III.A. Prescribed Fire in Existing Grassland

Introduction

Prescribed fire can be used to maintain disturbance-adapted sandplain grasslands by manipulating ecological succession. The principal goals of grassland management with prescribed fire are to reduce woody vegetation cover, create conditions that maintain plant and animal species that rely on grassland habitat, alter soil conditions and microclimate, and reduce fuels and fire risk.

Figure 1. A 280-acre area of grassland managed by controlled burning at Camp Edwards in on Cape Cod. Photo from July 2016, two years after a fire treatment. Photo Credit: Jake McCumber.

Prescribed fire in sandplain grasslands typically aims to promote a diverse assemblage of target grassland species with a high proportion of warm-season grasses and native forbs, and a low proportion of cool season grasses and non-native invasive species, while reducing the regrowth of woody shrubs (Fig. 1). Prescribed fire can also maintain low fuel loads on a short-time basis, which can reduce fire hazards in some situations. Prescribed fire can also expose mineral soils, and maintain microclimates that foster germination and regeneration of fire-adapted or disturbance-dependent grassland species.

The behavior and consequences of prescribed fire for maintaining sandplain grassland vegetation can vary widely and depend on site conditions such as vegetation composition and structure, soils, climate, weather, fuel conditions, ignition patterns and techniques at the time of the fire, and applied fire variables such as seasonality and frequency at which prescribed fires are conducted. The use of prescribed fire exhibits logistical constraints that can hinder or prevent its use. Unpredictable weather, cost, manpower, local and regional regulations, smoke, health concerns, and perceived risk can all influence the effectiveness of burns by limiting options for applying prescribed fire. Management experience with fire and carefully planned experimental fire treatments during the last several decades provide rich information on fire effects in sandplain grasslands. Management of sandplain grasslands using fire can be complex and influenced by conditions that change on a daily or even hourly basis.

In this document, we evaluate the effects of prescribed fire in sandplain grassland compiled from published and unpublished studies and information obtained from Interviews with land managers. We focused on the following main questions relevant for sandplain grasslands management:

1) Does fire reduce woody growth?

2) Does fire maintain or increase grassland associated plant and animal species diversity?

3) Under which conditions is fire more or less effective at reducing woody species cover?

4) How can the effectiveness of prescribed fire be improved as a management tool to maintain sandplain grassland?

We focus on interpreting the main patterns that emerge from examining multiple experiences across multiple sites, with the understanding that responses to any one fire treatment under particular conditions may differ.

These studies represent only a portion of possible treatments and variables that could be tested. It is challenging to design and execute well-controlled studies to determine the impacts of management techniques on sandplain grassland when considering the combinations of individualistic species responses, treatments, short and long-term effects, and the number of replicates needed for sound investigations (Dunwiddie 1990).

Methods

We reviewed 75 sources that described or documented results of management actions in sandplain grasslands. Of these, 39 sources contained information on prescribed burning and 19 detailed specific management experiments or case studies. In addition, we Interviewed 13 professionals throughout the region about their experiences with prescribed fire in sandplain grasslands. Literature sources that tested active management treatments were classified by whether they: (A) reduced regrowth of woody vegetation and (B) increased biodiversity of plants or animals, or both (Fig. 2).

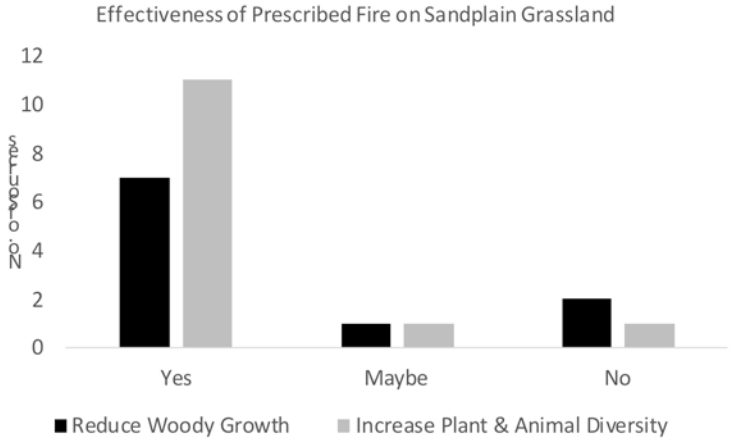

Figure 2. Number of sources that found prescribed fire in sandplain grasslands reduced woody shrub and tree regrowth.

This review of literature and interviews is used to summarize the state of current management understanding of fire regimes in sandplain grasslands and the effects of prescribed fire on: (1) fuels and soils, (2) vegetation composition, (3) vegetation structure, and (4) fauna in relation to seasonality and fire frequency. We then suggest ways that the use of fire

could be improved to decrease woody cover, increase graminoid cover, and maintain and promote biodiversity in sandplain grasslands.

Results

Overall, a large majority of sources found that prescribed fire reduced the regrowth of woody vegetation and increased biodiversity in some manner (Fig. 2). However, no study found that fire alone was completely effective over the long term in reducing woody regrowth or increasing biodiversity. Rather, our review found that most sources concluded that pairing fire with other management practices will be needed to control woody regrowth and maintain sandplain grassland biodiversity over the long term.

Figure 3. A prescribed burn during summer in the Cape Cod National Seashore. Photo Credit: Lena Champlin.

Fire regime

Fire regime is the most influential fire-related factor (or family of factors) that influences the outcome of prescribed burning in sandplain grasslands, and calibration to current and antecedent site-specific conditions is essential to reach desired management outcomes. Traditionally, fire regime has been defined as fire frequency, seasonality, intensity and severity (Keeley et al. 2009), but may include size, pattern and other factors as well.

Fire intensity and severity are often confused. In fire ecology, fire severity is the degree to which a site has been altered or disrupted by fire; loosely, a product of fire intensity and residence time (NWCG). Intensity, or fireline intensity, is the product of the available heat of combustion per unit of ground and the rate of spread of the fire (NWCG).

In sandplain grassland habitat, fire frequency and seasonality are often more important than intensity in some situations (W. Patterson III, Interview, Dunwiddie et al. 1995) (as seen in Fig. 3). In sources we reviewed, fire frequency and seasonality were most common in experimental designs, while severity and intensity were typically not specifically tested, though sometimes discussed. Frequency ranged from annual single burns to multi-year burns at varying intervals. Seasonality is site-specific and depends largely on vegetation type, climate and weather. For this region, seasonality of prescribed fire applied to sandplain grassland is typically divided into spring, summer and fall/winter (Table 1). Spring fires are often divided between times of dormant or growing season vegetation.

Table 1. Fire seasons typically applied to sandplain grassland in the northeast US.

Season	Stage	Timeframe
Spring	Dormant	March to late April (sometimes to early May)
Spring	Growing	Mid to early June
Summer	Growing	Mid-June to late September (sometimes to October)
Fall/winter	Dormant	Between summer growing seasons (usually September to March)

Effects on fuels and soils

Fire can reduce fuels on a short-time basis (typically 1-2 years) in sandplain grasslands, including standing dead wood (coarse woody debris), standing dead grasses, forbs and plant litter (thatch), and recalcitrant organic material (duff). Combustion of these fuels exposes mineral soil, which then experiences increased soil radiation and soil temperature. This microclimate promotes seed recruitment of warm-season grasses and forbs. Without fire, an excess of plant litter can build up to favor cool-season grasses by increasing shade, water retention and nitrogen that could favor non-native or invasive species (C. Buelow, Interview).

There is some evidence that prescribed fire in sandplain grasslands raise rates of nitrogen mineralization in soil, nitrogen being the nutrient that has the most direct effect on plant growth. For example, Dudley and Lajtha (1993) found that burning annually in a sandplain grassland for two years during April increased nitrogen mineralization rates and the ecosystem did not return to pre-burn concentrations within three years following fire. Martin (2008) studied species responses in sandplain grasslands that had been burned at different periods, and suggested that there was an initial addition of nitrogen to the soil following fire. Higher mineralization rates likely occur because soil temperature is elevated immediately after fire (J. Carlson, Interview). However, fire effects on soils diminishes as vegetation regrows. It is hard to detect differences in major soil nutrients between sandplain grasslands and other typical coastal plain woodlands or shrublands, or between recently-burned and unburned woodlands, where more biomass is consumed and effects on soils would presumably be greater (Neill et al. 2007).

Effects of fire seasonality and frequency

Fire seasonality can influence fire intensity, and fire intensity and severity are often correlated (Keeley 2009). In observations on Martha's Vineyard and Nantucket, spring fires are typically most intense, summer fires are the least intense (but most severe in their effects on vegetation), and fall fires typically have medium intensity (Dunwiddie 1990). As for spring fires, Joel Carlson suggests that, a secondary effect would be to reduce future inputs into the fuel load due to severity but not from the first order effects. Given the right conditions, summer fires can have the most ecologically important impact on fuel, soil, and seed germination (W. Patterson III, Interview). Drought conditions can cause the duff layer to ignite, leading to longer smoldering burns in the soil (Raleigh et al. 2003a), which might have greater impacts on the

shallow root systems of clonal woody plants in contrast with grasses that have deeper roots (J. McCumber, Interview). Karberg (2014) reported greater reduction of shrub cover in a more severe fall fire compared with less severe fall fires. Spring burns will generally not consume significant amounts of duff, though leaf litter accumulation may be reduced (Raleigh et al. 2003a). Further, although higher fire frequency can lead to greater amounts of bare mineral soil, fire intensity and severity can often, but not always, decrease if available fuels decrease with more frequent fires. This creates tradeoffs between the efforts involved in applying more frequent fires and their benefits, and these tradeoffs depend largely on site-specific conditions and overall management goals.

Effects on vegetation

In sandplain grasslands, initial species assemblages and their responses to fire can influence the effects of prescribed fire on vegetation composition (e.g. Karberg 2014). Life history characteristics of plants determine how they will respond to fire, making the seasonality crucial in determining species response (Raleigh et al. 2003a). As a general rule of thumb, early growing season burning in sandplain grasslands favors warm-season native grasses that are fire tolerant, and discourages non-native cool-season grasses that are fire intolerant (C. Buelow, J. Carlson, T. Simmons, Interview). Further, fall fires can promote forbs (Joel Carlson, Interview).

Figure 4. The rare New England silvery aster (*Symphyotrichum concolor*) only found on Nantucket Island, at Smooth Hummocks property. Credit: Chris Neill.

Little information on key aspects of life history exists for many of the infrequent species that are conservation targets of sandplain grasslands, such as the New England silvery aster (Symphyotrichum concolor) (Fig. 4). Farnsworth (2007) compared infrequent SPG species characteristics with those of close relatives and found that they typically experience distinct life-history traits such as (1) higher habitat specialization, (2) larger seed size, (3) smaller plant height, (4) less reliance on vegetative (colonial) reproduction, and (5) a tendency toward annual or biennial life history. However, there is no information on how many of these species respond to fire, though there is evidence that fire suppression could decrease species richness in grassland habitats. Leach and Givnish (1996) found that 8-60% of species were lost from prairie remnants in Wisconsin over a 32-52-year period most likely due to fire suppression, and that short, small-seeded, or nitrogen-fixing plants showed the heaviest losses.

Fire frequency depends on the available vegetation and fuels and should be tailored to overall objectives (J. Carlson, Interview). Typically, the necessary fire interval in sandplain

grasslands is about four years (C. Buelow, N. Sferra, Interview), and can be as few as three years (J. McCumber, Interview) or up to 7 years (D. Crary, Interview). W. Patterson III (Interview) suggests that two years is possible under the right conditions and anything longer than three years can accelerate dominance of woody species, especially if burns occur in the dormant season.

Figure 5. Head of the Plains, a 286-acre area on Nantucket managed by rotating burning in units in the fall (September to November) or spring (April to May) every five years to prevent woody growth. Photo Credit: Nantucket Conservation Foundation.

We reviewed work related to the effects of prescribed burning on some target sandplain grassland plant species and found that frequency and seasonality were only reported in some studies but are important variables that should be considered (Fig. 5). Raleigh et al. (2003b) found that little bluestem (*Schizachyrium scoparium*), Pennsylvania sedge (*Carex pensylvanica*), and the northern blazing star (*Liatris novae-angliae*) responded positively to spring burns (typically mid-May). Freeman et al. (n.d.) found that a single annual April burn increased the number of flowering stems, enlarged weekly floral displays, and in some cases, increased flower production of the state-listed eastern silvery aster (*Symphyotrichum concolor*). Vickery (2002a) found that *L. novae-angliae* populations at the Kennebunk Plains in Maine benefited from fire and that the number of flowering plants, the number of seeds per flower, and seedling establishment were higher after fire, but seasonality was not reported. Vickery (2002b) found that fire dramatically decreased seed predation from microlepidoptera after one year, but predation rebounded to pre-burn numbers two years later. Martin (2008) found that *C. pensylvanica* increased after fire.

A key element to the use of fire for sandplain grassland management is that the frequency and severity of fires be sufficient to reduce—or at least restrain—woody growth. Historically, the consensus among land managers and ecologists was that growing season burns shifted vegetation away from woody plants and toward herbaceous grassland vegetation, while dormant season burns simply maintained grassland (e.g. Karberg 2013). However, Joel Carlson suggests that fire managers and fire ecologists have known that dormant season fires are not necessarily effective at maintenance of sandplain grassland over the long term, even with repeated burning. This point is also addressed in Karberg (2014).

Summer fires are typically most effective at reducing woody regrowth. Dunwiddie et al. (1995) sampled four plots – one burned in spring, one in summer, one that was mowed, and a control, and found that summer burns decreased frequency and/or cover of shrub species

Figure 6. Grassland prescribed fire at Camp Edwards on Cape Cod in October 2013. Photo Credit: Jake McCumber.

while spring burns had little to no effect. These findings indicate that if sandplain grasslands are to be managed exclusively with fire, summer burns are necessary at least at some frequency to reduce woody regrowth. The effects of fire on woody growth could likely be enhanced if fires took advantage of other co-occurring natural stressing factors such as defoliation by insect herbivores, droughts, and salt spray (J. Carlson, J. McCumber, Interview). A number of other sources have examined the effects of fire frequency. On Nantucket, one study found that a single spring burn was only enough to stop shrub encroachment in the year following the burn and did not reduce total woody shrub cover (Zuckerberg and Vickery 2006). In another study, a single burning treatment showed no long-term impact on shrub cover, but biennial burning or mowing over 12 years reduced shrub cover and/or frequency on Nantucket (Dunwiddie 1998).

There is also evidence that annual or biennial fires applied during the growing season (mid-June to October) both reduced shrub growth and increased plant diversity (Fig. 6). Karberg (2014) studied Units 5 and 8 at Head of the Plains on Nantucket (burned once during summer with high drought index values) and found a large decrease in shrubs and an increase in grassland species. Dunwiddie (1998) found similar results, where burning was more effective than mowing for reducing woody growth and increasing graminoid and forb cover, but the study also concluded that the addition of more aggressive methods, such as repeated treatments during the growing season, harrowing, and application of herbicide may be necessary for long-term control of shrub expansion.

Studies also examined the effects of annual and biennial fires applied during the spring dormant season (March to late April). Dunwiddie et al. (1995) burned biennially for 12 years during April at Ram pasture, Nantucket and found that spring burns were less effective than summer burns at decreasing shrub growth and increasing plant diversity. Dunwiddie and Caljouw (1990) burned biennially for six years during April on multiple sites and found that spring burns stimulated growth of herbs, while summer burns stimulated growth of warm season grasses.

During fall/winter dormant season fires (September to March), it seems that only annual single burns have been studied in sandplain grasslands. Karberg (2014) studied fall fires in Units 2 and 9 at Head of the Plains on Nantucket and found varying results based on site conditions and the applied fire regime. Fire in Unit 9 had led to no major changes to plant species composition with the lowest intensity recorded, while fire in Unit 2 led to higher plant species richness four years post-burn.

Although fire is an effective tool for promoting sandplain grassland vegetation under certain conditions, there has been no study that found fire alone to be a viable long-term management solution; rather, fire in combination with other tools is necessary, which applies to other grassland systems as well. Outside the northeast, Hesling and Grese (2010) burned annually in April on a remnant Michigan tallgrass prairie and found that frequent fire helped maintain prairie species and reduced non-native species and cool-season grasses, but fire alone did not produce a diverse prairie plant community.

Effects on fauna

The effects of prescribed fire on fauna are understudied and both the short- and long-term impacts to target species in sandplain grasslands need further research. Although fire can have negative effects on fauna, the short-term negative impacts must be balanced with the long-term creation of beneficial habitat (J. Scanlon, Interview).

There can be clear short-term effects on sandplain grassland animals that are management targets. At Camp Edwards, Grasshopper Sparrows (*Ammodramus savannarum*) declined in burned plots the year immediately following a fire (J. McCumber, Interview). At Katama Plains on Martha's Vineyard, meadow voles (*Microtus pennsylvanicus*), an important food source for Northern Harriers (*Circus cyaneus*), decreased for the two years following a burn (Buresch, reported in Revised Management Plan of Katama 2000). However, *M. pennsylvanicus* populations are quite cyclic and fire might easily not have had any effect there (R. Wernerehl, Interview). Fire can also harm larval stages of moths and butterflies in the short term (M. Mello, Interview), but create conditions for long term success (Fig. 7). Further, fire can kill long-lived rare animals like the box turtle (*Terrapene carolina*) (M. Jones, Interview). Many, insects, particularly herbivorous insects, are extremely sensitive to environmental change (P. Goldstein, Interview).

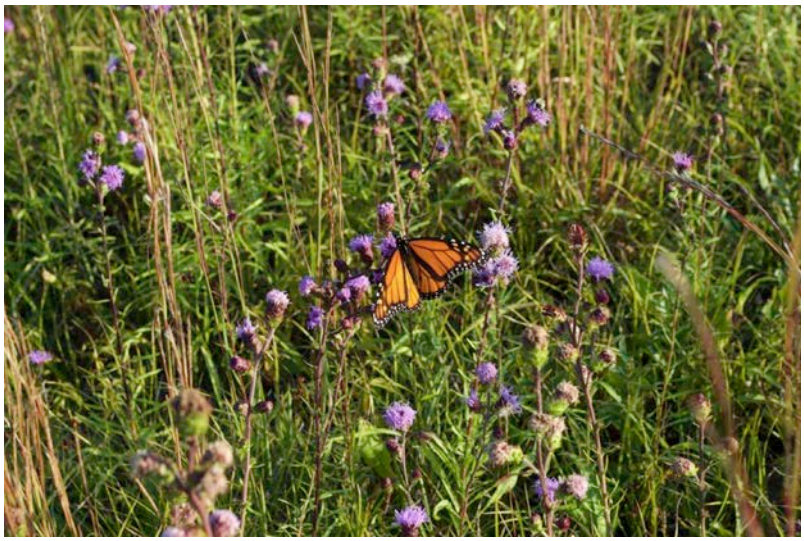

Figure 7. Monarch butterfly on northern blazing star at Kennebunk Plains in Maine. Photo Credit: Bob Wernerehl.

In the long term, the open grassland habitat created by fire supports many rare bird species and several insects including rare Lepidoptera (P. Goldstein, Interview). Though there was a decrease immediately after fire, at Katama Plains, Grasshopper Sparrows select nesting territories in sites that had been burned within the previous three years (Harris 1998, reported in Revised Management Plan of Katama 2000). Grasshopper sparrows require large open

spaces and will not nest within about 75 meters of a forest edge (D. Vitz, Interview). Upland sandpipers (*Bartramia longicauda*), another target of sandplain grassland management, also require similar large open spaces (J. McCumber, Interview).

Seasonality is likely the most important factor that influences fire effects on fauna in sandplain grassland because lifecycles of animals and insects tend to make them vulnerable during the growing season when prescribed fires occur most. For example, on Nantucket, target grassland bird species nest primarily between May and June, but sometimes to mid-July (D. Vitz, T. Simmons, Interview). If burning occurs during this time, fire-caused mortality could affect populations of target species.

Dunwiddie (1991) conducted burns for two years in April biennially (1983-85) on Nantucket and found a decrease in Arthropod abundance and an increase in Orthopera.

Adjusting fire frequency and the proportion of area burned in any one year can limit the negative effects of prescribed fire on fauna. Maintaining a patchy mosaic of time since fire across a sandplain grassland can increase biodiversity and provide refuge for grassland fauna. For example, to protect animals, managers at the Frances Crane Wildlife Management Area on Cape Cod, burn only one-fourth to one-third of a 400-acre grassland during a single year (D. Vitz, Interview). Burning smaller patches during different years introduces heterogeneity into the grassland and potentially creates a mosaic of grass and heathland habitats for different animal species (J. McCumber, Interview). Further heterogeneity could potentially be created by stacking heterogeneous woody debris piles to vary the intensity and patchiness of burning (J. McCumber, Interview). We found no actual measurements of these potential spatial effects.

Logistical and Practical Constraints on the Use of Fire

While prescribed fire can often be effective for maintaining sandplain grasslands and species targeted for conservation, this management can also be complicated to implement. Implementing an ecologically effective fire regime can be constrained by costs, unpredictable weather, local regulations, smoke impacts, health issues, and perceived risk. Air quality can be affected in surrounding areas depending on atmospheric conditions. These constraints are exacerbated because sandplain grasslands are concentrated in coastal regions, which are tourist destinations and near the public. Smoke management typically limits the application of prescribed fire during summer, which is when ecological benefits of fire management can be greatest (J. Carlson, Interview). Burning when the drought index is high, which also enhances desired effects on vegetation, often requires increased monitoring and mop-up to mitigate smoldering and smoke impacts (J. Carlson, Interview). Smoldering combustion is influenced by on-site conditions and weather, is the most inefficient type of combustion, and produces the highest amounts of pollutants (J. Carlson, Interview).

Although applying fire during particular times of stress (e.g. droughts or outbreaks of herbivorous insects) could increase the effects of fire and reduce the frequency of fires required to obtain similar vegetation responses, being able to take advantage of these events in particular places will likely be challenging.

Summary and Pathways to More Effective Management

The effects of fire on vegetation structure in sandplain grassland and effects of fire frequency and seasonality have been studied in field management experiments. Summer fires during drought conditions most effectively reduce woody vegetation, woody debris, thatch, and duff, which exposes mineral soil and favors warm-season grasses and native forbs and discourages cool-season grasses and non-native invasive species. Spring fires can also promote warm season grasses. Summer fires consistently reduced woody growth only when they were conducted within a frequency every two to five years. Fire seasonality largely controls the effects on individual species and the resulting community. Early growing season fire typically favors warm-season, fire-tolerant native grasses and negatively affects fire-intolerant cool-season, and often non-native, grasses. Further, spring burns tend to stimulate growth of some forbs, while summer burns stimulate growth of warm season grasses. Much less is known about the effects of fire on fauna, but burning a mosaic of patches is recommended.

A major challenge for the use of fire for long-term management of sandplain grassland is the ability to apply it frequently enough, and to apply it in summer, or during conditions of drought, defoliation, or other stresses when its ecological effects are greatest.

This review identified several major ways to improve understanding of potential benefits of the use of fire for sandplain grassland management.

(1) Test combinations of fire with mowing or other management techniques. They should be designed and monitored as field experiments. This approach could potentially maintain the beneficial effects of fire in creating microclimate and soil conditions that promote target forb and warm-season grass species and limit growth of woody plants even when it its impractical to apply fire frequently enough during summer to restrict woody regrowth with fire alone. These combinations could be tested as sub-plots that are mowed or receive vegetation removal within larger areas that are currently being managed with prescribed fire at some intervals.

(2) Improve understanding of how infrequent or rare plants respond to different fire regime combinations. These rarer plants are some of the major targets for sandplain grassland management and often have life histories that differ from closely-related but more common species. There is currently almost no information on how these species respond to fire and the effects of fire seasonality, intensity or frequency applied to sandplain grassland.

(3) More work is needed to determine how prescribed fire affects the mortality and population dynamics of fauna in sandplain grassland. These effects may be particularly important for less common and conservation target species that have small, declining and dispersed populations. It is also important for higher-profile species such as birds and for more common species such as some invertebrates that are important prey of grassland birds.

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