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EFFECTS OF A PRESCRIBED BURN ON THE ADULT BUTTERFLY ASSEMBLAGE OF A COASTAL GRASSLAND

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ABSTRACT

Coastal grasslands are globally threatened by development and natural succession. In the southeastern United States, these increasingly rare ecosystems are being managed using prescribed fire, but ecological responses to fire management are largely unknown, particularly among nontargeted species. We tested for short-term effects of controlled burning on the abundance and species richness of adult butterflies, which utilize coastal grasslands for nectaring resources and as migratory stopover sites. In February 2015, four plots of coastal grassland on Little St. Simons Island, Georgia, were burned and paired with unburned (control) plots of equal size. Throughout the following summer-fall flight season, we conducted monthly point-count surveys of adult butterflies. Burn and control plots did not differ in butterfly abundance or species richness. Only one species, the Gulf fritillary (*Agraulis vanillae*), exhibited a significant response to the fire treatment; it was more likely to occur in burned areas. Overall, we found no evidence that controlled burning negatively impacts the adult butterfly assemblage utilizing coastal grassland habitat; prescribed fire may therefore be a viable management technique to conserve a range of biodiversity in these imperiled ecosystems.

Keywords: butterflies, coastal grasslands, controlled burn, Lepidoptera, prescribed fire

INTRODUCTION

Coastlines worldwide are experiencing unprecedented anthropogenic changes, making it increasingly important to preserve and manage unique ecosystems (Brown and McLachlan 2002; Defeo et al. 2009). Coastal grasslands in particular are declining globally due to human development and woody expansion (Motzkin and Foster 2002; Feagin et al. 2010; Zinnert et al. 2016). Once common along the eastern coast of North America, coastal grasslands now exist primarily as isolated fragments on barrier islands. These ecosystems provide habitat for a variety of rare plant and animal species and serve as important stopover sites where migratory birds and butterflies rest and refuel (Georgia DNR 2005; Longcore et al. 2010; McCord and Davis 2010). Periodic disturbances play an important role in the formation and maintenance of coastal grasslands, which were historically influenced by natural factors such as salt spray, washover, grazing, and fire

(Smeins et al. 1991; Grace 1998; Wade et al. 2000). As a result of rapid loss and fragmentation, further protection of coastal grasslands and the biodiversity contained therein will likely require active ecological management to prevent succession into woodlands. Thus, prescribed fire has recently been applied to coastal grasslands in order to maintain and restore early successional plant communities (Dunwiddie et al. 1997; Grace 1998; Long Island Sound Study 2003).

When assessing ecological responses to fire, it is important to consider multiple components of natural communities beyond species targeted for management. Arthropods are among the most diverse members of terrestrial ecosystems and serve key functions such as herbivory and pollination, but they are often overlooked in fire management plans (Swengel 2001; Underwood and Christian 2009). In the eastern United States, coastal grasslands provide critical open habitat, host plants, and nectaring resources that support rich assemblages of butterflies, including permanent residents and migratory species following the Atlantic flyway (McCord and Davis 2010). In recent years, butterfly populations have declined worldwide even amongst the most common and widespread species (Van Swaay 1990; Van Dyck et al. 2009). The predicted consequences of fire for butterflies depend on the life history and niche requirements of individual species, as well as the fire regime. Immature stages (eggs, larvae, and pupae) are more vulnerable to direct mortality, while adults may respond to short- and long-term changes in microhabitat structure and nectar availability (Erhardt and Thomas 1991; Swengel 2001; Waltz and Covington 2004). The seasonal timing, intensity, and spatial scale of controlled burning may also mediate ecological effects on butterfly communities.

Previous research conducted in other grassland ecosystems has revealed highly variable effects of fire on focal species and communities of butterflies. For example, prescribed fire had positive effects on two species of conservation concern, the monarch (*Danaus plexippus*) and regal fritillary (*Speyeria idalia*), by altering vegetative composition and structure, respectively (Baum and Sharber 2012; Moranz et al. 2012). In contrast, several prairie and meadow specialists suffered severe population declines, with recovery taking five years or more depending on the species (Swengel and Swengel 2001; Vogel et al. 2010; Black et al. 2013). Few studies have measured community-level responses of butterflies to controlled burning of grasslands, but results have ranged from negligible changes in community structure (Fleishman 2000; Moranz 2012) to reduced species richness following fire (Vogel et al. 2010).

Given the importance of coastal grasslands to butterfly communities, as well as conservation concerns about butterflies and pollinators in general, we asked how the adult butterfly assemblage of a coastal grassland on Little St. Simons Island, Georgia, is affected by fire management. During the first year following a prescribed burn, we conducted monthly surveys of adult butterflies utilizing burn and control plots and tested for differences in abundance, richness, and species composition. Immature life history stages were excluded. Our methods broadly sampled across the butterfly community, including resident and migratory species associated with a range of open, wooded, and marsh habitats; no coastal grassland specialists or rare or threatened species are known to occur in the area, aside from the migratory monarch. The results of this study will contribute to a more comprehensive evaluation of the use of prescribed fire to manage coastal grassland biodiversity.

MATERIALS AND METHODS

Study Site

Little St. Simons Island is a Holocene barrier island located in the Altamaha River Delta, Georgia, USA. The island is relatively undisturbed and has a large, protected territory of South Atlantic Coastal Plain Dune and Maritime Grassland (NatureServe 2015), hereafter referred to as simply coastal grassland. This globally imperiled ecosystem primarily occurs along barrier island dune systems from North Carolina to Florida. The vegetative community is influenced by salt spray, storm surge inundation, and periodic flooding from heavy rains. On Little St. Simons Island, the dominant plant species are gulfhairawn muhly grass (*Muhlenbergia sericea* syn. *M. capillaris* var. *filipes*), goldenrod (*Solidago sempervirens*), and broomsedges (*Andropogon* spp.), interspersed with wax myrtle (*Myrica cerifera*). Other common plants include starrush whitetop (*Rhynchospora colorata*), juniperleaf (*Polypremum procumbens*), dog fennel (*Eupatorium capillifolium*) and various rushes (*Juncus* spp.). Over time, dune stabilization and nutrient cycling facilitate succession to maritime forest (Tackett and Craft 2010).

Prescribed fire was experimentally implemented on Little St. Simons Island (31.250999 N, 81.280886 W) as a management technique to prevent succession and maintain open areas that are required for coastal grasslands. Four patches of coastal grassland varying in size from 2 to 5 ha were burned on 18 and 19 February 2015 (Figure 1; Colbert 2016). Burning was conducted in winter to reduce the risk of wildlife stress and mortality just as the growing season began. A low-intensity fire was maintained to reduce soil damage and loss of important seed sources. Each burned patch was bordered by unmanaged coastal grassland, facilitating species dispersal and enabling a paired study design whereby each burn plot was paired with an adjacent control plot of approximately equal size. Parts of the site were previously burned between the 1990s and early 2000s, but ecological responses were not documented.

Point-count Surveys

Point-count surveys are a newly established method to estimate butterfly abundance and diversity in areas where traditional methods are impractical (Henry et al. 2015). Counting butterflies along set-route transects is a widely accepted practice but problematic in dense vegetation. Point counts, however, can be easily deployed and conducted in variety of habitats. Point-count surveys consist of counting and identifying butterflies in a 180-degree semicircle survey area extending from designated "points". Twenty-four points (n = 12 burn, 12 control) were strategically placed at least 100 m apart and at least 50 m from the edge of plots. The number of points per treatment plot varied from two to four depending on plot size.

Surveys were oriented toward the most open and visible direction to reduce interference and improve accuracy. To avoid disturbing the area to be surveyed, points were approached from the opposite flat side of the semicircle. The survey area was restricted to a 3-m radius of the semicircle to ensure proper identification. Surveys were limited to 1 min to reduce the risk of counting an individual multiple times during a survey. Surveys were conducted monthly from June through November and were restricted to warm (23–35 °C) and sunny (less than 50% cloud cover) days with relatively calm wind (less than 17 mph). The frequency of observations was limited by the remote location of the study site, variable weather conditions, and time constraints, which further prevented us from visiting each point every month; however, at least 16 points (8 burn, 8 control) were surveyed each month. Species identifications were confirmed by photographs and individuals were netted when necessary. Voucher specimens are deposited in the College of Coastal Georgia insect collection.

Figure 1. Burn plots (red; outlined in blue) and adjacent control plots (green) of coastal grassland on Little St. Simons Island, Georgia. The study site contains a matrix of open (grassland) and wooded (shrub) habitats and is bordered by salt marsh to the west and a sandy beach system to the east. This map was created with the use of ArcGIS® software by Esri. ArcGIS® and ArcMap™ are the intellectual property of Esri and are used herein under license. Copyright © Esri. All rights reserved.

Data Analysis

Response variables were nonnormally distributed, despite attempting data transformations, and the study design was unbalanced due to missing observations from some points during some months (see above); therefore, we used a series of nonparametric Mann-Whitney *U* tests to detect differences between burn and control plots in butterfly abundance and species richness by month. Within a given month, each point count was treated as an independent observation, though we cannot rule out the possibility that individual butterflies may have traveled between points. For species in which we observed at least 10 individuals total, we conducted a χ^2 test for an association between occurrence and treatment.

RESULTS

We observed 177 individual butterflies that were identified to one of 12 species representing three families (Nymphalidae, Pieridae, Hesperidae; Table I); 12 additional individuals that could not be confidently assigned to a species were excluded from analyses. Butterfly abundance and species richness, which both peaked in October, did not differ between burn and control plots during any month (Mann-Whitney *U* tests by month: $0.13 \leq P \leq 0.65$; Figure 2). Pooled across all points and months, total observed richness was 10 species in burned areas and 9 species in control areas. Species composition was 58% similar between treatments (Jaccard index = 0.58), although several species were represented by only one or two individuals. The most commonly observed species (in order of abundance) were the long-tailed skipper (*Urbanus proteus*), Gulf fritillary (*Agraulis vanillae*), common buckeye (*Junonia coenia*), and cloudless sulphur (*Phoebis sennae)*. Three of the four species were evenly distributed between burn and control plots (χ^2 tests: $P \geq 0.3$; Table I), while the Gulf fritillary was more likely to occur in burned areas ($\chi^2 = 7.14$, $P = 0.007$).

Table I. Butterfly taxa and number of individuals observed during monthly point-count surveys (June–November 2015) conducted in burn and control plots of coastal grassland on Little St. Simons Island, Georgia.

					Abundance	
Scientific name	**Common name**	**Habitat**	**Residency**	**Migratory**	**Burn**	**Control**
Hesperiidae						
Panoquina ocola	ocola skipper	M	R	Y	1	1
Panoquina panoquin	salt marsh skipper	M	R	N	0	1
Urbanus proteus	long-tailed skipper	O	R	Y	34	32
Nymphalidae						
Agraulis vanillae	Gulf fritillary	O	R	Y	32	13
Heliconius charitonius	zebra longwing	W	V	N	0	1
Junonia coenia	common buckeye	O	R	Y	13	18
Vanessa atalanta	red admiral	W	R	Y	3	5
Vanessa cardui	painted lady	O	V	Y	1	0
Vanessa virginiensis	American painted lady	O	R	Y	1	0
Pieridae						
Ascia monuste	great southern white	M	V	Y	5	4
Eurema lisa	little sulphur	O	R	Y	2	0
Phoebis sennae	cloudless sulphur	O	R	Y	5	5
Total Abundance					97	80
Species Richness					10	9

Habitat indicates whether each species is strongly associated with open (O), wooded (W), or marsh (M) habitats (Daniels 2004). *Residency* indicates whether the species is a resident (R) and predictably present or a visitor (V) and occasionally present in coastal Georgia (Daniels 2004). *Migratory* indicates whether the species tends to migrate (Y = yes, N = no; Scott 1986).

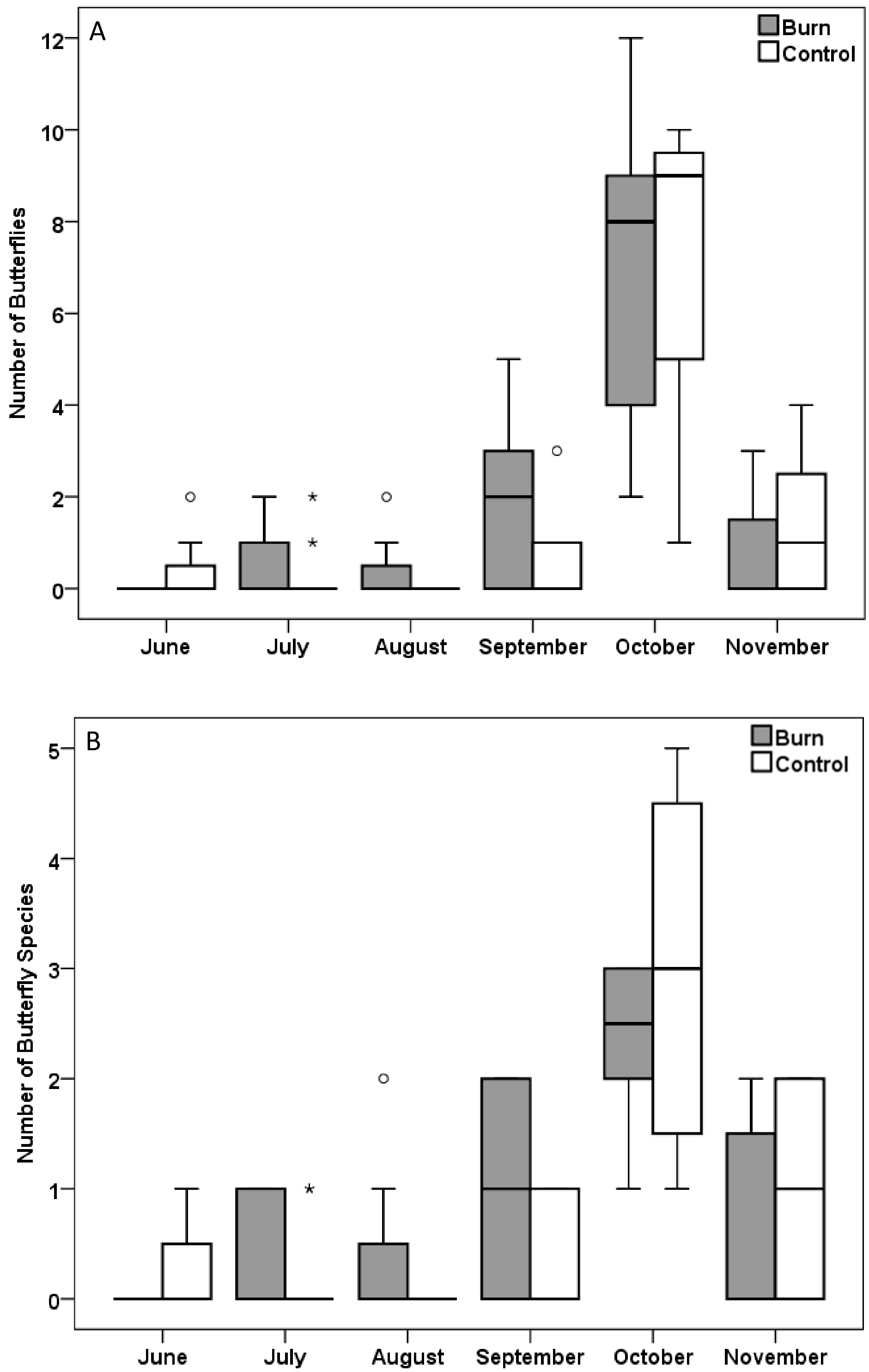

Figure 2. Monthly butterfly abundance (A) and species richness (B) from point-count surveys in burn and control plots of coastal grassland on Little St. Simons Island, Georgia. The controlled burn occurred in February 2015 and butterfly surveys began the following June. Boxes represent 1st and 3rd quartiles with medians. Whiskers are minima and maxima within 1.5 times the interquartile range excluding outliers (◦) and extreme values (*).

DISCUSSION

We found no evidence that controlled burning of coastal grasslands, under the regime prescribed on Little St. Simons Island, negatively impacts the diverse assemblage of adult butterflies utilizing this rare and threatened habitat. There were no detectable differences in overall butterfly abundance or species richness during the first postburn flight season. Dissimilarity in species composition between burn and control plots was driven by species that were rarely observed, reflecting in part our sampling method (point-count surveys) and frequency (once per month), which were not intended to produce a complete inventory. While this short-term study is the first such assessment conducted in a coastal grassland, the results are consistent with longer-term monitoring efforts in other grassland ecosystems, where butterfly communities exhibited weak responses to prescribed fire management (Fleishman 2000; Moranz et al. 2012; but see Vogel et al. 2010).

The four most commonly observed species, accounting for 80% of individuals across all points (Table I), are all associated with open habitats and exhibit migratory behavior, although they can establish resident breeding populations in coastal Georgia (Scott 1986; Daniels 2004). Peak abundance and richness coincided with their southward migration in early fall, highlighting the importance of coastal grassland habitat along the Atlantic flyway (Walker 1991). Of these species, only one—the Gulf fritillary (*A. vanillae*)—was unevenly distributed between treatments, with a greater occurrence in burn plots than in unmanaged control plots. The mechanism underlying the positive association between *A. vanillae* and burned areas is unknown, but one hypothesis is that fire enhances nectar resources consumed by this species. In a companion study, we found that burn plots contained a higher percent cover of forbs, especially goldenrod (*S. sempervirens*) and other herbaceous Asteraceae, which may have increased the availability of nectar for foraging adults (Colbert, unpublished data). Similarly, Davis et al. (2007) found forbs to be an important predictor of adult butterfly abundance and species composition. In contrast, some nectar-producing shrubs such as *Baccharis* are likely suppressed by fire, perhaps explaining why more butterfly species did not respond favorably to the prescribed burn.

Fire can also alter host plant availability, potentially causing delayed population responses, positive or negative, among resident butterfly species (Swengel 2001). Burning could indirectly benefit species whose larvae feed on plants that thrive in open, disturbed habitats, e.g., the Gulf fritillary on *Passiflora* or grass skippers (Hesperiinae) on grasses. Alternatively, the primary target of fire management at our study site, wax myrtle (*M. cerifera*), is a host plant for the red-banded hairstreak (*Calycopis cecrops*), which was observed in the area but not during point counts. More detailed studies, however, are needed to explore the relationship between fire, host plant abundance, and butterfly populations in coastal grasslands.

The absence of fire-induced changes in adult butterfly abundance or species richness may be attributable to the burn regime prescribed on Little St. Simons Island, particularly its spatial scale and configuration. The burned areas represented a relatively small percentage of the total area of coastal grassland on the island, and they were patchily distributed within a matrix of undisturbed vegetation, which likely buffered resident butterfly populations against mortality and facilitated recolonization. In a tallgrass prairie ecosystem, Swengel and Swengel (2001) found that as percentage of burned area increased, abundance of the regal fritillary (*Speyeria idalia*) decreased to the point of being undetectable. The low intensity of the prescribed burn, as well as its timing in the winter when resident species were dormant and migratory species were absent, may have also promoted the persistence of butterflies. Further research is required to systematically test for effects of different fire regimes on all stages of butterfly life history, including overwintering forms, and on population trends over time. Alternative explanations for the lack of differences between the two treatments include the following: historical use of fire in previous decades had lasting impacts on resident butterfly populations, or members of the community were underrepresented by our relatively small sample, which missed the beginning of the flight season and may have been biased toward larger bodied species.

In conclusion, our research suggests that patchy, winter, low-intensity burning of a coastal grassland does not deter adult butterflies from utilizing this critical habitat. Fire management may even benefit some species by enhancing nectar resources and maintaining unobstructed migratory flight paths. More extensive and longer-term monitoring is needed, but if diverse taxa including arthropods and key functional groups such as pollinators can be maintained while vegetative succession is inhibited, fire may indeed be a viable tool to conserve these rare and threatened ecosystems (Colbert 2016). Yet we caution that active management and restoration activities should not detract from greater efforts to protect coastal grasslands from further habitat loss and fragmentation.

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