concept with similar findings from Garren (1943); Wright and Bailey (1982); Evans (1988); Landers, Byrd, and Komarek (1990); Abrahamson and Hartnett (1990); and Waldrop, White, and Jones (1992). Fire has also exhibited benefits for other types of herbaceous vegetation. Glitzenstein, Streng, and Platt (1990) found that flowering and fruiting of grasses and asters were significantly enhanced by growing season burns. Rosene (1969) showed that burning can stimulate seed germination of fire-adapted plants (legumes and grasses), although competition among these plants may limit seed production of individuals (Buckner and Landers 1979). Martin and Cushwa (1966) found increased ger-

mination with partridge pea in response to moist heat, but Harshbarger, Perkins, and Martin (1975), who conducted a study to determine if the moisture content of the fuel at the time of burning would affect the subsequent density of legumes, reported no increase in the number of mature legume plants 6 months after burning. In contrast, Moore (1957), Cushwa et al. (1966), and Speake (1966) have reported an increase in quail food plants, especially *Lespedeza* spp, on spring or winter-burned areas relative to unburned areas. Grelen (1975) reported a higher percentage of forbs, including partridge pea, pencil flower (Fabaceae), and littleleaf tickclover (Fabaceae), on July-burned plots, relative to March- or May-burned plots. Landers (1981) observed greater growth of wiregrass after summer burning. Burning doubled seed production of sloughgrass in the flatwoods of southwest Florida (Moore 1972), stimulated growth and seeding of legumes (Stoddard 1931), and a single fall burn significantly increased forb production in the following year (Springer 1977). The effect is, however, short lived, and burning must be frequently repeated if seed yields are to be sustained (Landers 1981).

Annual spring burning seems to produce the most beneficial results on herbaceous quail food plants. Buckner and Landers (1979) reported several legume genera (annual and perennial partridge pea, *Galactia*, *Centrosema*, *Stylosanthes*), reaching peak densities and producing the greatest amount of seeds on annually burned plots relative to plots with 2-year and 3-year burn rotations. Grelen (1978) found greater herbage yields of grasses, legumes, composites, and other forbs for annually and biennially March-burned plots than for May-burned plots of comparable frequencies, but reported no significant differences in yields of triennially March- or May-burned plots. Grelen (1978) also noted that May-burned herbage yields were not significantly greater than yields of unburned plots due to the loss of annuals. McGee, Leopold, and Nyland (1995) found the richness of forb species increased after a spring burn. This was also the finding of Adams (1984) who noted that forb densities remained the same or increased in the first growing season post burn. Densities of grasses, legumes, and other forbs were found to increase markedly after winter fires (Moore, Swindel, and Terry 1982; Waldrop, White, and Jones 1992; Brockway and Lewis 1997). Cushwa, Hopkins, and McGinnes (1970) found, during a study in South Carolina, an average increase of 460 legume plants per acre on spring-burned areas (April, May) and an average decrease of 273 legume plants per acre on summer-burned areas (July, August). The results were not statistically significant. Total seed production of legumes was, however, significantly greater in summer-burned areas. Although the authors offer no explanation for these results, Buckner and Landers (1979) acknowledge that conditions that allow for peak plant growth for some species are not necessarily best for subsequent seed production.

Invertebrate food items of quail diets

Invertebrates make up the third component of the bobwhite quail diet. Insects are consumed every month, but from April to October, they comprised 21.5 percent of the total food intake with a peak in October of 37.7 percent of total food intake. The rest of the year arthropods made up 4.5 percent of the total food intake (Stoddard 1931). Seasonal variation of insect consumption occurs with hens during the breeding season who require a diet of 15 percent protein for an optimum hatch (Nestler et al. 1944). Also, young quail have larger protein requirements than adults (Stoddard 1931; Rosene 1969), with 1-week old chicks needing more animal matter than older chicks (Hurst 1970; Hurst 1972). Stoddard (1931) found the average animal matter intake for 20 chicks less than 2 weeks of age as 83.7 percent total food intake, while that of adults during the same time period was 22 percent total food intake. Favorite foods of quail chicks include beetles (Coleoptera), ants (Formicidae), true bugs (Hemiptera), spiders (Araneida), leaf hoppers (Homoptera), grasshoppers (Orthoptera), flies (Diptera) and all larval forms (Hurst 1970; Hurst 1972).

Effects of fire on invertebrates

The immediate effects of fire on arthropods were revealed by Rice (1932) who noted that few individuals survived, and those that did were located at the bases of bunch grasses. Since that study, additional research shows that fire actually has little lasting negative effect and often many positive effects on arthropods. Hurst (1970 and 1972) conducted surveys 5 to 7 months after burning and reported significantly greater arthropod density and biomass on burned areas than unburned sites due to the increased food supply in the form of more luxuriant and succulent plant growth. Hurst (1972) also noted that the herbivorous types of insects (beetles, true bugs, leafhoppers, grasshoppers, ants) increased in burned areas, and that these same types are important quail chick foods. Stoddard (1963) thought that burning made insects more available to quail by clearing out "rough" areas, thus yielding the habitat more open for chick movement.

The response of harvester ants to fire has been the subject of some recent studies. These studies found that fires did not significantly affect the numbers of ants (McCoy and Kaiser 1990; Zimmer and Parmenter 1998), especially those fires that occurred mid-day when ants are normally not as active aboveground (Zimmer and Parmenter 1998). If some foragers were killed by fire, the effects would be short term as nest workers would take over foraging duties (Gordon 1986) and would do so rapidly enough to make the situation only temporary (Porter and Jorgensen 1981). Zimmer and Parmenter (1998) further found that

the ants gathered the same kinds and amounts of seeds in burned areas as unburned areas and had the added benefit of harvesting the carcasses of other insects that were killed by the fire. McCoy and Kaiser (1990) attribute this equal foraging success to the somewhat greater foraging areas of ants in the burned areas, but agreed that much of the potential food resources of the ants were able to survive a fire.

In a survey of grasshopper species, Evans (1988) determined that the number of grass-feeding species declined with decreasing frequency of fire while the opposite was true for forb feeders, giving the overall effect of no change in species abundance or richness. Pyle and Crawford (1996) further determined that burning had no effect on June beetle or darkling beetle species populations. Fire has the effect of drawing in potential food sources in the form of pyrophilous arthropods. In their review of literature, McCullough, Werner, and Neumann (1998) pointed out the work of Evans (1972) and Holliday (1984) in identifying or observing up to three species of carabid beetle, and Kayll (1968) in observing several spider species, all of which migrate to recently burned environments. One of the most prolonged studies of the effects of fire on arthropods was conducted over a 30-year period by Siemann, Haarstad, and Tilman (1997). They found no significant changes in either abundance or richness of arthropods, yet did find a definite shift in species composition, implying the role of fire in deciding locally dominant species. A look at the taxonomic orders most affected revealed that densities of Diptera and Homoptera fell in correlation with increased burn frequency, while densities of Hemiptera increased (Siemann, Haarstad, and Tilman 1997). Although it is well established that fire will cause the direct mortality of some arthropods (Gillon 1971; Lyon et al. 1978; Martin and Mitchell 1980; Mitchell 1990; Fay and Samenus 1993), it is also apparent that many of these organisms are adapted to occasional fires (Evans 1984; Anderson, Leahy, and Dhillon 1989; Siemann, Haarstad, and Tilman 1997).

Conclusion

Recommendations to create viable quail habitat all have the same goal: high habitat diversity distributed in a mosaic pattern. Typically this requires reduced hardwood understory. An increase in herbaceous plant diversity and seed production is required, and cover, in the form of thickets for escape, nesting, and roosting sites, must be provided (Sharpe and Curtis 1988).

Used properly, prescribed burning can render the desired mosaic that forms ideal quail habitat; however, there are no clear, hard, or fast rules about the season or periodicity in which fire should occur to accomplish this. The effects of

various prescribed burnings depends upon the frequency of burning, the extent of burning, the location of a burn on a large scale (e.g., Sandhills, Flatwoods, Alabama blacklands, Tallahassee redhills, the Piedmont) or on a small scale (topography, amount of fuel and its combustibility, age and condition of the woods), and the weather conditions at the time of a burn, including wind direction and velocity, humidity, and temperature. Summer burning for quail is generally (Moore 1957), and only (Rosene 1969), recommended to recover an area with either thick, dense understory or large hardwoods that cannot be controlled by annual fall or winter burning. Once the area is recovered, or if the area is already favorable to bobwhite quail, fall, winter, or early spring burning is advised to maintain the habitat (Moore 1957; Hurst 1972; Moore 1972; Speake, Hill, and Carter 1975; Landers and Mueller 1986; Campbell 1988; Wade and Lunsford 1989). Burning after the nesting season has begun should be avoided due to its potential deleterious effects on quail nests, chicks, and food sources; however, the long-term effects of growing season burns on quail populations are unknown (Robbins and Myers 1992). Independent of the season of burning or its periodicity, thickets need to be protected from fire, but burned periodically, to restrict their growth and sustain them at a density sufficiently open at the birds' level for them to run freely.

3 Eastern Wild Turkey (*Meleagris gallopavo silvestris* Vieillot)

Introduction

Quality wild turkey habitat has been characterized as having open (park-like) and highly diversified forests (Stoddard 1963; Holbrook and Lewis 1967; Little 1980; Schroeder 1985; Gustafson, Parker, and Backs 1994) with well-distributed patches of cover (Stoddard 1963; Schorger 1966; Lindzey 1967; Hurst 1981a; Sisson et al. 1990), clearings (Latham 1939; Mosby and Handley 1943; Wheeler 1948; Schorger 1966; Holbrook and Lewis 1967; Badyaev 1995), and water sources (Latham 1939; Mosby and Handley 1943; Wheeler 1948; Bailey, Uhlig, and Breiding 1951; Schorger 1966; Korschgen 1967). The habitats should be relatively free from human disturbance to avoid a high incidence of nest desertion (Wheeler 1948; Stoddard 1963; Schorger 1966; Williams 1981; Exum et al. 1987; Williams and Austin 1988; Badyaev and Faust 1996; Badyaev, Martin, and Etges 1996) or nest depredation (Dickson, Adams, and Hanley 1978), and should be of adequate size to meet food, cover, and water needs of wild turkeys (Wheeler 1948; Holbrook and Lewis 1967; Smith and Teitelbaum 1986; Gustafson, Parker and Backs 1994; Badyaev 1995; Badyaev, Etges, and Martin 1996; Badyaev and Faust 1996; Badyaev, Martin, and Etges 1996). Open woodlands with little understory provide turkeys with the opportunity to take full advantage of their keen eyesight (Latham 1939; Stoddard 1963; Holbrook and Lewis 1967), and do not obstruct a speedy escape if needed (Schorger 1966). Pure pine stands with a closed canopy and closely spaced trees are reportedly of little use to turkeys (Mosby and Handley 1943; Badyaev 1995). Bailey, Uhlig, and Breiding (1951) reported that turkeys avoided areas with dense understories, unless they became alarmed by predators. This habitat preference is somewhat different for nesting females who choose nesting sites with few trees but lush herbaceous vegetation in the understory and a patchy midstory within the open woodlands habitat (Badyaev 1995). The forest openings allow growth of important forbs and grasses, support an abundance of insects, provide breeding grounds and brood habitat, and are used for nesting, loafing, and dusting (Wheeler 1948; Bailey, Uhlig, and Breiding 1951; Schorger 1966; Holbrook and Lewis 1967; Badyaev 1995). The need for water is not well understood. Wheeler (1948) and Korschgen (1967) noted that turkeys commonly drink water after alighting from

the roost site, while Mosby and Handley (1943) suggested that water sites provide protection from predators.

High habitat diversity in wild turkey range is recommended (Wheeler 1948; Schorger 1966; Speake, Hill, and Carter 1975; Speake et al. 1975; Healy 1981; Lutz and Crawford 1987; Seiss, Phalen, and Hurst 1990; Still and Baumann 1990; Lewis, J.B. 1992; Badyaev 1995), but others (Powell 1967; Dickson, Adams, and Hanley 1978) have noted high turkey populations in areas with little habitat diversity. Bailey et al. (1981) stated that although turkeys are adaptable and capable of surviving in various sizes of habitat and vegetation types, ranging from nearly pure pine to predominantly grassland, a diverse habitat provides optimum conditions. To achieve such a diversified quality environment for wild turkeys in the southeastern United States, researchers have advocated prescribed burning (Stoddard 1935, 1963; Holbrook 1973; Mobley 1982; Sisson et al. 1990).

Direct Effects of Fire on Turkey Populations

As with bobwhite quail, fire affects wild turkeys both directly and indirectly. Direct effects include the potential for fire to destroy nests, eggs, and poults. Stoddard (1935) and Sisson (1991) argue that spring or summer fires may be detrimental to turkey populations by way of destroying nests. However, their statements lack support from data and no other definitive studies exist. Other references of the effects of fire on turkey populations include Stoddard (1963; as cited by Hurst 1981b), who reported turkey densities of 1 per 10 hectares on game preserves that used prescribed burning, and Dickson, Adams, and Hanley (1978), who stated that burning appeared to have no effect on turkey populations. Nevertheless, these references are unreliable because no details of the methods used are given in either study. Greater densities of wild turkey were seen, however, in stands that were treated to understory clearing and prescribed dormant season burning by Wilson, Masters, and Buekenhofer (1995). Additional and more articulate studies of the effects of fire, in any season, on turkey populations are needed.

Indirect Effects of Fire on Turkey Populations

Fire affects turkey habitat, thereby indirectly affecting turkey populations. Davidson, Siefken, and Creekmore (1994) demonstrated the use of fire to control ectoparasites in surrounding vegetation, but the effects of fire on endoparasites and pathogens are unknown (Hurst 1981b). Fire also controls understory plant

density, promotes the growth of desired herbaceous cover, attracts insects with new vegetative growth, and decreases litter accumulations. Despite the significant changes in the environment that occur as a result of fire, how the resulting altered habitat affects turkey numbers is virtually unknown. In Louisiana, annual burning appeared not to have any impact on turkey populations (Dickson, Adams, and Hanley 1978), while turkey densities increased on forested lands in Arkansas, North Carolina, and Florida with triennial, dormant season burns (Wilson, Masters, and Bukenhofer 1995).

Ectoparasites and Fire's Effects

Wild turkeys frequently have ectoparasites (Prestwood 1973) with poults having a greater variety than adult turkeys (Kellogg et al. 1969). Rogers (1955) was one of the first to report that prescribed burning could be used to control tick abundance. He found adult black-legged ticks were significantly less widespread in 1- and 2-year old roughs than in areas that had not been burned for 14 years. Two annual burns in Georgia significantly reduced larval and adult lone star tick populations (Siefken 1991). Jacobson and Hurst (1979) found that poults foraging on plots burned 3 months previously had significantly less prevalence of nymphal lone star ticks than did poults that foraged on plots unburned for 4 years. More specifically, 35.1 percent (20/57) of poults on unburned plots were infested with ticks, whereas 1.6 percent (1/59) of poults on burned plots were infested. A study in Oklahoma found that a burn in June reduced adult lone star tick abundance in the leaf litter layer, but if ticks were in the lower duff layer or in the soil itself, they were likely to survive the burn (Hoch et al. 1972). Davidson, Siefken, and Creekmore (1994) reported similar results when a substantial proportion of a tick population in Georgia survived an initial burn; but larval, nymphal, and adult stages of lone star ticks were significantly reduced when annual and biennial burning were conducted consecutively for 4 years.

Note that these studies represent only the short-term effects of fire on ectoparasites. Rogers (1955) found that tick abundance on burned and unburned plots was comparable after 3 years without fire. In conducting biennial burns, Siefken (1991) and Davidson, Siefken, and Creekmore (1994) found that tick abundance was reduced significantly the year of the burn, while in the year burning was omitted, the abundance of larval lone star ticks was equal on burned and unburned plots. Davidson, Siefken, and Creekmore (1994) concluded that annual winter burning, or burning later in the spring or summer (after March) when more of the tick population is active, could be an effective tool for the control of ectoparasites. Accordingly, Mather, Duffy, and Campbell (1993) concluded that

burning for several years, having a hot fire, or burning after April may be a more effective way to control ectoparasites.

Understory Vegetation

Predation

Researchers agree on the importance of providing cover for protection from predators (Hurst 1981a; Bailey, Uhlig, and Breiding 1951; Robbins and Myers 1992). Escape cover for adult turkeys and poults may be in the form of thickets, forests, or dense grassy fields (Hurst 1981a). Turkey abundance in different habitats may depend partly on the degree of protection from predators provided in each habitat. Brood habitat of hens who successfully raised a brood, compared to hens who did not successfully raise a brood, had less basal area per hectare, greater herbaceous plant height, and were closer to roads, clearings, and water sources (Metzler and Speake 1985; Badyaev 1995). Similar habitat structure is seen in association with higher nest site fidelity (Badyaev and Faust 1996) and a lower probability of nest depredation (Badyaev 1995). Bowman and Harris (1980) showed highly heterogeneous habitats to be less likely to suffer nest depredation than habitats low in heterogeneity. Williams and Austin (1988) also reported less predation in heterogeneous habitats than in the homogeneous habitats of palmetto or cypress woods. A dense understory can provide concealment for birds traveling from one habitat patch to another (Smith and Teitelbaum 1986). Mosby and Handley (1943) rarely observed turkeys in large forest openings, and Williams and Austin (1988) noticed that turkeys seldom used grassy areas, provided food was present under forest cover. Furthermore, open areas are thought to act as deterrents for turkey in moving between habitat patches (Lewis, J.C. 1964; Raybourne 1968; Schroeder 1985; Gustafson and Parker 1994).

Roosting

Understory cover in wild turkey habitat is also important for the critical role it plays in poult survival (Sisson 1991). For the first 2 weeks of life, poults spend their nights in dense ground cover. When they are able to fly well, poults may roost in trees with the hens (Schorger 1966; Williams et al. 1973; Williams 1981). Roosting sites in Florida were often located at the base of a tree, stump, or cypress knee, under or near the cypress canopy (Williams et al. 1973; Williams 1981). In Georgia, broods roosted in pond pine, red bay, recently burned saw palmetto, or on the edge of grassy openings in pine forests (Hon et al. 1978). Occasionally, broods roosted in dense clumps of herbaceous vegetation (Williams et

al. 1973), or in fairly open cover (Williams 1981). During periods of flooding, broods roosted in saw palmetto in an ecotone between a grazed glade and oak scrub habitat (Williams et al. 1973).

Effects of fire on understory vegetation

Researchers have encouraged the use of fire to control understory hardwoods in the southeastern United States (Ferguson 1961; Brender and Copper 1968; Grano 1970). Long-term effects of various burning regimes indicate that annual summer burning is most effective at eradicating small-stemmed hardwoods, while annual winter, periodic winter, and periodic summer burns generally result in an increase in understory stem density (Lotti, Klawitter, and LeGrande 1960; Langdon 1981). Early growing season fires were found to be detrimental to the survival of hardwood species, especially those fires occurring more frequently (Glitzenstein, Platt, and Streng 1995) or just after leaf expansion (Wade and Johansen 1986a, b; Wiese et al. 1989; Robbins and Myers 1992). Waldrop et al. (1987) found that the aboveground portions of hardwood species less than 5 cm dbh will not survive most fires. The root systems of these hardwoods, however, will survive and will undergo post-burn sprouting. More recent studies have shown that many hardwood species are either not affected or may benefit from periodic fire (Lewis, Tanner, and Terry 1988; McGee, Leopold, and Nyland 1995) in any season (Brose, Van Lear, and Cooper 1999). A 14-year study in Arkansas has indicated more effective control of hardwoods with burns of greater frequency. That study showed equal understory control with both annual and biennial summer burns with annual burns achieving the results faster (Grano 1970). Grano (1970) also reported prolific sprouting of hardwoods for the first year after annual or biennial summer burning with stem density decreasing thereafter.

Management recommendations for understory vegetation

All fires, regardless of season, temporarily reduce cover used for predator protection and roosting (Stoddard 1963). Fires in spring and early summer tend to burn completely, which kills hardwood stems and significantly diminishes woody cover (Ferguson 1957; Ferguson 1961; Brender and Copper 1968; Boyer 1990; Glitzenstein, Platt, and Streng 1995). Ambient factors in spring and summer often create pyre that is drier and will burn more intensely (Chen and Gerber 1990), causing the greater mortality (Glitzenstein, Platt, and Streng 1995). Burning during winter, the dormant season, reduces cover until new growth occurs in spring (Robbins and Myers 1992), and may expose birds to increased predation (Mueller, Atkinson, and DeVos 1989). However, Wilson, Masters, and Bukenhofer (1995), found an increased incidence of turkey in habitats treated

with dormant-season fires. Although the detrimental effects of burning during various seasons on the amount of cover accessible to turkey may seem to leave no available option, the natural compromise to reduce negative effects is to conduct patchy burns (Robbins and Myers 1992). Thick vegetative cover and heterogeneous habitat structure may increase appropriate turkey nesting sites and help the turkey avoid predation (Bowman and Harris 1980; Martin and Roper 1988; Martin 1988, 1993; Clark and Nudds 1991; Knopf and Sedgwick 1992; Riley et al. 1992; Steele 1993; Gregg et al. 1994; Badyaev 1995; Badyaev, Martin, and Etges 1996). Since turkey begin their dispersal and continue with nesting from March to June (Badyaev and Faust 1996), any burning, even patchy burns, would not be recommended during this period.

Nest site selection

Hardwood stems, fallen logs, shrubs, and vines not only provide escape cover, but also preferred nesting sites (Mosby and Handley 1943; Stoddard 1963; Healy 1981; Hurst 1981a; Williams 1981; Exum et al. 1987; Ransom, Rongstad, and Rusch, 1987; Lutz and Crawford 1987; Schmutz, Braun, and Andelt 1989; Seiss, Phalen, and Hurst 1990; Day, Flake, and Tucker 1991; Rumble and Hodorff 1993; Badyaev 1995). Pines, sweet gum trees, blackberry, gallberry, blueberry, huckleberry, greenbrier, honeysuckle, red bay, live oak, yaupon, wax myrtle, muscadine, broomsedge, plume grass, and bracken fern are common plants at nest sites in Georgia and Alabama (Hillstead 1973; Hon et al. 1978; Sisson et al. 1990). In Florida, cypress woods, saw palmetto ecotones, wiregrass, and wax myrtle thickets were favored vegetation (Williams et al. 1969, Williams and Austin 1988). Vegetation at the nest site is such that nests are well concealed, but the area immediately around the site is open and provides the hens with a wide field of view and quick mobility (Hillestad and Speake 1971; Healy 1981; Exum et al. 1987; Badyaev 1995). Mosby and Handley (1943), Wheeler (1948), Hillestad (1973), Speake, Hill, and Carter (1975), Hon et al. (1978), and Badyaev (1995) reported nest sites in or near edges of openings ranging from roads, logging trails, and firebreaks to abandoned fields or forest clearings. These clearings facilitate movement for hens to and from nests, while perhaps curtailing the noise of movement through the understory (Badyaev 1995). Still and Baumann (1990) observed hens nesting near logging roads and skid trails. However, few nesting sites were located near rock, dirt, or paved roads open to vehicular traffic. Other nest site characteristics include a nearby water source (Wheeler 1948; Korschgen 1967; Williams, Austin, and Peoples 1976, 1980; Healy 1981; Badyaev 1995), proximity to the base of a tree, shrub or other vertical object (Mosby and Handley 1943; Wheeler 1948; Healy 1981; Williams 1981; Badyaev 1995), and areas of bare ground in the vicinity (Williams and Austin 1988). Availability of nearby dried plant material may also be a factor in nest site selection; research-

ers (Hillestad 1973; Williams 1981; Williams and Austin 1988) have noted hens covering recently laid eggs with vegetation and dried plant material is thought to function as camouflage for the nest (Williams and Austin 1988). Despite well-defined nest site characteristics, Williams and Austin (1988) regarded nesting habitat preferences as being weak because turkey nest sites changed freely from one habitat to another, for either renesting the same year or nesting between years.

Effects of fire on turkey nest site selection

The effects of fire on wild turkey nest site selection have only recently been studied. In general, data indicates that fire plays a critical role in creating or maintaining habitats suitable for nesting by controlling the density of understory vegetation and removing litter to produce areas of bare ground. Smith et al. (1990) found that hens nested on loblolly pine plantations that had been thinned and burned within the past 6 years. For nesting, hens equally used mature pine stands unburned for 1 to 6 years (Seiss, Phalen, and Hurst 1990). In Georgia, pine uplands left unburned for 1 to 3 years was the preferred nesting habitat (Sisson et al. 1990).

Unburned roughs surrounded by burned pinewoods are ideal for nesting hens (Sisson 1991). Still and Baumann (1990) found that 69 percent of nests (20/29) were in pine stands that had been burned within the past 2 years, but the majority of these nests were in vegetation that had not burned due to dampness or topography. Exum et al. (1987) reported that 89 percent of nests (33/37) were on sites never burned or unburned for 3 to 4 years. Hon et al. (1978) concluded that the presence of burned areas is an important consideration for nest site selection in habitats dominated by saw palmetto because 9 out of 16 nests in that community were near areas burned the preceding winter. Of the 16 nests, 4 were in small unburned clumps of vegetation surrounded by freshly burned areas, 5 were within 38 m of newly burned vegetation, while the remaining 7 nests were located in areas burned 1 year prior to nesting. Burned and regenerated red bay and wax myrtle clumps were used for nest concealment by 6 of the 16 nesting hens in Hon et al. (1978). Also, Sisson et al. (1990) reported that 61 percent of nests (14/23) were in vegetation that had been burned within the past 2 years. Although some fire exclusion is needed, periodic burning of cover may prove beneficial.

Nesting activity

Coordinating fire regimes and nesting activity is critical to wild turkey management. Regional variations in the onset of breeding occur, with southern areas

having an earlier breeding season than northern counterparts (Williams 1981). In general though, the important months of nesting activity by wild turkeys in the southeastern United States are April, May, and June (Badyaev and Faust 1996). Earlier breeding and nesting activity can occur with mild weather (Wheeler 1948; Bailey and Rinell 1967), and was noted in March for Virginia and Florida (Mosby and Handley 1943; Bailey and Rinell 1967). Nesting and hatching can extend to the end of July for late first broods or hatching of second broods (Williams and Austin 1988; Still and Baumann 1990; Sisson et al. 1991). Hatching dates range from March through July (Bailey and Rinell 1967; Hon et al. 1978; Williams and Austin 1988; Still and Baumann 1990) with peak hatching occurring in May and June (Mosby and Handley 1943; Wheeler 1948; Williams et al. 1969; Sisson et al. 1991). Williams, Austin, and Peoples (1976), reported re-nesting for the second, third, and fourth times, but knowledge of the dates of activity is limited. Reported dates of re-nesting activity range from May through the end of July (Exum et al. 1987, Williams and Austin 1988, Sisson 1991, Sisson et al. 1991).

Effects of fire on nesting activity

The effects of prescribed burning on ground-nesting bird populations, specifically the wild turkey, depend on the extent of destruction of nests in progress, the rate of re-nesting, and the size and frequency of burning (Robbins and Myers 1992). Re-nesting attempts by hens occur more often than previously thought (Williams, Austin, and Peoples 1980), but depend on how far nesting has progressed at the time of disturbance (i.e., predation, flushing hen from nest, fire). Williams, Austin, and Peoples (1976) first noted a greater frequency of re-nesting after disruption during the laying period than during the incubation period. Williams, Austin, and Peoples (1980) later reported the same result. This phenomenon has been confirmed by Williams and Austin (1988) who reported that 57 percent of hens (17/30) re-nested when disrupted during the laying period, whereas only 28 percent of hens (26/93) re-nested after disruption during incubation. No hens re-nested after 18 days of incubation. Thus, it appears that a disturbance to nesting hens late in the incubation period, from late April to early June, would be most detrimental to turkeys (Robbins and Myers 1992). Badyaev, Martin, and Etges (1996) noted that re-nesting interval length (averaging 16 days) was positively correlated to length of survival of the first nest with 1 hen re-nesting 40 days after predation of her first nest. They also found a negative correlation with the length of the first nest survival to the distance moved to a re-nesting site and the amount of understory vegetation required at the new site. Large, clean burns that leave little cover for protection and nesting could also be deleterious to turkey populations (Stoddard 1963). Stoddard (1963) and Hurst (1981a) recommended burning in patches or burning on a rotation (no scale given).

Stoddard 1963 has advised burning in late winter or early spring to avoid nesting activity.

The importance of bare ground for wild turkeys

Prescribed burning in wild turkey management also serves to decrease the litter layer, thereby creating bare areas of soil and ash. Dusting occurs daily in the summer months by both sexes and all ages of turkeys in these bare areas (Bailey and Rinell 1967; Stringer 1977). Various researchers (Wheeler 1948; Schorger 1966; Stoddard 1963) have indicated that these sites are preferred sites for dusting, but note that their statements are based on observation only.

Nutrition of the eastern wild turkey

An array of food items comprises the year-round diet of eastern wild turkeys. Mosby and Handley (1943) identified food items from over 80 families and 354 species of plants, and also reported that turkeys eat all plant parts, including roots, tubers, bulbs, stems, buds, leaves, flowers, fruits, seeds, seed pods, seed capsules, and seed heads (Mosby and Handley 1943; Davis 1976). Such variety of food intake is necessary because food availability varies with season and habitat (Dickson 1990; Edwards, Guynn, and Loeb 1993). Thus, managing wild turkey habitats for diversity in favored food species has been encouraged (Mosby and Handley 1943; Holbrook 1973; Bowman 1981; Dickson 1990; Edwards, Guynn, and Loeb 1993).

Fall and winter food items

Mast provides most fall and winter nourishment. Acorns, beechnuts, and dogwood fruits are choice items (Latham 1939; Good and Webb 1940; Mosby and Handley 1943; Wheeler 1948; Glover and Bailey 1949; Holbrook 1973; Exum et al. 1987; Williams and Austin 1988; Dickson 1990). Acorns are consumed as they become available in fall, increase in importance in winter, and are a primary food item in spring, but decline to less than 5 percent of total summer food intake (Good and Webb 1940; Mosby and Handley 1943; Wheeler 1948; Kennamer, Gwaltney, and Sims 1980; Dickson 1990). Beechnuts constitute a significant portion of turkey diets from October through January (Glover and Bailey 1949). Dogwood fruits are heavily consumed from September through December, but are still important foods during the spring (Mosby and Handley 1943; Glover and Bailey 1949; Kennamer, Gwaltney, and Sims 1980; Exum et al. 1987; Dickson 1990). Black gum fruits and wild black cherries are staple items in wild turkey diets (Good and Webb 1940; Halls 1977a, 1977b). Pine seeds are readily eaten when available (Holbrook 1973), and are mostly consumed from

December through May (Kennamer, Gwaltney, and Sims 1980). Virginia creeper fruits are often consumed in November and December (Mosby and Handley 1943). Ash, sassafras, hackberry, persimmon, red cedar, sumac, wild grape, poison ivy, honeysuckle, and green vegetation are foods of secondary importance during fall and winter (Mosby and Handley 1943; Wheeler 1948; Holbrook 1973; Kennamer, Gwaltney, and Sims 1980; Exum et al. 1987). In years of mast failure or flood conditions, turkeys obtain nourishment from dogwood fruits, wild grapes, wild black cherries, blackberries, and greenbrier seeds (Glover and Bailey 1949; Bailey, Uhlig, and Breiding 1951; Schorger 1966). Females expanded their home range area in an attempt to locate acorns in years of poor production (Badyaev, Etges, and Martin 1996). Hemlock leaves, ferns, mosses, and buds of beech, ash, hackberry, pin oak, and birch are eaten in times of extreme food shortages (Glover and Bailey 1949; Schorger 1966).

Effects of fire on the fall/winter diet

The effects of fire on notable winter food items vary with species and the timing of fire. In general, hardwoods (including some oaks, beech, black gum, black cherry, ash, sassafras, hackberry, persimmon, red cedar, and birch) are susceptible to fire, and when subject to fire, can experience scarring and mortality. Sassafras, however, can tolerate light winter burning (Rosene and Freeman 1988). Growing season fires may stimulate growth and fruiting of dwarf live oak (Williams 1977a) and running oak (Williams 1977b), while high intensity burning in spring or summer was found to work best for regeneration and stocking of oaks (Brose and Van Lear 1998; Brose, Van Lear, and Cooper 1999). Glitzenstein, Streng, and Platt (1990) and Glitzenstein, Platt, and Streng (1995) found, however, that oak mortality was significantly greater after spring burns than those in any other season. Regardless of the season of burning, fruit production will decrease the first year after burning in sweet gum (Grelen 1975), sassafras (Leonard 1977), various oaks (Stoddard 1963; Springer 1977), black gum, and black cherry (Halls 1977a, 1977b). Older dogwood trees are fire resistant, and fire stimulates fruit production, but young trees are susceptible to fire damage (Lay 1956; Rosene and Freeman 1988).

Fire is beneficial to pines by stimulating growth, but a hot, summer fire could increase pine mortality (Grelen 1975; Boyer 1990). Conversely, Glitzenstein, Streng, and Platt (1990) and Glitzenstein, Platt, and Streng (1995) noted no increase in longleaf pine mortality as a result of growing season burns, while Brockway and Lewis (1997) reported no negative effects with either periodic summer or winter burns. Woody vines, such as honeysuckle and greenbrier, are fire tolerant as reported by Rosene and Freeman (1988) and Jones (1988), but Cushwa et al. (1969) found that a hot summer fire decreased wild grape and

honeysuckle abundance. Annual and biennial burning (Holbrook 1973), as well as frequent summer burning (Stoddard 1963; Robbins and Myers 1992), is not recommended because fruit and mast supplies will become limited as the occurrence of mast-bearing species is reduced. Although forest stands need to be kept in open conditions for wild turkeys by eradicating some hardwoods and other fruit-producing understory vegetation, protecting a few of each mast-producing species from fire is recommended (Holbrook 1973; Exum et al. 1987).

Spring and summer food items

Grass seeds and soft mast, primarily berries, constitute the bulk of adult turkey summer diets, and a significant portion of poult diets. Dewberry, blackberry, huckleberry, blueberry, and gooseberry are consumed as they become available (as early as April in Florida) and consumption continues through October. In years of food shortages, berries may be eaten as late as January and February (Wheeler 1948; Glover and Bailey 1949; Hurst and Stringer 1975; Davis 1976; Healy 1978; Hurst 1978; Kennamer, Gwaltney, and Sims 1980; Exum et al. 1987; Williams and Austin 1988). Grass seeds are ingested year-round by wild turkeys (Glover and Bailey 1949; Bailey, Uhlig, and Breiding 1951), although they are mostly consumed in late summer and early fall (Exum et al. 1987). In Alabama, blackberries were the most important vegetative food items consumed by poults, and were most abundant, during June and July. Carpet grass accounted for 51 percent of total food volume in August, and in September crabgrass constituted 26 percent of total food volume (Blackburn, Kirk, and Kennamer 1975). Grasses, including bahia grass, crabgrass, bristlegrass, panic grass, bermuda grass, and oats comprised 61.5 percent of total food volume for July through September for juvenile turkeys (Hamrick and Davis 1971). Other summer food items reported include muscadine, poison ivy, greenbrier, wild black cherry, wax myrtle, wild grapes, buttercup, wood sorrel, chickweed, vetch (Fabaceae) and hopclover (Fabaceae) (Good and Webb 1940; Wheeler 1948; Glover and Bailey 1949; Hamrick and Davis 1971; Hurst and Stringer 1975; Williams and Austin 1988). Green vegetation is also prominent in summer turkey diets (Kennamer, Gwaltney, and Sims 1980; Exum et al. 1987; Williams and Austin 1988).

Effects of fire on the spring/summer diet

In general, the effects of fire on soft, mast-bearing species are decreased fruit yields for the first year after burning, but prolific fruiting 3 or 4 years later (Stoddard 1963). Many researchers (Stoddard 1935; Stoddard 1963; Hurst 1978; Rosene and Freeman 1988) have reported low berry production the first year after burning. In addition, Robbins and Myers (1992) warn that a fire early in the growing season when shrubs are flowering may eliminate fruit production for

that year. In contrast, an abundance of soft mast was found in a 4-year-old rough (Hurst 1978). According to Oldenburg (1987), blueberries produce much more mast after summer burning (July or August). Wax myrtle flourishes after being pruned by fire due to increased light levels and decreased competition (Hofstetter 1974). Gallberry apparently thrives with frequent winter burning. Hughes and Knox (1964) reported that January and October burns increased gallberry stem numbers, and hence fruiting capability, above pretreatment levels, while April, June and August burns decreased stem numbers. Burning every 3 to 4 years or burning on rotation every 4 years is recommended for maintenance of soft-mast bearing species (Stoddard 1935; Hurst 1978).

Prescribed burning is also beneficial to wild turkeys by increasing the abundance of herbaceous vegetation (Lay 1956; Cushwa, Brender, and Cooper 1966; Hurst 1978; Mobley 1982; Jones 1988). Herkert (1994) notes that burning off dead plant matter positively influences future plant biomass (Knapp and Seastedt 1986; Hulbert 1988). Holbrook (1973) noted improved palatability and nutritional quality of understory vegetation. Although any fire temporarily reduces the food supply, this reduction persists longer following dormant season fires than growing season burns (Robbins and Myers 1992). Burns occurring annually in late spring will stimulate growth of grasses while decreasing both diversity and habitat heterogeneity (Abrams and Hulbert 1987; Gibson 1988; Collins 1992; and Towne and Knapp 1996). Landers (1981) observed greater growth of wiregrass after summer burning, and new growth of *Panicum* spp is encouraged by burning (Rosene and Freeman 1988). Summer burning is also thought to encourage grasses rather than forbs (Holbrook 1973). Grelen (1978) found significantly greater herbage yields of grasses, legumes (Fabaceae), asters, and other forbs on annually and biennially March-burned plots than on May-burned plots of comparable frequencies. Cushwa et al. (1969) reported an increased abundance of grasses, legumes, and asters one growing season after a hot fire. Many grassland burns have resulted in greater densities of legumes (Lemon 1967; Adams and Anderson 1978; Niering and Dreyer 1989; Dudley and Lajtha 1993; Nagel, Nicholson, and Steuter 1994) and significantly so in annually burned plots (Towne and Knapp 1996). Other plots showed forb density increases up to 6 years post-burn (Gibson and Hulbert 1987). Nevertheless, increased yields of herbaceous vegetation are short-lived, and repeated burnings must be conducted to maintain such yields (Lay 1956; Nuzzo, McClain and Strole 1996;). Grelen (1978) reported that yields on triennial March- and May-burned plots did not significantly differ from each other or from yields of unburned plots. In contrast, Nuzzo, McClain, and Strole (1996) found that the percent of forb cover was higher on burned rather than unburned plots.

Burning cannot only increase the abundance of herbaceous plants, but can also increase their flower production. In Florida, wiregrass was thought to have never bloomed, until C.E. Lewis (1964) reported blooming after summer fires (April-August). Annual and periodic May burns resulted in more, but smaller ramets of *Pityopsis graminifolia* (aster). Seed production was not reduced because reduced flower production by individual ramets was compensated for by the establishment of a larger number of flowering ramets per clone (Hartnett 1987). Platt, Evans, and Davis (1988) also noted increased ramet production in clonal forbs (primarily asters) due to growing-season fires killing the apical meristems. Late spring and early summer burning stimulated peduncle production in six native grasses more than fires in winter or early spring, and unburned grasses did not produce any seed stalks (Biswell and Lemon 1943). Summer burning stimulated flowering in cutthroat grass (*Panicum*), whereas winter burning or an absence of burning did not (Myers and Boettcher 1987). Glitzenstein, Streng, and Platt (1990) found that growing season burns significantly enhanced flowering and fruiting by grasses and asters. Note again though that these effects of increased flowering are short-lived and repeated burning must be conducted to sustain such production (Biswell and Lemon 1943). Other reported effects of burning include summer burns (April-August) decreasing average flower duration within a population, resulting in increased synchronization (Platt, Evans, and Davis 1988), and a delay in flowering (Hartnett 1987; Platt, Evans, and Davis 1988). Hughes (1975) found seed production by *Panicum* spp to be affected by season of burning. He observed that plants burned in October produced seeds in April, while those burned in January, March, and May produced seeds in May, June, and July, respectively.

Seeds of herbaceous vegetation are also thought to be more available on burned sites than unburned sites because of decreased litter layer (Stoddard 1963; Cushwa et al. 1969; Wilson, Masters, and Bukenhofer 1995), however this may not be important for turkeys because they are strong scratchers (Hurst 1981b).

Invertebrate food items

Another component of wild turkey diets are invertebrates. During winter turkeys of all ages eat insects hibernating or overwintering in ground vegetation (Glover and Bailey 1949; Kennamer, Gwaltney, and Sims 1980), but invertebrates are mostly consumed by poults in summer (May-September; Kennamer, Gwaltney, and Sims 1980; Exum et al. 1987). Insects are ingested heavily the first 2 weeks of poult life, but less as poult age increases (Hurst and Stringer 1975; Davis 1976; Stringer 1977; Exum et al. 1987). Therefore, invertebrate consumption drops steadily from May through September (Blackburn, Kirk, and Kennamer 1975; Hurst and Stringer 1975). Invertebrates comprised 54 percent

of total food intake by poults in June, 11 percent in July, and only 3 percent by September (Blackburn, Kirk, and Kennamer 1975).

Great variety exists in species of invertebrates taken (Davis 1976). Mosby and Handley (1943) identified 313 species of invertebrates from 537 turkeys. Animal food items consumed consisted of eggs, egg cases, larvae, nymphs, pupae, cocoons, and adults (Mosby and Handley 1943). Beetles, grasshoppers, true bugs, leafhoppers, butterflies, and moths are the most important animal foods (Wheeler 1948; Glover and Bailey 1949; Schorger 1966; Hamrick and Davis 1971; Hurst and Stringer 1975; Healy 1978; Hurst 1978; Williams and Austin 1988). Grasshoppers made up 15.5 percent of total food intake by juvenile turkeys from July through September (Hamrick and Davis 1971), and beetles constituted 19.6 percent of total food intake by poults in Florida (Williams and Austin 1988). Spiders, snails, pill bugs, ants, flies, slugs, millipedes, and centipedes provide supplement to turkey animal food diets (Mosby and Handley 1943; Glover and Bailey 1949; Hamrick and Davis 1971; Hurst and Stringer 1975; Stringer 1977; Hurst 1978; Exum et al. 1987). Other animal foods consumed include ticks, small wasps, snail shells, salamanders, crustaceans, snakes, and other small reptiles (Mosby and Handley 1943; Schorger 1966; Hurst 1978).

Effects of fire on invertebrates

Insects and other invertebrates are most vulnerable to fire during life stages that occur within surface litter or plant stems and leaves (Robbins and Myers 1992). Rice (1932) reported that few animals survived a spring burn, and those that did were located at the bases of bunch grasses. Hurst (1978) suggested that litter-dependent insects (e.g., ground beetles) might be more abundant on unburned sites. The time of greatest susceptibility will vary among species depending on their life histories (Robbins and Myers 1992). Some species will be less vulnerable in winter because they are in a resistant stage or within the soil matrix, while others are less vulnerable during the growing season when they are more mobile and can escape a fire (Nagel 1973; Robbins and Myers 1992). Sisson (1991), however, found no significant differences in invertebrate abundance between sites burned in spring or winter.

The short-term and immediate effects of fire on invertebrates is to decrease their abundance and cause those that survive to migrate to areas with greater cover, but animals recolonize burned sites as new vegetative growth appears (Rice 1932; Davis 1976; Robbins and Myers 1992). Two or 3 months after burning, Nagel (1973) found significantly more arthropods, especially herbivorous species, on burned sites as compared to unburned sites, while Hurst (1972) saw the same pattern 5 to 7 months post-burn. Cancelado and Yonke (1970) reported collect-

ing significantly greater Homoptera (leafhoppers) and Hemiptera (true bugs) populations on a site burned 7 months previously than on unburned sites. Ant species seem not to be significantly impacted by periodic burning (McCoy and Kaiser 1990; Zimmer and Parmenter 1998) with similar effects seen with June beetle and darkling beetle species (Pyle and Crawford 1996). Fire may actually have the effect of drawing in potential food sources in the form of pyrophilous arthropods. In their review of literature, McCullough, Werner, and Neumann (1998) pointed out the work of Evans (1972) and Holliday (1984) in identifying or observing up to three species of carabid beetle and Kayll (1968) in observing several spider species, all of which migrate to recently burned environments. Siemann, Haarstad, and Tilman (1997) conducted one of the most prolonged studies of the effects of fire on arthropods over a 30-year period. They found no significant changes in either abundance or richness of arthropods yet did find a definite shift in species composition, implying the role of fire in deciding locally dominant species. A look at the taxonomic orders most impacted revealed that densities of Diptera and Homoptera fell in correlation with increased burn frequency while densities of Hemiptera increased (Siemann, Haarstad, and Tilman 1997). Although it is well established that fire will cause the direct mortality of some arthropods (Gillon 1971; Lyon et al. 1978; Martin and Mitchell 1980; Mitchell 1990; Fay and Samenus 1993), it is also apparent that many of these organisms are adapted to occasional fires (Evans 1984; Anderson, Leahy, and Dhillon 1989; Siemann, Haarstad, and Tilman 1997). Burning every other year or burning on rotation every 3 years is recommended to increase insect abundance and availability (Hurst 1978; Exum et al. 1987). Sisson (1991) encourages burning 1 month before the initiation of nesting season to coincide with poult hatching, growth of new vegetation, and insect abundance, but Rosene (1969) does not advise burning at the end of March or in April since insects emerge at these times.

Hurst (1978) and Sisson (1991) have studied the implications of the effects of fire on invertebrates, for wild turkeys. Hurst (1978) reported that poults that fed on recently burned plots ate significantly more animal food than poults that fed on 3- and 4-year-old roughs. On burned sites, insects were heavily consumed because of either greater abundance or availability. Snail shells were also eaten more frequently on the litter-free burned sites. Only spiders were consumed more on unburned sites. Apparently, cover conditions for spiders were not sufficient on burned sites. Sisson (1991) revealed the importance of insects in selection of habitats by hens with poults. He found broods used burned pinelands, grazed woodlands, and old fields; areas characterized by high insect populations.

Conclusion

Recommendations for improving or maintaining eastern wild turkey habitats are directed toward providing high habitat diversity. To achieve this, clearings or travel lanes must be provided for use as strutting grounds, dusting areas, summer food sources, invertebrate "catching grounds," and brooding sites. Understory density of brush, shrubs, and saplings needs to remain low and open, yet sufficient enough for use as escape cover, nesting sites, and sources of soft mast. A diversity of mast-producing trees for use as fall and winter food sources needs to be maintained.

Prescribed burning is the primary management tool used to render quality wild turkey habitat. Nonetheless, there are no rules or set methods for the season or periodicity with which fire should occur to achieve this (Mosby and Handley 1943; Davis 1976; Williams and Austin 1988). As with bobwhite quail, the effects of prescribed burning depend ultimately on the frequency of burning, the size of the burn, its location, and the weather conditions at the time of burning (wind direction and velocity, humidity, and temperature). In general, patchy burning every 2 to 4 years is recommended to improve or maintain wild turkey habitats. Annual burning is not recommended because it limits fruit and mast supplies. Winter burning (January, February) has been advocated, while burning during the breeding season (March-June) is ill advised. Both growing season and dormant season burns have advantages and disadvantages. Those considering summer burns can reduce the negative impacts by reducing the size of a burn, conducting patch burns, and varying the time of year at which burning occurs (Robbins and Myers 1992). Regardless of periodicity or season of burning, fire-sensitive mast-bearing hardwoods must be protected from fire to ensure adequate mast during the fall and winter.

4 White-Tailed Deer (*Odocoileus virginianus*)

Introduction

The white-tailed deer is a highly adaptable ungulate, capable of surviving in a variety of habitat types, withstanding a range of temperatures, and subsisting on a diversity of foods (Speake, Hill, and Carter 1975; Smith and Coggin 1984; Johnson et al. 1995). Usually, the best habitat conditions for deer occur where there is a wide variety and large quantity of palatable, nutritious food (Dasmann 1971; Harlow 1984). Deer habitat management in the southeastern United States is primarily concerned with providing a diversity of browse and forage species, and secondarily concerned with providing cover for escape or protection from severe weather conditions. Lay (1967b) recommends management practices that will provide diverse habitats (e.g., mixture of stand sizes, types and species, well distributed clearings, etc.), and subsequently a variety of food resources. Used properly, prescribed burning will provide quality white-tailed deer habitat by reducing undesirable woody growth, bringing palatable species within reach of deer, increasing the abundance of herbaceous vegetation in semi-open or open conditions, stimulating fruit and berry production, and improving the nutrient quality of forage species (Shrauder and Miller 1969; Lewis and Harshbarger 1976; Whittington 1984; Wade and Lunsford 1989; Carlson et al. 1993).

Direct Effects of Fire on White-tailed Deer

Prescribed burning usually causes little direct mortality to white-tailed deer (Vogl 1967; Lyon et al. 1978). Deer respond to an approaching fire by moving away or ahead of it, and by using streambeds or other wet sites as refuges (Vogl 1967; Ivey and Causey 1984). Springer (1977) warned that prescribed spring burns (March, April) might harm newborn fawns due to their sedentary nature for the first 2 weeks of life (Marchinton and Hirth 1984). Fawns are able to run by the time they are a few days old, therefore most would be able to escape a prescribed burn, although fawns separated from their mothers are not likely to survive (Robbins and Myers 1992). Still, rescheduling a burn to eliminate any

and all wildlife damage may actually indirectly increase wildlife losses by having the site succeed to a less productive vegetational stage (Vogl 1967).

Documented responses of deer to prescribed burned sites indicate that deer are attracted to newly or recently burned areas due to changes in food availability (Alexander and Dickson 1970; Dills 1970; Halls 1978; Stransky and Harlow 1981; Carlson et al. 1993). Researchers have reported heavy browsing of scrub oak, sassafras, black gum, chestnut oak, and other forage species on burned sites (Hallisey and Wood 1976; Carlile, Whelan, and Tipton 1977; Hardin, Klimstra, and Silvy 1984). Fire may also elevate fruit production in some plant species (Lay 1956; Johnson and Landers 1978; Stransky and Halls 1979). Ivey and Causey (1984) reported that 2 weeks after burning, deer preferred the hardwood/pine habitat to the pine habitat due to hardwood mast being exposed by the fire. Reports of deer avoiding burned areas are restricted to sites severely affected by burning or areas void of cover (Armstrong 1980; Ivey and Causey 1984).

Indirect Effects of Fire on White-tailed Deer

Most studies of the effects of prescribed burning on white-tailed deer evaluate how fire alters their habitat, and consequently their food resources. Fire is beneficial to deer by increasing the quantity and improving the quality of woody and herbaceous foods, which ultimately affect the population through growth, development, reproduction, and survival. Fire also proves beneficial by controlling ectoparasite abundance. Potential negative effects of fire to deer include damage to important mast-producing species and reduced cover for escape or protection from the elements. However, several authors argue that cover does not play an important role for fawns and adult deer in the southeastern United States due to moderate temperatures (Dasmann 1971; Harlow 1984; Marchinton and Hirth 1984; Smith and Coggin 1984). Furthermore, Whittington (1984) and Newson (1984) stated that cover was seldom a critical factor in the Piedmont and Coastal Plain, respectively, except where deer are subject to night hunting or free-running dogs. Thus, the effect of fire on protective cover for white-tailed deer is arguably negligible.

Ectoparasites

White-tailed deer serve as host to at least 25 species of arthropod parasites, the most common being ticks, lice, and a louse fly (Kellogg et al. 1971). Strickland, Gerrish, and Smith (1981) reported 18 species of ticks from deer, 13 of which are common. Deleterious effects of ticks to deer include blood loss, cutaneous

wounds with secondary infections, tick paralysis, disease transmission, and deer fawn mortality (Robinson et al. 1967; Bolte, Hair, and Fletcher 1970; Strickland, Gerrish, and Smith 1981). Durden et al. (1991) reported possible hair loss, blindness, abnormal behaviors, and death from heavy infestations. Hayes and Prestwood (1969) also stated that parasitism compounded by malnutrition could lead to mortality. Newborn fawns seem most susceptible to tick infestations because (1) peak fawning occurs March-August (Loveless 1959; Harlow and Jones 1965; Jacobson, Guynn, and Mott 1981; Cook 1984), a time when adult tick activity is greatest (Bolte, Hair, and Fletcher 1970); and (2) newborn fawns are relatively sedentary and do not groom themselves enough to dislodge the ticks (Bolte, Hair, and Fletcher 1970). In addition, Kellogg et al. (1971) reported heavier tick infestation in deer during summer months as compared to the rest of the year. Jacobson, Guynn, and Mott (1981) also noted that infestations in deer by nymphal and larval ticks were heaviest from February through September and July through October, respectively. Once fawns reach 6 weeks of age though, little detriment by ectoparasites occurs because most adult and nymphal tick activity subsides by mid-July and also because fawns become more adept at grooming themselves (Bolte, Hair, and Fletcher 1970).

Effects of fire on ectoparasites

Limited research utilizing prescribed burning for the control of ectoparasites is available. Rogers (1953, 1955) was one of the first to report that prescribed burning could be used to control tick abundance. He found adult black-legged ticks were significantly less widespread in 1- and 2-year-old roughs than in areas that had not been burned for 14 years. Prescribed burning was also shown to have negatively impacted overall numbers of larval and nymphal forms of the tick *Amblyomma americanum* (lone star tick), but adult members of the population were not affected (Hoch et al. 1972). Conversely, two annual burns in Georgia significantly reduced larval and adult lone star tick populations (Siefken 1991). Significant decreases in populations of the tick *Dermacentor andersoni* (Smith, Cole, and Gouck 1946) and *Ixodes scapularis* (black-legged tick; Rogers 1953) have been reported after burning. Wilson (1986) also recorded notable decreases in populations of *Ixodes dammini* (deer tick), for at least 12 months post-burn. The research showed a 70.0 to 83.3 percent decline in adult tick densities in surveys conducted from 2 weeks to 12 months after spring and fall burns. Populations tested 30 months after burning were found to have stabilized between the burned and unburned habitats (Wilson 1986). In conducting biennial burns, Siefken (1991) and Davidson, Siefken, and Creekmore (1994) found that tick abundance was reduced significantly the year of the burn, while in the year burning was omitted, the abundance of larval lone star ticks was equal on burned and unburned plots. Davidson, Siefken, and Creekmore (1994) concluded

that annual winter burning, or burning later in the spring or summer (after March) when more of the tick population is active, could be an effective tool for the control of ectoparasites. Accordingly, Mather, Duffy, and Campbell (1993) concluded that burning for several years, having a hot fire, or burning after April may be a more effective way to control ectoparasites.

Nutrition of the White-tailed Deer

The diet of white-tailed deer is comprised of a variety of plants and plant parts (Harlow 1961a; Goodrum and Reid 1962; Newsom 1984; Johnson et al. 1995; Stromayer et al. 1998), yet relatively few species compose the bulk of deer diets. Deer consume the leaves, flowers, fruits, and twig ends of hardwood and shrub species, and the stems and leaves of forbs, grasses, and fleshy fungi (Johnson et al. 1995; Stromayer et al. 1998). The succulent, new growth of woody plants, forbs, and grasses provides a plethora of food for deer in the spring (Harlow and Hooper 1972; Vansant 1976; Newsom 1984; Johnson et al. 1995). Important summer food items include grasses, fungi, soft mast, green leaves, and stems of woody plants and forbs (Dunkeson 1955; Harlow and Hooper 1972; Vansant 1976; Johnson et al. 1995; Stromayer et al. 1998). Acorns constitute the majority of deer diets for the fall season in years of good mast production (Pearson and Burnett 1940; Pearson 1943; Dunkeson 1955; Harlow 1961a, 1965a; Duvendeck 1964; Lay 1965; Goodrum, Reid, and Boyd 1971; Harlow and Hooper 1972; Vansant 1976; Wentworth, Johnson, and Hale 1990; Johnson et al. 1995; Stromayer et al. 1998). In years with poor acorn yields, cabbage palmetto berries; fruits of black gum, dogwood, red bay, coralberry, and sumac; and leaves of broadleaf evergreens are consumed (Pearson 1943; Vansant 1976; Wentworth, Johnson, and Hale 1990). Fruits of various hardwoods, fungi, and green and dried vegetation also supplement the fall diets of white-tailed deer (Dunkeson 1955; Harlow 1965a; Harlow and Hooper 1972; Vansant 1976; Johnson et al. 1995). Acorns remain an important winter food item if available, otherwise fruits, grasses, dried and green vegetation, fungi, and lichens are also eaten (Harlow 1965a; Harlow and Hooper 1972; Johnson et al. 1995; Stromayer et al. 1998). The consumption of dried leaves and other vegetation was noted to increase as mast availability decreased. However, the dried material may have been consumed by deer only when they were foraging for fallen mast or fungi (Vansant 1976). Stromayer et al. noted that deer in Georgia browsed a large volume of privet, a naturalized semi-evergreen shrub, and especially so in years of acorn shortage.

The consumption of fungi by deer is usually sporadic, thus reflecting the growth habits of fungi (Vansant 1976). Nevertheless, fleshy fungi are a significant, year-round food item for deer whenever available (Harlow 1961a, 1965a; Harlow

and Hooper 1972; Vansant 1976; Whittington 1984; Johnson 1995). Dunkeson (1955) reported that deer went to considerable effort to root fungi out of the duff. In addition, fleshy fungi are important sources of nutrients for white-tailed deer (O'halloran et al. 1987).

Browse vs. herbaceous vegetation

Stransky and Harlow (1981) and Robbins and Myers (1992) have both noted that the relative importance of browse to herbaceous vegetation is being questioned in diets of deer of the southeastern United States. Many researchers consider deer to be primarily a browsing herbivore (Stransky and Harlow 1981; Johnson et al. 1995; Stromayer et al. 1998), but some studies have shown the importance of forbs and grasses in white-tailed deer diets. Dunkeson (1955) found that herbaceous plants made up the largest single class of deer food from March to November, and that grasses were also a significant food item. In a fall and winter food survey, Harlow (1961a) reported that herbaceous material amounted to more than twice the amount of all other types of food combined for deer in the Everglades. When sampling late fall and early winter deer diets throughout Florida, Harlow (1965a) noted that deer in southern Florida consumed greater amounts of herbaceous material than deer in northern counterparts. Verme and Ullrey (1984) regard deer as grazers, turning to browse when herbaceous forage is unavailable. In contrast, a 5-year study of the foraging habits of white-tailed deer by Johnson et al. (1995) revealed that browse consistently composed well over 50 percent of the volume of rumen contents in all seasons with herbaceous vegetation being of "secondary importance." Stromayer et al. (1998) found that deer browsed privet, a naturalized semievergreen shrub, heavily in the winter in Georgia. They further noted that deer turned mainly to privet and some other available browse, rather than herbaceous vegetation, in the fall of years with poor acorn production. This finding was corroborated by Johnson et al. (1995) who found that deer consumed other fruits and the leaves of dicotyledonous evergreen shrubs when acorns were scarce, but conceded that herbaceous forage may be underrepresented in rumen analyses.

Nutrition, health, and reproductive capacity

Deer show direct responses in physiology and population structure to qualitative aspects of their food supply (Klein 1970). When range conditions deteriorate, weight loss, arrested antler development, decreased reproductive capacity, lowered resistance to parasitism and diseases, and increased mortality of adult deer and fawns result (Harlow 1965b; Murphy and Coats 1966; Hayes and Prestwood 1969; Klein 1970; Dasmann 1971; Wentworth, Johnson, and Hale 1990; Wentworth, Johnson, and Hale 1992). In studying the effects of dietary protein on

deer, Murphy and Coates (1966) reported that deer on the lowest protein ration (7 percent protein) lost weight at a greater rate than deer on intermediate (10 percent protein) or high (13 percent protein) protein rations. Murphy and Coates (1966) also stated that antler development in fawns and survival of does and fawns were directly affected by decreased protein levels in the diet. Klein (1970) asserted that deer in poor physiological condition often suffer from lowered resistance to parasites, heavier parasite infestations, and greater opportunities for disease transmission. Poor nutrition can directly affect the productivity of female deer through decreased conception rates, increased in utero mortality and increased mortality of newborn fawns (Klein 1970). Verme (1962) studied the effects of nutritional status of female deer on the production and survival of fawns. He reported that does who were fed a high-quality diet throughout the year had only 7 percent pre- and post-natal losses of fawns, whereas does who were fed a low quality winter diet followed by a low- or moderate-quality spring diet experienced fawn losses of 50 to 90 percent, respectively. Verme (1963) reported that well-fed does had more twins, had them earlier, and the fawns were larger.

Effects of fire on forage quantity

Fire can be utilized and is recommended to avoid critical periods of food scarcity and to provide food at a level that is readily accessible to deer (Alexander and Dickson 1970; Dills 1970; Halls 1978; Stransky and Harlow 1981; Carlson et al. 1993). Many, but not all, studies have reported an increase in browse and forage production after prescribed burning; see Table 1 (Hilmon and Hughes 1965; Mumaw 1965; Lay 1967a; Devet and Hopkins 1968; Hallisey and Wood 1976; Lewis and Harshbarger 1976; Carlile, Whelan, and Tipton 1977; Springer 1977; Hurst, Campo, and Brooks 1980; Hurst and Warren 1982; Brose and Van Lear 1998; Brose, Van Lear, and Cooper 1999). Wood (1988) reported no significant differences in forage production between burned and unburned plots 1 and 2 years after a January burn. Usually, a temporary reduction in browse occurs because fire top-kills browse species, but sprouting from the root crown ensues (Dills 1970; Wade, Weise, and Shell 1989), thereby increasing browse production (Lay 1967a; Stransky and Harlow 1981). Dills (1970) reported a reduction in browse the growing season after a March burn, but 2 years post burn, browse yields on burned sites surpassed those produced on the unburned control. Hallisey and Wood (1976) reported no significant differences in browse production by scrub oak on burned and unburned plots the first growing season after an April burn, but yields 1 to 4 years post-burn were significantly greater on burned plots than unburned plots. Carlson et al. (1993) found density of sprouts to increase and remain elevated up to 14 months in some species. Nutritional quality was also enhanced as several species showed higher crude protein and phosphorus

levels. Hengst and Dawson (1994) and Huddle and Pallardy (1996a) found oak resprouting to be of primary importance in maintaining oak populations over other browse species after fire, but Huddle and Pallardy (1999) found that the number of seedlings of all types decreased post-burn. To minimize the impact of reduced browse production the growing season after burning, Ivey and Causey (1984) recommend limiting burn units to thirty hectares or less, or conducting burns close to the time of new spring growth.

Table 1. Known effects of prescribed burning on deer forage plants in southern forests.

Species	Reaction To Prescribed Burning	Source
Red Maple <i>Acer rubrum</i>	Needs protection from fire Prolific sprouting after a winter burn Easily injured by fire, and once injured starts to decay Resprouts vigorously after burning Reduced abundance after spring and summer fire	Rosene and Freeman 1988 Devet and Hopkins 1968 Massey 1961 Massey 1961 Brose and Van Lear 1998
Rattan <i>Berchemia scandens</i>	Abundance is reduced by fire	Stransky and Harlow 1981
American Beautyberry <i>Callicarpa americana</i>	Fire will kill aboveground parts	Rosene and Freeman 1988
Trumpet-Creeper <i>Campsis radicans</i>	Resprouts prolifically after burning	Glasglow and Bateman 1961
Butterfly Pea <i>Centrosema virginianum</i>	Will withstand annual burning	Rosene and Freeman 1988
Fringetree <i>Chionanthus virginicus</i>	Hot fires capable of killing roots Resprouts prolifically after a light burn	Goodrum and Halls 1961
Sweet Pepperbush <i>Clethra alnifolia</i>	Increased abundance after burning	Kral 1961
Black Titi <i>Cliftonia monophylla</i>	Resprouts prolifically after burning Well adapted to fire	Shrauder and Miller 1969 Eichhorn 1961 Robbins and Myers 1992
Dogwood <i>Cornus</i> spp	Older trees will withstand burning Burning stimulated fruit production Fire kills aboveground parts, but resprouts after burning	Rosene and Freeman 1988 Lay 1956 Johnson, F.M. 1961
Hawthorn <i>Crataegus</i> spp	Will not tolerate annual burning Reduced abundance after a low-intensity winter burn	Rosene and Freeman 1988 Wade et al. 1989
White Titi <i>Cyrilla racemiflora</i>	Resprouts prolifically after burning Well adapted to fire	Shrauder and Miller 1969 Jeter 1961 Robbins and Myers 1992
Strawberry-Bush <i>Euonymus americanus</i>	Protect from hot fires	Adams 1961
Yellow Jessamine <i>Gelsemium sempervirens</i>	Decreased productivity three years postburn Increased abundance after burning Frequent burning may damage roots, reduce production or kill the plant	Lay 1956 Rich 1961 Rich 1961

Species	Reaction To Prescribed Burning	Source
St. Andrew's Cross <i>Hypericum</i> spp	Fire destroys aboveground parts	Rosene and Freeman 1988
Large Gallberry <i>Ilex coriacea</i>	Resprouts prolifically after burning	Johnson, A.L. 1961
Possumhaw <i>Ilex decidua</i>	Resprouts prolifically after burning	Johnson, A.L. 1961
Gallberry <i>Ilex glabra</i>	Resprouts prolifically after burning Thrives with annual winter burning Well adapted to fire Vigorous fruit production two to four years postburn	Hilmon and Hughes 1965 Hughes and Knox 1964 Robbins and Myers 1992 Stoddard 1963
Holly <i>Ilex opaca</i>	Decreased productivity after burning	Lay 1956
Yaupon <i>Ilex vomitoria</i>	Resprouts prolifically after burning Needs protection from fire Decreased productivity one year postburn Hot or frequent fires will eliminate	Shrauder and Miller 1969 Rosene and Freeman 1988 Lay 1956 Lay 1961a
Virginia Sweetspire <i>Itea virginica</i>	Periodic burning increases abundance	Harlow 1961b
Eastern Redcedar <i>Juniperus virginiana</i>	Stems are easily girdled by fire Follage does not readily burn	Crawford 1961 Crawford 1961
Yellow Poplar <i>Liriodendron tulipifera</i>	Reduced abundance after a low-intensity winter burn Resprouts vigorously after burning Reduced abundance after high intensity fire	Wade et al. 1989 Hooper and Lueth 1961 Brose, Van Lear, and Cooper 1999
Japanese Honeysuckle <i>Lonicera japonica</i>	Will withstand burning Prolific sprouting after a winter burn Fire consumed all aboveground vegetation Decreased abundance the growing season after burning Importance values increased after a low-intensity winter burn	Rosene and Freeman 1988 Devet and Hopkins 1968 Stransky et al. 1976 Cushwa et al. 1969 Wade et al. 1989
Red Mulberry <i>Morus rubra</i>	Fire will scar trees Reduced abundance after a low-intensity winter burn	Rosene and Freeman 1988 Wade et al. 1989
Wax Myrtle <i>Myrica cerifera</i>	Withstands fire, but burning decreases the seed crop Well adapted to fire	Rosene and Freeman 1988 Robbins and Myers 1992
Black Gum <i>Nyssa sylvatica</i>	Excessive burning will leave scars Productivity increased with spring burning Decreased productivity the second year postburn Resprouts prolifically after burning	Rosene and Freeman 1988 Carlile et al. 1977 Lay 1956 Halls 1977a, Moore 1961
Red Bay <i>Persea borbonia</i>	Burning stimulates seed germination Prolific sprouting ensues burning	Goodrum 1961b, 1977 Goodrum 1961b, 1977
Black Cherry <i>Prunus serotina</i>	Fire scars trees Fire kills aboveground parts, but resprouts prolifically after burning Importance values increased after a low-intensity winter burn	Rosene and Freeman 1988 Halls 1977b Wade et al. 1989

Species	Reaction To Prescribed Burning	Source
White Oak <i>Quercus alba</i>	Fire will damage trees	Collins and Murry 1961
Laurel Oak <i>Quercus laurifolia</i>	Fire not recommended Fire will damage trees	Rosene and Freeman 1988 Collins and Murry 1961
Water Oak <i>Quercus nigra</i>	Fire scars trees Fire will damage trees	Rosene and Freeman 1988 Collins and Murry 1961
Willow Oak <i>Quercus phellos</i>	Fire will damage trees	Collins and Murry 1961
Chestnut Oak <i>Quercus prinus</i>	Productivity increased after spring burning	Carlile et al. 1977
Runner Oak <i>Quercus pumila</i>	Bears vigorously for several years after burning If burned annually, will not produce acorns Reduced acorn production the growing season following burning, but vigorous production thereafter Increased mast production after growing-season burns High abundance on plots burned annually during the dormant season Low abundance on plots burned annually during the growing season	Shrauder and Miller 1969 Rosene and Freeman 1988 Devet and Hopkins 1968, Johnson and Landers 1978 Oldenburg 1987, Williams 1977 Glitzenstein et al. 1990 Glitzenstein et al. 1990
Post Oak <i>Quercus stellata</i>	Resprouts after burning More susceptible to growing-season burns than dormant season burns	Ferguson 1961 Ferguson 1961
Live Oak <i>Quercus virginiana</i>	Fire scars trees and kills small ones Reasonably fire tolerant when burned with humidities above 45% Resprouts after topkilled Reduced acorn production the growing season following burning, but vigorous production thereafter	Rosene and Freeman 1988 Armstrong 1980 Armstrong 1980 Springer 1977
Sumac <i>Rhus spp</i>	Fire not recommended Seed germination is stimulated by fire Prolific sprouting after a winter burn Reduced abundance after a low-intensity winter burn	Rosene and Freeman 1988 Armstrong 1980 Devet and Hopkins 1968 Wade et al. 1989
Blackberry <i>Rubus fruticosus</i>	Burning stimulates new growth Increased abundance after burning Peak fruit production four years after burning Vigorous fruit production two to four years postburn	Lay 1977 Cushwa et al. 1969 Wade et al. 1989 Johnson and Landers 1978 Stoddard 1963
Palmetto <i>Sabal palmetto</i>	Resprouts prolifically after burning	Hilmon and Hughes 1965
Sassafras <i>Sassafras albidum</i>	Will withstand light winter burning Productivity increased after spring burning Susceptible to fire damage, but resprouts after burning	Rosene and Freeman 1988 Carlile et al. 1977 Leonard 1977
Saw Palmetto <i>Serenoa repens</i>	Well adapted to fire	Robbins and Myers 1992

Species	Reaction To Prescribed Burning	Source
Greenbrier <i>Smilax</i> spp	Will withstand burning Relatively fire tolerant Vigorous growth after a hot burn Increased forage growth the second year after burning Prolific sprouting after a winter burn Importance values increased after a low-intensity winter burn Resprouts after burning	Rosene and Freeman 1988 Armstrong 1980 Armstrong 1980 Lay 1956 Devet and Hopkins 1968 Wade et al. 1989 Goodrum 1961a
Common Sweetleaf <i>Symplocos tinctoria</i>	Burning increases the quality and quantity of browse	Speake 1961
Blueberry <i>Vaccinium</i> spp	Increased mast production after growing-season burns Peak fruit production three growing seasons after burning Vigorous fruit production two to four years postburn Fire may stimulate growth in the Coastal Plain	Oldenburg 1987 Johnson and Landers 1978 Stoddard 1963 Dale 1961
<i>Viburnum molle</i>	Increased productivity two years postburn	Lay 1956
Grape <i>Vitis</i> spp	Will not tolerate burning Resprouted prolifically after a winter burn Importance values increased after a low-intensity winter burn	Rosene and Freeman 1988 Devet and Hopkins 1968 Wade et al. 1989

Fire Frequency

Increases in forage production are temporary (Shrauder and Miller 1969; Hurst, Campo, and Brooks 1980), and burning needs to be repeated to maintain yields (Devet and Hopkins 1968). Lay (1956) reported no differences in forage between burned and unburned plots three years post-burn. Springer (1977) found no differences in forb production two springs after an October burn, while McGee, Leopold, and Nyland (1995) determined that richness of forb species increased post-burn. Hilmon and Hughes (1965) reported that forb production peaked 3 years post-burn, but declined thereafter. Prescribed burning every 3 to 5 years is recommended to maintain high quantities of available forage for deer (Harlow and Bielling 1961; Devet and Hopkins 1968; Shrauder and Miller 1969; Speake, Hill, and Carter 1975; Hallisey and Wood 1976). Brockway and Lewis (1997) found Graminoid species to increase in total cover by 900 percent when treated with biennial burns. Nuzzo, McClain, and Strole (1996) also found that herbaceous species richness was significantly elevated after the burning. Lewis and Harshbarger (1976) reported that periodic burning yielded significantly greater coverage of woody species than annually- or biennially-burned plots with negligible changes in species composition as compared to unburned plots. Huddle and

Pallardy (1996b) found greater mortality of trees in annual versus periodic burns because of increased fire intensity while Nuzzo, McClain, and Strole (1996) found no change in richness in woody species. Burning more frequently may lead to a reduction in browse (Harlow and Bielling 1961; Landers 1987) and an increase in forbs and grasses (Lewis and Harshbarger 1976; Stransky and Harlow 1981; Landers 1987; Nuzzo, McClain and Strole 1996; Brockway and Lewis 1997), while less frequent burning would allow a thick midstory to develop out of the reach of deer (Blair 1967) and would ultimately inhibit plant growth underneath (Blair 1967; Speake, Hill, and Carter 1975; Dunning 1993; Wilson, Masters, and Bukenhofer 1995; Nuzzo, McClain, and Strole 1996).

Season of burning

Different seasonal burning regimes promote different components of the deer diet. Robbins and Myers (1992) found that growing-season fires tend to promote the herbaceous component, while dormant-season fires promote browse production. Brockway and Lewis (1997), however, found that graminoid species do benefit from periodic dormant-season fires. Because browse species respond with vigorous new growth (Devet and Hopkins 1968) and because deer are considered to be primarily a browsing herbivore, dormant-season burning is generally recommended to provide quality deer habitat. Recognition of the importance of herbaceous vegetation to deer in the southeastern United States has led some researchers to point out possible benefits of growing-season fires (Robbins and Myers 1992; Nuzzo, McClain, and Strole 1996). Landers (1987) proposes that a patchy growing-season burn and the resulting succulent growth of herbaceous species may better meet the nutritional requirements of pregnant does and fawns. Carlson et al. (1993) found that some browse species burned in the growing-season had higher crude protein and phosphorus levels than those in unburned plots. Researchers have reported increased production of mast, grass seeds, and herbaceous vegetation resulting from growing-season burns (Biswell and Lemon 1943; Stransky and Harlow 1981; Oldenburg 1987). Stransky and Harlow (1981) concluded that infrequent summer burning increases the abundance and kinds of herbaceous vegetation. Thus, growing-season burns conducted periodically or alternated with dormant-season burns are not likely to destroy white-tailed deer habitat, and may even enhance it by increasing forb and grass density (Robbins and Myers 1992).

Effects of fire on forage quality

Prescribed burning serves not only to increase the abundance of browse, but also its nutritional quality (Carlson et al. 1993). After evaluating various studies, Stransky and Harlow (1981) concluded that crude protein and phosphorus,

which are limited nutrients in the southeastern United States, generally increase in browse on burned plots versus browse of unburned plots. There was considerable variation among species and the effect decreased as the growing season progressed, but the differences were significant. In no study did they find that burning had a deleterious effect on the protein and phosphorus contents of browse species. Carlson et al. (1993) found that some browse species burned in the growing-season had higher crude protein and phosphorus levels than those in unburned plots. Springer (1977) reported that crude protein levels of browse on fall-burned (October) sites had significantly increased the following spring (February-May), but not the second growing season after burning. Springer (1977) obtained similar results for phosphorus levels recorded during the following growing season (March-December). Hallisey and Wood (1976) also found significantly greater protein levels in scrub oak foliage on sites 1- to 4-years post-burn than on unburned sites. Crude protein significantly increased in blueberry foliage one growing season after burning, but not thereafter (Hallisey and Wood 1976). Japanese honeysuckle showed significantly greater protein levels on burned sites 3 and 9 months after burning as compared to unburned plots (Stransky, Hale, and Halls 1976). Red maple, sourwood, and sassafras contained significantly more protein 3 months after a March burn; but 6 months after the burn, no significant differences could be found (Dills 1970). American beautyberry, yaupon, and common sweetleaf had higher protein and phosphoric acid contents on burned sites (Lay 1957, 1961a, 1961b; Speake 1961). Increased protein and phosphoric acid levels on burned sites were likewise reported for tree huckleberry, dogwood, water oak, sassafras, sweetgum, *Viburnum molle*, and muscadine (Lay 1957). Hallisey and Wood (1976) also found increased calcium and magnesium concentrations in browse the growing season following an April burn, but not thereafter. Studies also indicate an increase in browse palatability after burning due to fiber and lignin contents of browse decreasing shortly after burning. However, fiber and lignin contents return to pretreatment levels a few months post-burn (Stransky and Harlow 1981).

Changes in browse quality due to prescribed burning appear to last not more than one growing season. Burning at any season increases the protein and phosphorus content of browse, but most of the benefits disappear within 1 to 2 years (Lay 1957; Carlson et al. 1993). Given the existing data, it seems likely that any major improvement in forage nutritive value is not likely to occur when prescribed burning is conducted every 3 to 5 years (Wood 1988). Nevertheless, note that these studies are representative only of the short-term effects of fire on the nutritive value of vegetation, and that the effects of repeated fires and various burning regimes needs further evaluation.

Effects of fire on fungi

An initial study of the effects of fire on fungi reported that a March burn did not affect the production or nutrient quality of fleshy fungi (O'halloran et al. 1987). O'halloran et al. (1987) and Shrauder and Miller (1969) both contend that fungi serve to alleviate nutritional deficiencies during food shortages that may be the result of a prescribed burn. The effects of repeated burns and different seasonal burns on fungi still need to be evaluated (O'halloran et al. 1987).

Conclusion

The use of prescribed burning in white-tailed deer habitat is not a new concept and comes highly recommended as a means to increase the abundance and nutritive value of food resources for deer, and ultimately the range carrying capacity. Most researchers advocate periodic dormant-season burns because browse is considered to be an important component of deer diets. However, the importance of browse in southern deer diets is being questioned. With this realization, researchers have investigated the effects of growing-season burns, and consequently, have concluded that periodic growing-season burns would not destroy deer habitat. Annual summer burning may eliminate browse species, and annual winter burning limits mast production. For these reasons, annual burning is ill advised. Regardless of the season or frequency of burning, hardwood species should be protected from fire (Shrauder and Miller 1969; Whittington 1984) to ensure an optimum and diverse fruit production (Lay 1967a), and food items for deer at times when herbaceous vegetation may not be available (Robbins and Myers 1992). Maintaining hardwood stands along stream bottoms is recommended as these provide a variety of high-quality foods for deer (Newsom 1984).

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14. ABSTRACT <p>Prescribed burning has become an increasingly common management tool to modify habitats for many species in the southeastern United States. On military installations in the southeast, prescribed burning is used frequently on a landscape scale to control midstory encroachment in habitats of the endangered red-cockaded woodpecker (<i>Picoides borealis</i>). On Army installations, as much as one-third of red-cockaded woodpecker habitat is scheduled for prescribed burning annually under installations' Endangered Species Management Plans. Such a wide-scale use of prescribed burning to achieve management objectives focused on one species raises valid concerns of ancillary effects to other biological resources on military installations.</p> <p>Military land managers need a current scientific perspective on the effects of prescribed burning on the three most popular terrestrial game species in the southeast: bobwhite quail (<i>Colinus virginianus</i> L.), eastern wild turkey (<i>Meleagris gallopavo silvestris</i> Vieillot), and white-tailed deer (<i>Odocoileus virginianus</i>). This literature review provides land managers useful information for planning and implementing a balanced burning program as well as information useful for educating the public on the effects of prescribed burn programs on installations.</p>					
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