Fire and Biodiversity: Studies of Vegetation and Arthropods

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Introduction

Fire is a critical management tool in natural and mature old-field pine uplands of the Coastal Plain in the southeastern United States (cf. Myers 1990, Hermann 1995). During the last 30 years, prescribed bums have gained almost universal acceptance within wildlife and natural resource agencies. However, for much of that time, prescribed bums were used almost exclusively to decrease fuel loads and minimize the threat of wildfire. Bums were almost always prescribed within a time frame limited to the dormant or winter season and with an intensity and/or frequency that did little more than remove leaf litter and grasses. Dormant-season fire was also applied to prune hardwoods and vines in attempts to maintain an open, grassy forest.

In recent years, ecologists have encouraged natural resource managers to modify traditional prescribed fire regimes to mimic natural processes or at least recreate their outcome. This is especially true in southern longleaf pine (*Pinus palustris*) forests (cf. Means and Grow 1985, Noss 1989). Land stewards are urged to bum more frequently than in the past and to include growing- or warm-season bums (more accurately termed dry-lightning season, see below). The push to include growing-season fires in long-term management plans is based largely on an increased understanding of some important native plant responses to specific time of bum (cf. Brewer and Platt 1994a,1994b, Platt et al. 1988, Robbins and Myers 1992, Glitzenstein et al. 1995a,1995b). In addition, James et al. (1997) suggest that modification of traditional fire regimes might aid in the recovery of the endangered red-cockaded woodpecker (*Picoides borealis*). Recently, a few entomologists have also discussed positive aspects of growing-season fires for insect conservation. For example, Hall and Schweitzer (1992) noted that for some species, fire should occur during time periods when adult insects are mobile rather than quiescent or sedentary.

-Despite the documented benefits of growing-season bums, a number of biologists question altering the use of fire. Game bird managers have expressed concern over possible nest mortality and loss of arthropods as food. Also, foresters worry that growing-season bums will depress tree establishment and/or growth. In addition, some lepidopterists believe prescribed fires may be incompatible with management for butterflies (cf. Swengel 1996) and other arthropods of conservation interest because they might increase mortality.

These views indicate potential conflicts with periodic application of lightning-season fire for ecosystem management. Past hesitancy of land managers to alter traditional prescribed fire regimes often has been based on concern over such conflicts. At times, a need for information to guide prescribed bum activities has preceded the research required to address pertinent issues. Three recent reviews of the effects of season of bum in the Coastal Plain (Glitzenstein et al. 1995a, Robbins and Myers 1992, Streng et al. 1993) provide a basis to evaluate these concerns and to determine future research needs.

In this paper, we summarize and update the state of knowledge for some components of prescribed fire in the southeastern Coastal Plain, with a primary focus on effects of season of bum on plants and arthropods. Specifically, we: 1) briefly explain season of fire terminology; 2) present a short synopsis of how fire regimes affect trees and groundcover vegetation in Coastal Plain pine forests; 3) review relevant arthropod literature; 4) discuss preliminary data from ongoing studies on season of bum on arthropods, including consideration of resources for pollinators (especially fall migrating butterflies); and 5) consider prescribed fire management in light of biodiversity issues.

Terminology and Study Design Considerations

Before exploring management issues, we review terminology related to seasonality of fire in the Coastal Plain. The phrases **warm** and cool **season,**

summer and **winter, growing and dormant season,** and **lightning** and **non-lightning season** are related, but not synonymous terms; dates associated with each phrase may shift depending on the latitude of a site. For clarity, the month and locality should be specified in a description of season of burn effects. In addition, it is useful to know soil type, past fire history and groundcover condition. The term fire **regime** characterizes a series of bums and includes season, frequency and severity. It is a summary of the fires applied to a site over time and provides a general description of the role of fire in structuring a specific habitat. In upland Coastal Plain forests, an evaluation of a site's fire regime or past fire history provides more useful information for understanding the ecology of the site than does a description of any one burn.

The phrase **lightning season** is of interest because it is related to local weather patterns associated with natural ignition of fire. Komarek (I 964) documented that Florida's thunderstorms are common in May through September, peaking in July and August, and that lightning-ignited fires are common from April through August, peaking in May and June. Robbins and Myers (I 992) noted that in Florida, early months of the thunderstorm period corresponded to drier weather conditions and proposed that a lack of moisture explains the shift in time between peak thunderstorms and frequency of lightning-ignited fires. Because this time period is delimited by local weather, the peak fire period of May to June may shift somewhat at sites north or west of Florida.

Platt et al. (1988) and others have postulated that the growing or lightning season is the time when most natural fires occurred in northern Florida. Due to the relatively high frequency of fire in the Coastal Plain, it is difficult if not impossible to corroborate season or bum intervals based on traditional means, such as tree ring fire scars or charcoal layers in sedimentation. Nevertheless, the significance of this fire period is bolstered by studies on the ecological responses of dominant plant species to different seasons of bum (see below). To facilitate communication, phrases describing time of fire should be defined by stipulating the month(s) of the bum period (see Robbins and Myers 1992, Streng et al. 1993).

Fire and Plants

Evaluation of the effect of different times of fire on vegetation is a complex process. Habitat type and past fire history of a study site must be considered (cf. Glitzenstein et al. 1995a). For example, old-field groundcover produces a fuel base with different pyrogenicity compared with vegetation dominated by wiregrass (*Aristida stricta* or *A. beyrichiana*). A site subjected to many years of fire suppression will respond differently to fire compared with a site that has been burned frequently. Fire weather and ignition patterns may also contribute significantly to fire effects (Glitzenstein et al. 1995a, 1995b, Robbins and Myers 1992).

Frequency may be as important as season of fire in determining bum effects (Glitzenstein et al.1995a, 1995b). However, this factor is especially difficult to study because there are few places that have been studied for sufficiently long periods of time. Two of the most well-known sites are the Santee Fire Plots in South Carolina (Waldrop et al. 1987) and the Stoddard Fire Plots in northern Florida (Hermann 1995). Unfortunately, neither site is characterized by the type of groundcover thought to have dominated much of the eastern Coastal Plain uplands (cf. Peet and Allard 1993) before settlement by Europeans. The groundcover of the Santee Plots, although thought to be characteristic of old-growth forests, may be specific for non-wiregrass dominated regions of South Carolina (Glitzenstein et al. in preparation). The Stoddard Plots are old-field vegetation. Sites in central Florida studied by Rebertus et al. (1989, 1993) have more typical, presettlement groundcover, however these plots have experienced past fire suppression (Glitzenstein et al. 1995a, 1995b). Despite shortcomings and differences, vegetation data from all three sites indicate that short bum intervals (averaging three years or less between fires) promote high diversity grass- and forb-dominated understory and that longer intervals produce a lower diversity woody species-dominated understory and midstory.

Pines and Season of Burn

Concerns are often expressed over potential negative effects of non-dormant-season bums on pines. Streng et al. (1993) present convincing evidence that growth of established pines need not be sacrificed when fires are prescribed during non-winter months. Robbins and Myers (1992) noted widely varying results related to growth and mortality. They point out that negative outcomes often can be attributed to extreme burn conditions and that this situation is not restricted to lightning or growing-season fires. High ambient air temperature associated with late growing season (generally later than the time span covered by the lightning season) may contribute to higher overstory pine mortality. Robbins and Myers (1992) stress that this comes into play only when fire intensity is high (the result of extreme weather conditions and/or excess fuel accumulation) or in young trees. Mortality may be of more concern for "off-site" pines, such as loblolly (*P. taeda*), slash (*P. elliottii*) or shortleaf (*P. echinata*), than in longleaf stands.

Based on available literature, lightning-season bums do not necessarily harm pine trees, especially longleaf pines (Glitzenstein et al. 1995a, 1995b). However, fire does affect each life stage of longleaf pine differently. Studies reviewed by Robbins and Myers (1992) indicate that growing-season fires may enhance growth of grass-stage (juvenile) longleaf pine and not necessarily depress growth of adult trees. Although established juveniles thrive with fire, seedlings less than one or two years old are usually killed by fire. This age-related (actually size-related) survivorship explains why annual bums at any season prohibit recruitment of southern pines (Hermann 1995).

Longleaf seeds require patches of bare soil to become established. Inclusion of growing-season bums in a land management plan may increase the chances for longleaf pine recruitment because they may permit creation of additional areas appropriate as seed bed. On nutrient poor, sandy soils, exposed mineral soil may persist for a year or two after a fire, but on richer soil, bums must occur the year that the seed falls. Longleaf seeds are dispersed in the fall, but cones are not easily noticed until the spring, after opportunities have passed for bums in the preceding dormant season. To take advantage of unexpected “mast years” with large numbers of cones, lightning-season fires that do not scorch crowns or cones may be useful in preparing seed beds.

However, bums that occur too late in the growing season may be problematic. Robbins and Myers (1992) note pine mortality may be high after fires in late summer to fall (generally August to October) compared with early growing-season bums. Caution is also urged when lightning-season fire is first reintroduced into a landscape. Excessive litter may build up at the base of large, old longleaf pines when fires have been absent or when exclusively low-intensity dormant-season burns are applied. A bum of even moderate intensity may cause it to ignite and smolder, resulting in mortality (J. Stevenson personal communication: 1997). This situation can be overcome by hand raking around at-risk trees with excessive fuel loads or using a series of dormant-season bums designed to remove built up litter.

Hardwoods and Season of Burn

Hardwood management often is mentioned as justification for burn programs. Waldrop et al. (1987) reported that, after 30 years, annual winter fire plots had substantially more hardwood stems compared with other treatments; plots with annual summer bums had the fewest hardwood stems. Glitzenstein et al. (1995a, 1995b) presented convincing data that “spring” (April to May) fires greatly increase oak stem mortality compared with bums at other times. However, the results of much of the research on effects of season of bum are confusing (Streng et al. 1993). Rebertus et al. (1987, 1993) suggest that higher intensity is associated with lightning-season fires and is a significant factor in increased mortality of arboreal oak stems, although other studies appear to be in

conflict with this interpretation. For example, Glitzenstein et al.(1995a) conclude that, when a site is burned on a regular basis and does not require habitat restoration, fire intensity plays less of a role in oak stem mortality. Robbins and Myers (1992) point out that variation in other variables, including fuel loading, fuel moisture and fire weather, may "... obscure or accentuate seasonal differences."

It must be remembered that oaks are a natural part of upland pine forests. The goal of a fire management program should be not to eradicate hardwood species appropriate to a site, but rather to manage stem density and height to promote vegetation structure deemed suitable to the habitat. It is also important to understand that decreasing stem height does not eliminate hardwood fruit; native runner oaks and many other upland woody species produce fruit when stems are at groundcover height. Research is needed on the effect of season and frequency of bums on reproduction of these species. Robbins and Myers (1992) discovered that the literature on fire effects on fruit production in groundcover woody plants is ambiguous. However, there is no indication that growing-season fires depress acorn and berry abundance.

Herbaceous Species and Season of Burn

Responses of some forbs and grasses to lightning-season fires provide compelling evidence that season of bum should be varied in long-term management plans. Patterns of regrowth, quantity of flower production and flowering phenology are all characteristics that respond to season of bum. In the Coastal Plain, perhaps the most well-known example of plant response to the season of bum is found in wiregrass. Lewis (1964), Parrott (1967) and Glitzenstein et al. (1995a) all demonstrate that flowering of this regionally dominate species is strongly enhanced by exposure to fire in March to August. However, ongoing research indicates that ambient temperature interacts with season of bum in a complex fashion so that late dormant-season bums on unusually warm days may mimic the outcome of later fires by stimulating flowering (Walker et al. unpublished).

Flowering of some other common forbs and grasses is strongly influenced by the date of a fire. In a study at St. Marks National Wildlife Refuge in northern Florida, Platt et al. (1988) present data associating flower density and phenology differences with season of bum. In a follow-up report, Streng et al. (1993) showed that five grasses and eight forb taxa were influenced by date of fire. It appears that all of these grasses follow the flowering pattern seen in wiregrass and require, or at least benefit from, April to August burns. Fires at other times of the year resulted in less than 20-percent flowering. At the

Apalachicola National Forest, also in northern Florida, a smaller experiment using two times of fires (January and May to June) evaluated abundance of flowering stalks for plant species that are potential sources of nectar for butterflies (Hermann and Van Hook unpublished, see also below). Figure 1 illustrates preliminary results for three of the fall-blooming composites. Although these plants all flower during approximately the same time period, they demonstrate dramatically different responses to season of bum. Blazing stars (*Liatris* sp.), goldenrods (*Solidago* sp.) and golden asters (*Pityopsis* sp.) have enhanced flowering following May or June fires. These results are similar to those reported by Glitzenstein et al. (1995a). Conversely, growing-season bums appear to eliminate flowering in an annual senna (*Seymeria cassiodes*) (Figure 1).

Bum month can also influence timing (phenology) of flowering of some groundcover species 4 to IO months after the bum. However, the relationship between flower phenology and reproductive success is unknown; more flowers at a point in time does not automatically mean increased seed production. However, many forb flowers are important resources for numerous insects (see below) and a shift in blooming may affect these animals. Furthermore, following fire, pollinator responses to flower abundance may influence seed set. Platt et al. (1 988) demonstrated that fire could alter flowering at the community level. Bums in July and August delayed peak flowering and synchronized flowering among fall flowering species. These shifts may influence nectar availability, pollinators and pollination of groundcover plants.

Timing of prescribed bum may have significance for some plant species of special concern. For example, cutthroat grass (*Panicum abscissum*), a threatened species in central Florida, displays a pattern similar to wiregrass and does not flower to any great extent unless it is burned during March through August (Myers and Boettcher 1987). *Schwalbea americana*, an endangered forb species, exhibits a different pattern of response to fire. Kirkman and Drew (1995) indicate that fire stimulates flowering in this species, regardless of season of bum.

In summary, an examination of published information on responses of groundcover to season of fire at both community and population levels, reveals that no one time of bum enhances all species (Glitzenstein et al. 1995a, Platt et al. 1988). In addition, short-term (less than 10 years) application of growing-season fire to intact habitat does not result in major shifts in the herbaceous community relative to dormant-season bums (Streng et al. 1993). However, the observations do suggest that a variety of times and frequencies (cf. Robbins and Myers 1992) are required for implementation of prescribed fire within the context of ecosystem management.

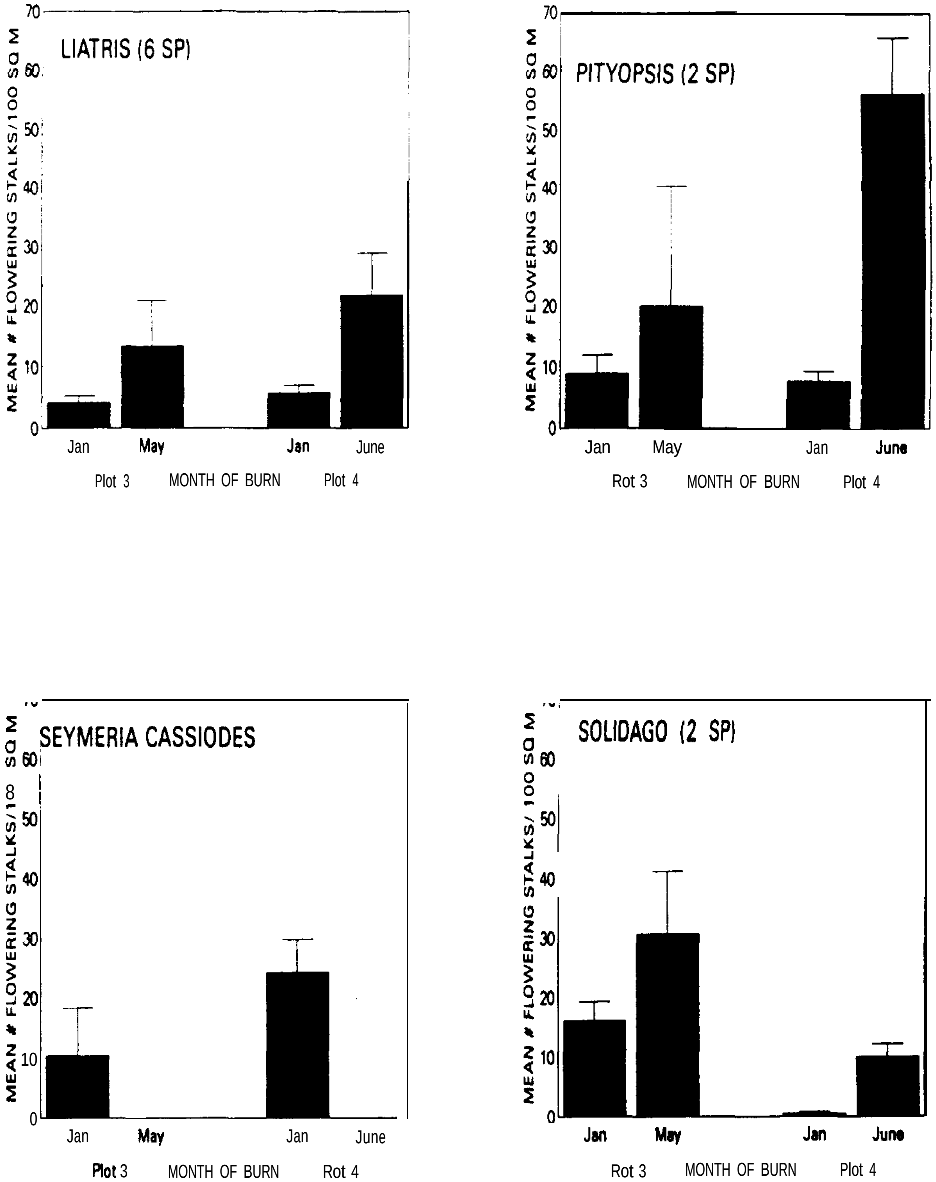

Figure 1. Examples of mean density of flowering stalks for four forb species following dormant- (January) or growing-season (late May and early June) fires on two wiregrass-dominated study plots in the Apalachicola National Forest in northern Florida (Hermann and Van Hook unpublished). Data are means +/-1 se and based on 100- by l-meter transects (n =10 for each plot and treatment). These taxa are among many forbs in the groundcover community thought to provide nectar for fall migrating butterflies.

Fire and Arthropods

Until recently, studies of arthropods in fire-maintained habitats were usually limited to two general considerations: the ecological and economic consequences of fire as a control agent of pathogens (cf. Brennan and Hermann 1994) or as a promoter of insect pests by stressing host trees. In addition, some survey work has covered arthropods in ecosystems that naturally experienced fire at long intervals. A large volume of literature on fire and insects relates to habitats with fire intervals of 50 to 200+ years. Wikars (1997) provides a review of fire-adapted insects in boreal forests and notes that there are nearly 40 European insect species (mostly beetles) that are pyrophilous (favored by fire). These species have declined over the last century, in large part due to lack of fire.

There has been less of an effort to document arthropod fire dependency in frequently burned habitats of the Southeast (cf. Folkerts et al. 1993, Robbins and Myers 1992). In the past, this likely was due to traditional views held by some entomologists that fire "ravaged" southern pine forests, implying that, at least, butterfly collecting and studies would be unproductive on burned sites (Klots 1951: 33). More recently, lack of attention may be due, in part, to the fact that most if not the majority of the invertebrate fauna is dependent on specific habitat structure and\or vegetation composition. That is to say, many adaptations to fire may be indirect. Most Coastal Plain upland species likely require some habitat characteristics of the open-canopy, sunny, grass-dominated upland pine forest. If fire is withheld from old-field land (Hermann 1995) or old-growth longleaf pine stands (Gilliam 1995), the vegetation composition and structure begin to change within a few years. We assume that arthropod communities change as well.

There is little published information on the effect of season of bum on arthropods in Coastal Plain upland pine forests (Robbins and Myers 1992) or any habitat with frequent fires. In one short study in longleaf pine-wiregrass sites, no differences were observed in alpha-diversity of arthropod families from sites burned in February versus May (Lara Pavon 1995). Also of interest is Panzer's (1988) review of published literature from Midwest prairies; he found no indication of long-term effects on insects of different times of fire.

Hall and Schweitzer (1992) present natural history information for some insect species of special concern and use this knowledge to suggest some likely responses to fire. They surveyed four North Carolina Nature Conservancy Preserves for butterflies, moths and grasshoppers. Their general conclusion was the same that Panzer (1988) reached for prairies. They suggest that in southeastem savannas and flatwoods, many arthropods will survive and/or recolonize best after fire if the bum is in the growing season when most species have a mobile phase. Hall and Schweitzer (1992) caution against annual dormant-season fires when rare arthropods are present. They conclude that alternating fire years among areas with similar habitats and/or prescribing patchy bums will decrease the chance of local extinction of species. Hall and Schweitzer (1992) also use natural history information to suggest fine tuning of local bum plans. For example, the broad-winged sedge grasshopper (*Stethophyma celata*) is still flightless in May and early June; when this species is present, it may be appropriate to delay prescribed fire until late June when some reproduction has occurred (Hall and Schweitzer 1992).

Of special interest is the impact of season of bum on pollinators, especially butterflies and bees, and the flowers that provide pollen and nectar. Fire affects these insects directly, by imposing mortality on immobile stages, and indirectly, by altering density and/or time of availability of flower resources. Change at either level may influence the amount and/or quality of seed that results. Research on these topics is sorely needed.

Preliminary Studies on Season of Burn Effects on Arthropods and Plants

Because there is limited information on the effects of season of bum on arthropods in southern upland pine forests, we present data from two ongoing projects. In both studies (one in old-field vegetation and the other in wiregrass-dominated groundcover), arthropods were collected using portable suction devices (model 122, D-Vat Company). This collection method results in data that are best used for relative comparisons and not for tests of differences in absolute values among studies.

In one study (Brennan et al. 1995, 1997), two sites on a southern Georgia old-field bobwhite quail hunting preserve were burned, one in February and the other in early May. Figure 2 presents data on arthropod biomass and abundance. Sample periods were during June, July and August, three months important for brood rearing in bobwhite quail. The first (June) sample was collected almost seven weeks after the May fire. Insect abundances were either equal on the two burn treatments or the May bum plots supported more individuals; biomass measurements showed similar results. Percentage cover of herbaceous quail food plants were also monitored. There was no significant difference between fire treatments; no important plant group was greatly depleted by growing-season fire and some were enhanced (Figure 2). In addition, the number of bobwhite quail coveys counted by the land manager during the hunting season was either the same or slightly higher on sites burned in May versus February (Figure 2). This result was also observed in two subsequent years.

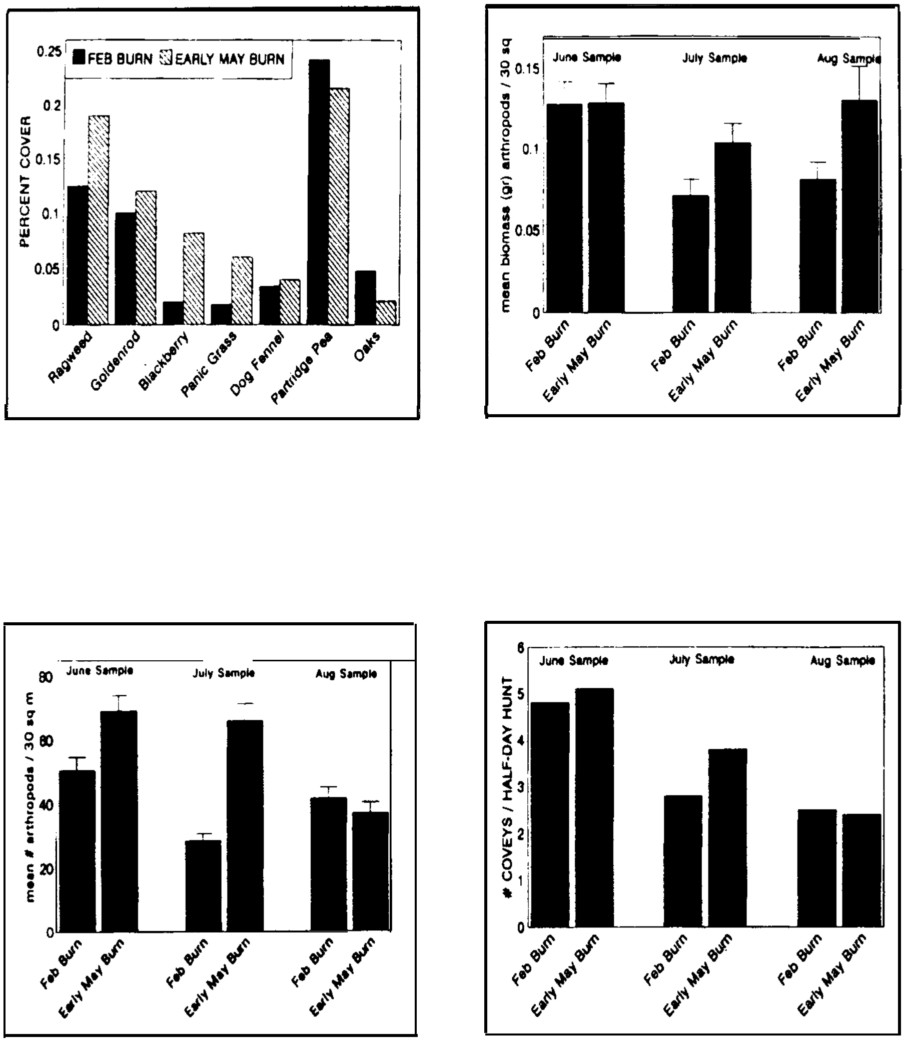

Figure 2. Data from two experimental fires on a private bobwhite quail hunting preserve in southern Georgia (based on Brennan et al. 1995, 1997). The groundcover vegetation consists of old-field species. Bums were applied in late February and early May to plots that encompassed previously established hunting courses, each a few hundred acres in size. Data on arthropods and plants are presented as means +/- 1 se and based on 1- by 30-meter transects (n = 25 for each bum type). Information on number of quail coveys was provided by the land manager of the private preserve.

In the other study (mentioned earlier), plots were located in mesic, wiregrass-dominated areas in the Apalachicola National Forest (NF) in north-em Florida. USDA Forest Service staff burned experimental plots, half in January and half in late May or June. Figure 3 illustrates a subset of data (Hermann and Flowers unpublished) that correspond to the sample time period used in the study by Brennan et al. ***(1995,*** 1997). In contrast to that work, the May fires in the Apalachicola NF occurred less than two weeks before insect sampling in June. Therefore, it is not surprising that June arthropod abundances were substantially lower on the lightning-season (May) plots compared with the dormant-season ones. Arthropod abundances on all plots declined by the July sample period, but lightning-season plots supported significantly more individuals compared with. the dormant-season plots. This pattern continued in August (Figure 3). In this study, only three orders (Collembola, Hymenoptera and Homoptera) were collected in sufficient numbers to permit evaluation; all three taxa showed the same patterns in abundance and were similar to the arthropod fauna taken as a whole.

Results from the Apalachicola NF sites indicate that by the end of the growing season, many components of habitat structure were apparently not significantly different between the two burn treatments. For example, by August, the mean percentage cover of wiregrass was similar on all sites (dormant season = 39.6 percent, growing season = 40.0 percent cover). As noted earlier, there were differences in flower abundance for some of the groundcover forbs (Figure 1). An additional difference may reside in moisture content of some of the groundcover species. Preliminary data suggest that, in August, plants on dormant-season fire plots had less moisture, per gram of wet biomass, compared with plant tissue from growing-season fire plots (Figure 3).

Migrating Butterflies as Species of Special Concern

Monarch butterflies (***Danaus plexippus***) rely on nectar resources obtained during migration to support fall and perhaps spring movement to and from Mexico (Brower 1995). Monarch migration is the only ecological phenomenon of its kind granted a standing in CITIES documents (Wells et al. 1983). At a recent international meeting, biologists voiced concerns about diminishing habitat quality and resources for migrating butterflies. In the fall, critical resource elements are located in the Coastal Plain and prescribed fire effects directly influence the availability and quality of both assets (S. Hermann and T. Van Hook personal observation 1997). The Apalachicola NF plots are being used to study butterfly foraging and flower resources during the fall migration. The sites are part of a large migration route involving the entire eastern half of the United States. As noted above, results from the ongoing project indicate that season of bum may alter which plant species are available as nectar resources (Figure 1). Additional work examines whether monarchs and other migratory

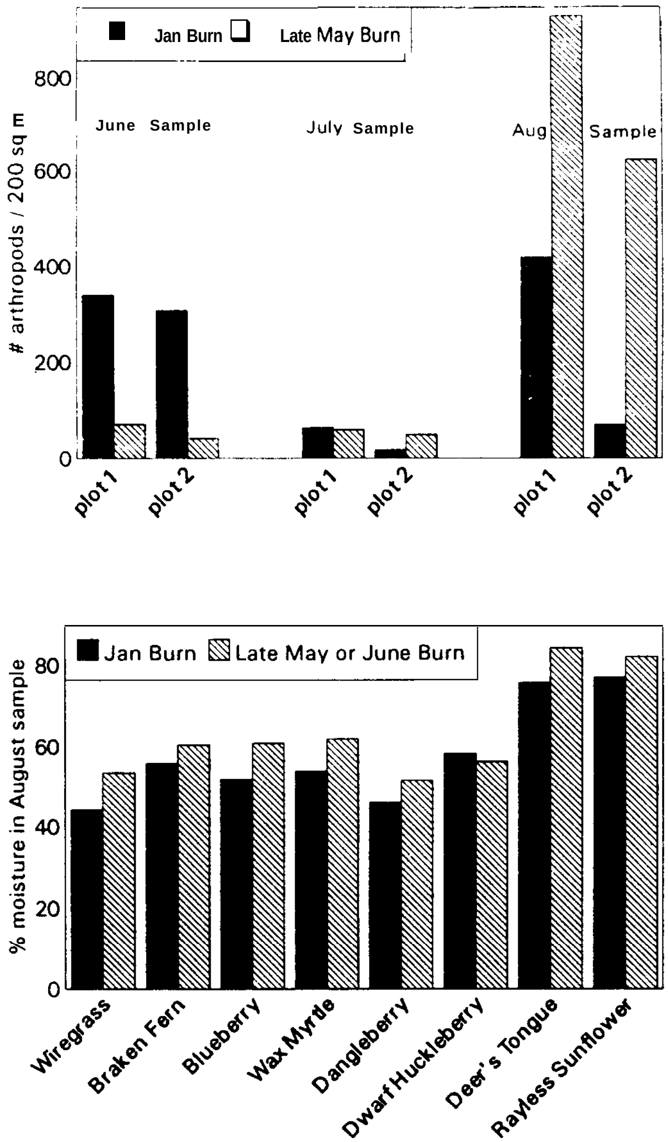

Figure 3. Data from season of bum plots in the Apalachicola National Forest (Hermann and Flowers unpublished). Arthropod numbers are based on 200- by l-meter transects, averaged over two transects per plot treatment. Plant biomass was collected in August, weighted wet, dried and re-weighted. Percentage moisture content of tissue was calculated by species, as (wet-dry)/wet. The consistently higher moisture in plant tissue from May/June burns may explain, in part, the observed difference in the August sample in numbers of arthropods on January- versus May-burned sites.

butterflies are affected by fire-induced differences in floral resources (Van Hook and Hermann unpublished).

Prescribed Fire, Season of Burn and Biodiversity

Implementation of ecosystem management has greatly expanded challenges for public land stewards. Today, agencies are required to promote not only game species, but also the full range of natural biodiversity. This means maintaining appropriate habitat for numerous species, including many of special concern. The dependancy of a dominant groundcover species, wiregrass, on lightning-season fire to trigger flowering has been known for 30 years. Over the last decade, information has begun to accumulate on other plant species. Walker (1993) noted that the majority of the nearly 400 plants of special concern that are indigenous to longleaf pine forests possess characteristics adapted to fire. As noted above, Platt et al. (1988) and Streng et al. (1993) demonstrated that different seasons of fire produced different patterns of flowering in the groundcover community (see also Figure 1). These alterations may in turn influence organisms such as migrating butterflies and other pollinators.

Robbins and Myers (1992) suggest that natural biodiversity will be promoted by including a variety of seasons of burn in long-term management plans. They acknowledge that bums in some seasons may be more difficult logistically than others and discuss some practical considerations related to lightning-season fires. Hall and Schweitzer (1992) comment on the apparent paradox in using a management tool (tire) to promote appropriate habitat for a species of special concern when the same tool may also kill individuals of the target species. Panzer (1988) suggests some techniques for safeguarding populations of immobile invertebrates. He recommends leaving some unburned areas each year to serve as refugia. This approach is valuable whenever unstudied and/or rare species are present.

Our review of available information suggests that thoughtful application of prescribed fire is vital to the conservation of natural diversity in pine uplands of the Coastal Plain. There is evidence that inclusion of lightning-season fires in management plans for public lands need not come at the expense of traditional management targets such as timber and game birds. Although dormant-season bums meet some needs for many species of groundcover plants and arthropods, our review suggests that prolonged periods lacking lightning-season fires may eventually have negative effects on the natural biodiversity of the region. Without lightning-season fire, some plant species may have little opportunity for reproduction. Even though many, if not most of these species are long-lived perennials, they need to produce seed, at least periodically. However, alterations in community composition or structure may not be observable for decades (cf. Glitzenstein et al. 1995a, Streng et al. 1993).

Agency staff charged with management of traditional natural resources have been hesitant to expand seasons of prescribed burns. In some cases, such reluctance is warranted; researchers have only recently begun to examine valid points of concern. There are many questions related to effects of lightning-season bums that have not been thoroughly studied, including 1) what members of the groundcover plant community benefit from fire at this time; 2) what affects do timing of bum within the lightning season have on plant flowering, and do these effects impact associated insects; 3) how frequently must different times of bum be applied to maintain natural biodiversity of native groundcover; 4) are there arthropod species' differences in response to time of bum; 5) what level of bird nest mortality is associated with lightning-season fire; and 6) how do game and other birds associated with groundcover use a landscape that includes both dormant and lightning-season bum areas?

Although these and many other topics remain to be studied fully, the results of the preliminary work cited above suggest that inclusion of expanded times of bums will have positive results for a broad range of management needs. To enhance prescribed fire goals, land stewards must monitor a variety of habitat responses to bum actions and adjust management activities accordingly, including providing refugia when needed. Increased knowledge of a wide range of organisms in the habitat will result in more effective application of prescribed fire and, consequently, better ecosystem management.

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References

Brennan. L.A. and S.M. Hermann. 1994. Prescribed fire and forest pests: Solutions for today and tomorrow. J. Forest. 92(11): 34-37.

Brennan, L.A., J.M. Lee and S. Wellendorf. 1995. The new bobwhite initiative at Tall Timbers: First year progress report. Pages 2 l-28 *in* L.A. Brennan, K.C. Gainey and T.L. Pruden, eds., Proc. Tall Timbers Game Bird Seminar. 91 pp.

Brennan, L.A., J.M. Lee, E. Staller, S. Wellendorf and R.S. Fuller. 1997. Effects of seasonal fire applications on bobwhite brood habitat quality and hunting success. Abstract. Page 33 *in* Quail IV: Fourth National Quail Symp. Tall Timbers Res. Sta., Tallahassee, FL. 48 pp.

Brewer, J.S. and W.J. Platt. 1994a. Effects of fire season and herbivory on reproductive success in a clonal forb, *Pityopsis graminifolia* (Michx.) Nutt. J. Ecol. 82: 665-675.

Brewer, J.S. and W.J. Platt. 1994b. Effects of fire season and soil fertility on clonal growth in a pyrophilic forb, *Pityopsis graminifolia* (Asteraceae). Am. J. Bot. 81: 805-814.

Brower, L.P. 1995. Understanding and misunderstanding the migration of the monarch butterfly (Nymphalidae) in North America: 1857-1995. J. Lep. Soc. 49: 304-385.

Folkerts, G., M. Deyrup and D.C. Sisson. 1993. Arthropods associated with xeric longleaf pine habitats in the southeastern United States: A brief overview. Pages 159-192 *in* S.M. Herrnann, ed., The longleaf pine ecosystem: Ecology, restoration and management, Proc. Tall Timbers Fire Ecology Conf. 18.

Gilliam, ES. 1995. Old-growth longleaf pine stand structure under conditions of chronic fire exclusion. Page 403 *in* S.M. Hermann, ed., The longleaf pine ecosystem: Ecology, restoration and management, Proc. Tail Timbers Fire Ecology Conf. 18.

Glitzenstein, J.S., D.R. Streng and W.J. Platt. 1995a. Evaluating the effects of season of bum on vegetation in longleaf pine savannas. Project rept., Nongame Prog., Florida Game and Fresh Water Fish Commiss., Tallahassee. 118 pp.

Glitzenstein, J.S., W.J. Platt and D.R. Streng. 1995b. Effects of fire regime and habitat on tree dynamics in north Florida longleaf pine savannas. Ecol. Monogr. 65: 441-476.

Hall, S.P. and D.F. Schweitzer. 1992. A survey of the moths, butterflies, and grasshoppers of four Nature Conservancy preserves in southeastern North Carolina. Rept. to Nature Conservancy, North Carolina Chapter, Carrboro, NC. 122 pp.

Hermann, S.M. 1995. Stoddard fire plots: Lessons for land management thirty-five years later. Pages 13-20 *in* L.A. Brennan, K.C. Gainey and T.L. Pruden, eds., Proc. Tall Timbers Game Bird Seminar. 91 pp.

James, F.C., C.A. Hess and D. Kufrin. 1997. Species-centered environmental analysis: Indirect effects of fire history on red-cockaded woodpeckers. Ecol. Appl. 7: 118-129.

Kirkman, K. and M.B. Drew. 1995. Season of fire effects on the federally endangered Schwalbea americana: preliminary results. Page 167 *in* S.I. Cerulean and R.T. Engstrom, eds., Fire in wetlands: A management perspective, Proc. Tall Timbers Fire Ecology Conf. 19.

Klots, A.B. 195 1. A field guide to the butterflies. Peterson Field Guide Ser., Houghton Mifflin Co., Boston, MA. 349 pp.

Komarek, E.V. 1964. The natural history of lightning. Pages 139- 183 *in* Proc. Tall Timbers Fire Ecology Conf. 3.

Lara Pavon, M. 1995. Diversity and response of ground cover arthropod communities to different seasonal bums in longleaf pine forests. M.S. thesis, Florida A&M Univ., Tallahassee. 56 pp.

Lewis, C.E. 1964. Forage response to month of burning. Res. Note SE-35, Southeast. For. Exp. Sta., USDA For. Serv., Ashville, NC.

Means, D.B. and G. Grow. 1985. The endangered longleaf pine community. ENFO 85: 1-12.

Myers, R.L. 1990. Scrub and high pine. Pages 150-193 *in* R.L. Myers and J.J. Ewel, eds., Ecosystems of Florida. Univ. Central Florida Press, Orlando. 765 pp.

Myers, R.L. and S.E. Boettcher. 1987. Flowering response of cutthroat grass (*Panicum abscissum*) following fire. Bull. Ecol. Soc. Am. 68: 375 (Abstract).

Noss, R.F. 1989. Longleaf pine and wiregrass: Keystone components of an endangered ecosystem. Nat. Areas J. 9: 211-213.

Panzer, R. 1988. Managing prairie remnants for insect conservation. Nat. Areas J. 8: 83-90.

Parrott, R.T. 1967. A study of wiregrass (*Aristida stricta* Michx.) with particular reference to fire. M.S. thesis, Duke Univ., Durham, NC.

Peet, R.K. and D.J. Allard. 1993. Longleaf pine vegetation of the Southern Atlantic and Eastern Gulf Coast regions: A preliminary classification. Pages 45-81 in S.M. Hermann, ed., Proc. Tall Timbers Fire Ecology Conf. 18.

Platt, W.J., G.W. Evans and M.M. Davis. 1988. Effects of fire season on flowering of forbs and shrubs in longleaf pine forests. Oecologia 76: 353-363.

Rebertus, A., G.B. Williams and E.B. Moser. 1989. Longleaf pine pyrogenicity and turkey oak mortality in Florida xeric sandhills. Ecology 70: 60-70.

Rebertus, A., G.B. Williamson and W.J. Platt. 1993. The impacts of temporal variation in fire regime on savanna oaks and pines. Pages 2 15-225 *in* S.M. Hermann, ed., The longleaf pine ecosystem: Ecology, restoration and management, Proc. Tall Timbers Fire Ecology Conf. 18.

Robbins, L.E. and R.L. Myers. 1992. Seasonal effects of prescribed burning in Florida: A review. Misc. Publ. No. 8, Tall Timbers Res. Sta., Tallahassee, FL. 96 pp.

Streng, D.R., J,S. Glitzenstein and W.J. Platt. 1993. Evaluating effects of season of bum in longleaf pine forests: A critical review and some results form an ongoing long-term study. Pages 227-263 in S.M Het-mann, ed., The longleaf pine ecosystem: Ecology, restoration and management, Proc. Tall Timbers Fire Ecology Conf. 18.

Swengel, A.B. 1996. Effects of fire and hay mowing on abundance of prairie butterflies. Biol. Conserv. 76: 73-85.

Waldrop, T.A., D.H. Van Leer, ET. Lloyd and W.R. Harms. 1987. Long-term studies of prescribed burning in loblolly pine forests of the Southeastem Coastal Plain. Gen. Tech. Rept. SE-45, Southeast For. Exp. Sta., USDA For. Serv., Asheville, NC. 23 pp.

Walker, J. 1993. Rare vascular plant taxa associated with longleaf pine ecosystems: Patterns in taxonomy and ecology. Pages 105-125 in S.M. Hermann, ed., The longleaf pine ecosystem: Ecology, restoration and management, Proc. Tall Timbers Fire Ecology Conf. 18.

Wells, S.M., R.M. Pyle and N.M. Collins. 1983. The IUCN invertebrate red data book. Int. Union of Nature and Natur. Resour., Gland, Switzerland.

Wikars, L.-O. 1997. Effects of forest fire and ecology of fire-adapted insects. Summaries of Uppsala Diss. from the Faculty of Sci. and Tech. 272, Acta Univ. Upsala, Sweden. 35 pp.