Diurnal Lepidopteran Response to Prescribed Burning and Roller Chopping in Florida Flatwoods

Emma V. Willcox, *Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, FL 32611*

William M. Giuliano, *Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, FL 32611*

Abstract: In recent years, Florida's pine flatwoods, which provide habitat for numerous Lepidopteran species (butterflies and moths), have exhibited considerable declines in quantity and quality. These declines are primarily attributed to changes in historic fire regimes which have resulted in excessive shrub growth and loss of herbaceous vegetation. Prescribed burning and roller chopping are being promoted as a means to improve these areas of degraded pine flatwoods. However, impacts of these practices on pine flatwoods-associated Lepidopterans, many of which are important herbivores and pollinators, are largely unknown. The objectives of this study were to 1) compare diurnal Lepidopteran species richness and abundance on treated (management activities such as prescribed burning implemented) and untreated (no management activities implemented) pine flatwoods sites and 2) compare species richness and abundance of nectar-producing forbs and shrubs on treated and untreated sites. We assessed seasonal effects of prescribed burning, roller chopping, and combinations of the two treatments on Lepidopterans and plant community characteristics using a paired sample approach. These variables were compared between sampling locations randomly located within treated and untreated areas. For our single season study, Lepidopteran abundance was lower on dormant season burn sites. Flowering forb abundance and richness declined on growing season burn and roller chop/burn sites. Until further research is completed, application of prescribed burning and roller chopping practices in pine flatwoods where active Lepidopteran management is a priority should be done on smaller areas in a mosaic arrangement. This approach will promote a variety of pine flatwoods habitats in different successional stages that could be utilized by a range of Lepidopteran species.

Keywords: abundance, butterflies, fire management, flowering plants, Lepidoptera, pollinators, prescribed burning, roller chopping, species richness

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 64:1–8

Lepidopteran species (butterflies and moths) play an essential role in natural systems as herbivores and pollinators (Scott 1986, Hendrix and Kyhl 2000) and are capable of fostering public sympathy and interest in conservation (New 1991, 1997). They are often considered a flagship or umbrella taxa for conserving other wildlife and have the potential to act as indicators of habitat type, quality, and condition (Erhardt 1985, Kremen 1992, Launer and Murphy 1994, Nelson and Anderson 1994, New 1997) and presence of certain bird species (Swengel and Swengel 1999). As a result, they are frequently the target of invertebrate management, research, and conservation efforts (New 1997).

Many species of Lepidoptera inhabit the pinelands of the southeastern United States, including Florida's pine flatwoods (Covell 1984, Gerberg and Arnett 1989, Opler 1998). Two of the species found in pine flatwoods, the arogos skipper (*Atrytone arogos arogos*) and southern dusted skipper (*Atrytonopsis hianna loammi* Whitney), are listed by the Florida Fish and Wildlife Conservation Commission (FWC) as species of conservation concern due to declining populations (FWC 2005). Unfortunately, the pine flatwoods that provide habitat for these Lepidoptera are also deteriorating and in recent years have exhibited considerable declines in quantity and quality (Abrahamson and Hartnett 1990, U.S. Fish and Wildlife Service [USFWS] 1999, FWC 2005). Most (75%) of Florida's pine flatwoods (Cox et al. 1997) are privately owned and used primarily for livestock production (Cox et al.1997, FWC 2005). Changes to management practices in these flatwoods and pine habitats across the southeastern United States, particularly modification of historic fire regimes (i.e., deviations in fire intensity, return frequency, and seasonality), have resulted in excessive shrub growth and reductions in herbaceous vegetation (Wade et al. 1980, Robbins and Myers 1992, Glitzenstein et al. 1995, Abrahamson and Hartnett 1990, Platt 1988). These vegetation changes have altered the structure and composition of pine flatwoods, contributing to their degradation and reducing their suitability for associated wildlife, including grassland- and open country-associated Lepidopteran species (FWC 2005).

To maintain and restore remaining areas of privately-owned pine flatwoods, FWC and the U.S. Department of Agriculture are using assistance-based programs, such as the Farm Bill's Environmental Quality Incentives Program and Wildlife Habitat Incentives Program, to encourage landowners to implement appropriate management activities on their lands. Management activities promoted under these programs include use of prescribed fire and roller chopping during dormant (November–March) and growing (April–October) seasons. Prescribed fire and roller chopping are management techniques that reduce shrub cover and encourage growth and flowering of grasses and forbs. Enhancement of herbaceous plant communities can improve the quality of degraded pineland and prairie habitats where changes in fire use have permitted the proliferation of shrubby vegetation to the detriment of herbaceous groundcover species (Platt et al.1988, Tanner et al. 1988, Fitzgerald and Tanner 1992, Glitzenstein et al. 1995, Watts and Tanner 2003, Watts et al. 2006, Willcox 2010).

Effects of management activities on Lepidopteran communities occupying pine flatwoods have not been studied. Many rare butterflies require vegetation management in some form to maintain their populations (New 1991, Oates 1995, Robertson et al. 1995). In pine flatwoods, one might expect prescribed burning and roller chopping to benefit grassland-associated butterflies through successional changes to the plant community (Platt 1988, Tanner et al. 1988, Fitzgerald and Tanner 1992, Glitzenstein et al. 1995, Watts and Tanner 2003, Watts et al. 2006, Willcox 2010). Vegetation changes, such as promotion of native herbaceous plants could be expected to provide supplementary nectar-producing plants as food for adult butterflies, sites for egg-laying, and forage for developing caterpillars. However, in other areas of North America, declines in Lepidopteran species richness and abundance have been observed following fire, at least in the short-term, suggesting that this management practice may threaten populations of locally endangered species (Dunwiddie 1991; Swengel 1996, 1998; Siemann 1997). With assistance-based management programs currently encouraging use of fire and roller chopping in pinelands, further studies of the impacts these practices have on pine flatwoods-associated Lepidopterans are needed. Such research can help determine if use of these practices to manage pine flatwoods vegetation is also appropriate to conserve this insect order. The objectives of our study were to 1) compare diurnal Lepidopteran species richness and abundance on treated (management activities such as prescribed burning implemented) and untreated (no management activities implemented) pine flatwoods sites and 2) compare species richness and abundance of nectar-producing plants, important as a Lepidopteran food source, on treated and untreated sites.

Study Area

We conducted research on 50 privately- and publicly-owned, paired treatment and control sites across six counties (Desoto, Highlands, Lee, Manatee, Osceola, and Sarasota) in central and south Florida. Study sites consisted of pine flatwoods habitats with varying management histories and grazing regimes being prescribed burned and roller chopped by local landowners and land managers using varying, individual protocols. Florida's pine flatwoods are characterized as having an overstory of scattered slash (*Pinus elliotti* Engelm.) and longleaf (*P. palustris* Mill.) pine, either in pure stands or in combination. The understory and shrub layer includes saw palmetto (*Serenoa repens* [Bartram] Small), wax myrtle (*Morella cerifera* [L.] Small), gallberry (*Ilex glabra* [Pursh] Chapm.), fetterbush (*Lyonia lucida* [Lam.] K. Koch), staggerbush (*Lyonia fruticosa* [Michx.], G. S. Torr), dwarf huckleberry (*Gaylussacia dumosa* [Andrews] Torr. and A. Gray), dwarf live oak (*Quercus mimima* [Sarg.] Small), and tarflower (*Bejaria racemosa* Vent.). An appreciable herbaceous layer exists when the shrub layer is relatively open. This layer contains a wide variety of grasses (e.g., *Agrostis*, *Andropogon*, *Aristida*, *Eragrostis*, *Panicum*, and *Paspalum* spp.). Common forbs include legumes (e.g., *Cassia*, *Crotalaria*, *Galactia*, *Tephrosia* spp.), milkweeds (*Asclepias* spp.), milkworts (*Polygala* spp.), and a wide variety of composites (e.g., *Aster, Chrysopsis, Eupatorium, Liatris,* and *Solidago* spp.; Abrahamson and Hartnett 1990, USFWS 1999).

Treatment types included dormant season (November–March) burn, growing season (April–October) burn, dormant season roller chop, growing season roller chop, and a roller chop/burn combination treatment. The roller chop/burn combination treatment (hereafter referred to as roller chop/burn) involved roller chopping in the dormant season followed by burning within six months. We established 11 dormant season burn, 9 growing season burn, 9 dormant season roller chop, 12 growing season roller chop, and 9 roller chop/burn sites, each of which was paired with a control site.

Methods

Lepidopteran Surveys

We used a paired sampling approach to examine effects of treatment type (i.e., prescribed burning, roller chopping, and roller chopping/burning) on Lepidopteran species richness and abundance. Richness and abundance were compared between sampling points randomly located in paired treated (e.g., dormant season burned) and untreated (control) flatwoods sites. Paired treatment and control sampling points were adjacent, being located in the same pasture or management unit. In addition, paired points within each management unit had similar current and past management histories (e.g., grazing intensity), surrounding land-use, plant community (e.g., overstory cover), and soil conditions. We established one randomly selected sampling point within each treatment and control site. To minimize edge effects, we rejected and randomly relocated sampling points that fell within 50 m of the edge of a treatment or control site. Sites within which treatment and control sampling points were located ranged from 2–20 ha in size.

We conducted Lepidopteran surveys in spring (March–April) of 2008 following the application of dormant and growing season burning and roller chopping treatments. Lepidoptera were surveyed using line transect techniques along two 100-m perpendicular transects centered on the sampling point (Swengel 1998, Giuliano et al. 2004, Shepherd and Dubinski 2005). We walked each transect at a steady pace of 10 m/min for a total survey time of 20 min (Shepherd and Debinski 2005). During this period, we recorded all Lepidoptera observed through binoculars or captured in a sweep net (Opler 1998, Glassberg 1999). The 20-min sampling period did not include capture, processing, or recording of individuals. We conducted surveys on calm (winds <17 km/h), sunny (cloud cover <60%), and warm (temperature >18 C) days between 1000 and 1500 hours (Shepherd and Debinski 2005).

Nectar-producing Forb and Shrub Sampling

We also used a paired sampling approach to examine effects of treatment type on richness and abundance of nectar-producing plant species which were compared at the same sampling points and on the same days as Lepidopteran surveys. Sampling involved counting number of nectar-producing forbs and shrubs exhibiting inflorescence within a 0.03-ha plot centered on the sampling point to provide a measure of flowering plant abundance (*n* of individuals; Dueser and Shugart 1978, Higgins et al. 2005).

Analyses

We used mixed model regressions to examine differences in Lepidopteran and nectar-producing plant species richness and abundance between untreated (control) and treated sites, both within (e.g., dormant season burn) and among (i.e., dormant season burn, growing season burn, dormant season roller chop, growing season roller chop, and roller chop/burn) treatment types. Study site pair was included in analyses as a blocking factor. Significant comparisons among treatment type were followed by Fisher's Protected LSD tests (Zar 1999).

We rank transformed all data sets prior to analyses due to violations of normality and homogeneity of variance assumptions (Conover 1998, Zar 1999, SYSTAT 2007). Statistical significance was concluded at $P \leq 0.1$ for all tests. We used this value, rather than the more common $P \leq 0.05$, to reduce the probability of making a Type II error (Mapstone 1995, Zar 1999). All statistical tests were performed using SYSTAT (2007) statistical software.

Results

Lepidopteran Species

We identified 20 Lepidopteran species during the study (Table 1). Lepidopteran species richness was unaffected by dormant and growing season burning and roller chopping and roller chopping/burning ($P \geq 0.129$). Lepidopteran abundance was affected by dormant season burning, decreasing by 64% from 3.3 ± 0.6 ($\pm$ SE) individuals on burn to 1.2 ± 0.5 individuals on control sites ($P = 0.026$). No other treatment had an effect on Lepidopteran abundance ($P \geq 0.424$). Comparisons among treatments revealed the effects of dormant season burning were different from those of all other treatments (Table 2).

Table 1. Lepidopteran abundance on Florida pine flatwoods sites subject to six habitat treatments, March–April 2008.

		Abundance (*n* of individuals)									
		Dormant season burn[a] (*n* = 11)		Growing season burn[b] (*n* = 9)		Dormant season roller chop (*n* = 9)		Growing season roller chop (*n* = 12)		Roller chop/ burn (*n* = 9)	
Common name	Scientific name	C[c]	T[d]	C	T	C	T	C	T	C	T
Black swallowtail	*Papilio polyxenes*	3	0	7	4	2	0	3	4	1	3
Cabbage white	*Pieris rapae*	2	2	1	1	0	3	2	2	3	1
Checkered white	*Pontia protodice*	0	1	4	4	4	4	0	3	9	6
Cloudless sulphur	*Phoebis sennae*	2	0	1	0	0	0	1	0	1	1
Common buckeye	*Junonia coenia*	0	2	0	2	2	1	4	1	4	4
Eastern tiger swallowtail	*Papilio glaucus*	1	0	0	0	0	0	0	0	0	0
Giant swallowtail	*Papilio cresphontes*	0	0	0	0	0	0	0	0	3	0
Gray hairstreak	*Strymon melinus*	0	0	2	1	0	0	0	0	0	0
Gulf fritillary	*Agraulis vanillae*	0	0	0	1	0	0	0	1	0	0
Least skipper	*Ancyloxypha numitor*	0	0	2	0	0	1	2	0	0	1
Little metalmark	*Calephelis virginiensis*	3	0	0	1	0	1	2	4	0	2
Monarch	*Danaus plexippus*	0	0	0	0	0	0	1	0	0	0
Obscure sphinx	*Errinyis obscura*	0	0	0	5	0	0	0	0	0	0
Orange sulphur	*Colias eurytheme*	0	0	0	0	0	0	0	0	1	0
Palmetto skipper	*Euphyes arpa*	0	0	0	0	0	1	0	0	0	0
Red admiral	*Vannesa atalanta*	0	0	2	1	0	0	0	0	1	0
Short-lined chocolate	*Agnomonia anilis*	0	0	0	0	0	0	0	0	1	0
Southern broken dash	*Wallengrenia otho*	0	0	0	0	0	0	1	0	0	0
Southern skipperling	*Copaeodes minimus*	2	0	2	1	0	2	0	2	0	1
Zebra swallowtail	*Eurytides marcellus*	13	7	10	19	5	2	3	3	12	7

a. Dormant season, November–March
b. Growing season, April–October
c. C = Control.
d. T = Treated.

Table 2. Comparison of effects of six habitat treatments on Lepidopteran, flowering forb, and flowering shrub species richness and abundance in Florida pine flatwoods, March–April 2008.

Lepidopteran, flowering forb, and flowering shrub abundance and species richness[a]	Treatment type ($\bar{x} \pm$ SE)[b]						
	Control ($n = 50$)	Dormant season burn[c] ($n = 11$)	Growing season burn[d] ($n = 9$)	Dormant season roller chop ($n = 9$)	Growing season roller chop ($n = 12$)	Roller chop/ burn ($n = 9$)	P
Abundance (n of individuals)							
Lepidoptera	2.7 ± 0.4A	1.2 ± 0.5B	4.3 ± 1.7A	1.7 ± 0.3A	2.0 ± 0.7A	3.0 ± 0.9A	0.065
Flowering forb	61.3 ± 14.7A	61.1 ± 29.7A	15.2 ± 6.2A	302.7 ± 159.1AB	238.4 ± 115.6B	322.4 ± 163.9B	0.015
Flowering shrub	72.3 ± 16.3A	118.3 ± 30.5A	71.8 ± 16.2A	30.0 ± 13.2A	55.8 ± 51.3B	10.0 ± 5.0B	0.002
Richness (n of species)							
Flowering forb	3.9 ± 0.4A	3.2 ± 0.4AB	2.7 ± 0.4A	6.0 ± 1.2AB	7.0 ± 0.8B	5.8 ± 1.1B	0.035
Flowering shrub	3.0 ± 0.2A	4.4 ± 0.5A	2.9 ± 0.4A	3.1 ± 0.5A	1.7 ± 0.6B	1.6 ± 0.3B	0.002

a. Only Lepidopteran, flowering forb, and flowering shrub species richness or abundance significantly affected by treatment presented ($P \leq 0.1$).
b. Means in a row followed by the same letter do not differ significantly ($P > 0.1$).
c. Dormant season, November–March
d. Growing season, April–October

Nectar-producing Forbs and Shrubs

We observed a total of 51 flowering forb species from 21 families (Table 3) and 16 flowering shrub species from 8 families (Table 4). Of these families, 8 forb (Asteraceae, Fabaceae, Gentianaceae, Hypoxidaceae, Lamiaceae, Polygalaceae, Xyridaceae, and Scrophalariaceae) and 5 shrub (Arecaceae, Aquifoliaceae, Ericaceae, Hypericaceae, and Fagaceae) had a combined abundance over all sites of ≥ 100 flowering individuals and were subject to further analyses.

Dormant season burning had no effect on total flowering forb species richness or abundance ($P \geq 0.880$). Flowering Xyridaceae species richness ($P = 0.058$) and abundance ($P = 0.056$) were affected by dormant season burning. Species richness of flowering Xyridaceae decreased by 100% from 0.4 ± 0.2 species on control sites to 0.0 ± 0.0 species on burned sites. Flowering Xyridaceae abundance decreased by 100% from 7.8 ± 6.8 individuals on control sites to 0.0 ± 0.0 individuals on burned sites. Species richness and abundance of all other forb families examined were unaffected by dormant season burning ($P \geq 0.239$).

Total flowering shrub species richness and abundance were unaffected by dormant season burning ($P \geq 0.397$). Dormant season burning had an effect on flowering Ericaceae abundance ($P = 0.097$), which increased by 135% from 3.1 ± 3.0 individuals on control sites to 7.3 ± 4.3 individuals on burned sites. Flowering Ericaceae species richness ($P = 0.131$) and species richness and abundance of all other shrub families examined ($P \geq 0.130$) were unaffected by dormant season burning.

Total flowering forb species richness and abundance were unaffected by growing season burning ($P \geq 0.224$). Growing season burning had an effect on flowering Polygalaceae species richness ($P = 0.053$) and abundance ($P = 0.024$). Species richness of flowering Polygalaceae increased by 125% from 0.4 ± 0.2 species on control sites to 0.9 ± 0.2 species on burned sites. Flowering Polygalaceae abundance increased by 829% from 1.4 ± 0.9 individuals on control sites to 13.0 ± 5.8 individuals on burned sites. Growing season burning had no effect on species richness and abundance of any other forb families examined ($P \geq 0.241$).

Growing season burning had no effect on total flowering shrub species richness and abundance ($P \geq 0.314$). Growing season burning had an effect on flowering Hypericaceae species richness ($P = 0.083$) and abundance ($P = 0.083$). Species richness of flowering Hypericaceae decreased by 100% from 0.4 ± 0.2 species on control sites to 0.0 ± 0.0 species on burned sites. Flowering Hypericaceae abundance decreased by 100% from 0.7 ± 0.0 individuals on control sites to 0.0 ± 0.0 individuals on burned sites. Species richness and abundance of all other shrub families examined were unaffected by growing season burning ($P \geq 0.117$).

Dormant season roller chopping had no effect on total flowering forb species richness ($P = 0.531$). Total flowering forb abundance was affected by dormant season roller chopping ($P = 0.029$), increasing by 633% from 42.7 ± 17.2 individuals on control sites to 313.0 ± 158.0 individuals on roller chopped sites. Dormant season roller chopping also had an effect on flowering Asteraceae species richness ($P = 0.073$) and abundance ($P = 0.071$). Flowering Asteraceae species richness increased by 82% from 1.1 ± 0.3 species on control sites to 2.0 ± 0.4 species on roller chopped sites. Abundance of flowering Asteraceae increased by 185% from 4.1 ± 2.0 individuals on control sites to 11.7 ± 4.5 individuals on burned sites. Dormant season roller chopping had no effect on species richness and abundance of any other forb families examined ($P \geq 0.105$).

Total flowering shrub species richness and abundance were unaffected by dormant season roller chopping ($P \geq 0.499$). Species richness of flowering Ericaceae was affected by dormant season

Table 3. Flowering forb families and species identified on Florida flatwoods sites subject to six habitat treatments (dormant and growing season burn, dormant and growing season roller chop, and burn/roller chop combination), March–April 2008.

Family[a]	Species
Acanthaceae Acanthus (58)	*Ruellia caroliniensis*
Asteraceae Aster (917)	*Chaptalia tomentosa*, *Cirsium horridulum*, *Coreopsis leavenworthii*, *Erigeron quercifolius*, *E. strigosus*, *E. vernus*, *Eupatorium mohrii*, *Flaveria linearis*, *Hieracium gronovii*, *Liatris spicata*, *Lygodesmia aphylla*, *Oclemena reticulata*, *Pityopsis graminifolia*, *Pluchea rosea*, *Pterocaulon virgatum*
Boraginaceae Forget-me-not (2)	*Heliotropium polyphyllum*
Cistaceae Rock-rose (2)	*Helianthemum corymbosum*
Commelinaceae Spiderwort (11)	*Callisia ornata*
Convolvulaceae Morning-glory (46)	*Evolvulus sericeus*
Euphorbiacea Spurge (26)	*Cnidoscolus urens*, *Stillingia sylvatica*
Fabaceae Bean and pea (100)	*Crotalaria rotundifolia*, *Galactia elliottii*, *Mimosa quadrivalvis*, *Tephrosia florida*
Gentianaceae Gentian (462)	*Sabatia brevifolia*
Hypoxidaceae Yellow-star grass (228)	*Hypoxis juncea*
Iridaceae Iris (15)	*Sisyrinchium atlanticum*
Lamiaceae Mint (241)	*Piloblephis rigida*, *Scutellaria integrifolia*
Lentibulariaceae Bladderwort (1)	*Pinguicula lutea*
Liliaceae Lily (2)	*Aletris lutea*
Melastomataceae Meadowbeauty (29)	*Rhexia. mariana*, *R. nuttallii*
Orchidae Orchid (42)	*Spiranthes vernalis*
Polygalaceae Milkwort (4682)	*Polygala cymosa*, *P. grandiflora*, *P. incarnata*, *P. lutea*, *P. nana*, *P. ramosa*, *P. rugelli*, *P. setacea*
Primulaceae Primrose (275)	*Anagallis arvensis*, *Samolus ebracteatus*
Scrophulariaceae Snapdragon (137)	*Buchnera Americana*, *Gratiola hispida*, *Mecardonia acuminata*
Violaceae Violet (20)	*Viola lanceolata*
Xyridaceae Xyris (5964)	*Xyris elliotii*

a. Total flowering forb abundance by family presented in parentheses.

Table 4. Flowering shrub families and species identified on Florida flatwoods sites subject to six habitat treatments (dormant and growing season burn, dormant and growing season roller chop, and burn/roller chop combination), March–April 2008.

Family[a]	Species
Annonaceae Custard apple (15)	*Asimina reticulata*
Aquifoliaceae Holly (298)	*Ilex glabra*
Arecaceae Palm (1167)	*Serenoa repens*
Chrysobalanaceae Chrysobalana (30)	*Licania michauxii*
Ericaceae Heath (846)	*Bejaria racemosa*, *Gaylussacia dumosa*, *Lyonia fruticosa*, *Lyonia lucida*, *Vaccinium myrsinites*
Fagaceae Oak (3034)	*Q. chapmanii*, *Q. minima*, *Q. myrtifolia*
Hypericaceae St John's wort (118)	*Hypericum cistifolia*, *H. reductum*, *H. tetrapetalum*
Myricaceae Bayberry (79)	*Myrica cerifera*

a. Total flowering shrub abundance by family presented in parentheses.

roller chopping ($P = 0.072$), increasing by 133% from 0.3 ± 0.2 species on control sites to 0.7 ± 0.2 species on roller chopped sites. Flowering Ericaceae abundance ($P = 0.214$) and species richness and abundance of all other shrub families examined ($P \geq 0.214$) were unaffected by dormant season roller chopping.

Growing season roller chopping had no effect on total flowering forb species richness ($P = 0.518$). Total flowering forb abundance was affected by growing season roller chopping ($P = 0.009$), increasing by 70% from 4.3 ± 0.9 species on control sites to 7.3 ± 0.9 species on burned sites. Flowering Asteraceae species richness ($P = 0.015$) and abundance ($P = 0.009$) were affected by growing season roller chopping. Species richness of flowering Asteraceae increased by 180% from 0.5 ± 0.4 on control sites to 1.4 ± 0.4 on roller chopped sites. Flowering Asteraceae abundance increased by 23% from 9.9 ± 9.8 individuals on control sites to 12.2 ± 6.1 individuals on roller chopped sites. Growing season roller chopping also had an effect on flowering Fabaceae and Hypoxidaceae species richness ($P = 0.060$ and $P = 0.076$, respectively) and abundance ($P = 0.063$ and $P = 0.024$, respectively). Flowering Fabaceae species richness increased from 0.0 ± 0.0 species on control sites to 0.5 ± 0.3 species on roller chopped sites and abundance increased from 0.0 ± 0.0 individuals on control sites to 1.3 ± 0.8 individuals on roller chopped sites. Flowering Hypoxidaceae species richness increased by 200% from 0.2 ± 0.1 species on control sites to 0.6 ± 0.2 species on roller chopped sites and abundance by 4300% from 0.2 ± 0.1 individuals on control sites to 8.8 ± 3.8 individuals on roller chopped sites. Species richness and abundance of all other forb families examined were unaffected by growing season roller chopping ($P \geq 0.305$).

Growing season roller chopping had no effect on total flowering shrub species richness ($P = 0.518$). However, total flowering shrub abundance was affected by growing season roller chopping ($P = 0.068$), increasing by 140% from 21.2 ± 13.3 individuals on control sites to 50.8 ± 49.7 individuals on roller chopped sites. Growing season roller chopping had no effect on species richness and abundance of any shrub families examined ($P \geq 0.128$).

Roller chopping/burning had no effect on total flowering forb species richness and abundance ($P \geq 0.140$). Flowering Asteraceae and Hypoxidaceae species richness ($P = 0.029$ and $P = 0.071$, respectively) and abundance ($P = 0.027$ and $P = 0.034$, respectively) were affected by roller chopping/burning. Species richness of flowering Asteraceae increased by 325% from 0.4 ± 0.2 species on control sites to 1.7 ± 0.4 species on roller chopped/burned sites and abundance by 1660% from 0.5 ± 0.3 individuals on control sites to 8.8 ± 4.0 individuals on roller chopped/burned sites. Flowering Hypoxidaceae species richness increased by 100% from 0.4 ± 0.2 species on control sites to 0.8 ± 0.1 species on roller chopped/burned sites and abundance increased by 867% from 0.6 ± 0.3 individuals on control sites to 5.8 ± 2.4 individuals on roller chopped/burned sites. Flowering Polygalaceae abundance was also affected by roller chopping/burning ($P = 0.026$), decreasing by 302% from 11.4 ± 5.7 individuals on control sites to 45.8 ± 33.1 individuals on roller chopped/burned sites. Roller chopping/burning had no effect on flowering Polygalaceae abundance and species richness and abundance of any other forb families examined ($P \geq 0.161$).

Roller chopping/burning had no effect on total flowering shrub species richness ($P = 0.350$). Total flowering shrub abundance was affected by roller chopping/burning ($P = 0.004$), decreasing by 390% from 10.8 ± 2.7 individuals on control sites to 2.2 ± 0.8 individuals on roller chopped/burn sites. Species richness and abundance of all other shrub families examined were unaffected by roller chopping/burning ($P \geq 0.105$).

Comparisons among treatments revealed the effects of growing season roller chopping and roller chopping/burning on flowering forb species richness were similar, and different to those of all other treatments (Table 2). The effects of growing season roller chopping and roller chopping/burning on flowering shrub abundance were also similar (Table 2).

Discussion

Lepidopteran species richness and abundance were largely unaffected by treatment type with the exception of dormant season burning which caused declines in Lepidopteran abundance. However, results should be interpreted cautiously as the small size of some study sites and high mobility of adult butterflies can mask management affects on this insect group (Swengel 1998). The results of other studies examining the effects of prescribed burning on Lepidoptera are variable. In prairie habitats, while leaving areas entirely unmanaged rarely benefits Lepidoptera, regular prescribed burning can also result in low numbers, particularly for more specialized species. Wildfires or less frequent burns that resemble wildfires appear more appropriate in maintaining and increasing Lepidopteran abundance in these prairie situations (Swengel 1998). Studies by New (1991, 1993) also suggest infrequent burns may be most favorable to maintain Lepidopteran species richness and abundance. In contrast, Lepidopteran abundance was greater in regularly burned pine forest compared to control forests in Texas, potentially as a result of the more open mid- and understory created by burning (Rudolph and Ely 2000).

The effect of season of burn on Lepidoptera has not been widely examined. However, differences in responses of members of this insect order may depend on whether individuals are in a stage of activity or diapause (Swengel 2001). Burns that occur when Lepidoptera are in diapause may result in greater mortality of immatures and reduced abundance of adults later.

Our study found prescribed burning alone had no effect on total flowering forb species richness and abundance. However, certain forb (Xyridaceae and Polygalaceae) and shrub (Ericaceae and Hypericaceae) families were affected. Members of the Xyridaceae and Polygalaceae are not commonly used Lepidopteran nectar sources (Cech and Tudor 2005). Platt et al. (1988) and Streng et al. (1993) demonstrated that many forb species within the Asteraceae, including *Liatris*, *Pitopsis*, and *Solidago* spp. flowered more profusely following growing season burning. Many members of the Asteraceae, and, to a slightly lesser extent, Lamiaceae, and Fabaceae, provide an important nectar source for adult Lepidopterans, as well being host plants for butterfly larvae (Cech and Tudor 2005, Glassberg 1999). If these families had displayed increases in species richness and abundance, concurrent increases in Lepidopteran species richness or abundance may have been observed. The Ericaceae are important nectar producing shrubs for a number of Lepidopterans in Florida (Cech and Tudor 2005). However, our results suggest observed increases in Ericaceae abundance following burning did not affect butterfly numbers.

In our study, growing and dormant season roller chopping had no effect on total flowering forb species richness but resulted in increases in total flowering forb abundance. Increases in Asteraceae species richness and abundance were observed on dormant and growing season roller chopped sites. Increases in Fabaceae species richness and abundance were also observed on growing season roller chopped sites. These practices result in shrub cover, height, and occasionally density reductions (Willcox 2010). The opening up of the ground layer and reduced shading of herbaceous vegetation that occurs may allow for increased flowering of species within these families. However, despite the importance of members of these families in providing nectar sources for adult butterflies and as host plants for larvae (Cech and Tudor 2005, Glassberg 1999) there were no corresponding increases in Lepidopteran species richness and abundance on these sites. Flowering shrub abundance decreased on growing season roller chop and roller chop/

burn sites which may have some effect in terms of nectar production.

Dormant season burning may negatively affect Lepidopteran abundance in pine flatwoods in the short-term (1 yr). However, until further research examining response of immature and adult Lepidoptera to prescribed burning is conducted, the application of all treatments over large areas—in situations where the management of these insects is a priority—should be carefully considered. Examination of only mobile adults may result in treatment effects being masked. Until additional research is completed, application of prescribed burning and roller chopping practices in pine flatwoods where active Lepidopteran management is occurring should be done on smaller areas in a mosaic arrangement. This approach may promote a variety of pine flatwoods habitat conditions suitable for a range of Lepidopteran species. Treatment mosaics are likely to be beneficial not only to Leipidoptera, but nongame and game vertebrates including wild turkey (*Meleagris gallopavo*) and northern bobwhite (*Colinus virginianus*) (Dickson 2001).

Future research should examine abundance of both adult and larval Lepidoptera. In addition, vegetation characteristics at study sites should be more fully considered. Assessment of percent cover of different plant families would provide insight into the composition and availability of nectar sources and resting sites for adult butterflies, and host plants for caterpillar development. This, in combination with better enumeration of known butterfly food plants (for both adults and larvae), information on weather conditions, and data collection over additional seasons would provide more detailed information on the effects of burning and roller chopping on Lepidoptera.

Acknowledgments

Funding for this research was provided by the Florida Fish and Wildlife Conservation Commission State Wildlife Grants Program (SWG: 06007) and the University of Florida. We gratefully acknowledge all the private landowners and public land managers who allowed us to conduct research on their ranches and wildlife management areas. Finally, we thank Dixie Cline, Mary Hobby, Courtney Hooker, Karen Ridener, and Christine Sciarrino for their help with data collection and entry.

Literature Cited

Abrahamson, W. G. and D. C. Hartnett. 1990. Pine flatwoods and dry prairies. Pages 103–149 *in* R. L. Myers and J. J. Ewel, editors. Ecosystems of Florida. University of Central Florida Press, Orlando, Florida.

Cech, R. and G. Tudor. 2005. Butterflies of the east coast: an observer's guide. Princeton University Press, Princeton, New Jersey.

Conover, W. J. 1998. Practical nonparametric statistics. John Wiley and Sons, New York, New York.

Covell, C. V. 1984. A field guide to the moths of eastern North America. Houghton Mifflin, New York, New York.

Cox, J., R. Kautz, M. MacLaughlin, and T. Gilbert. 1994. Closing the gaps in Florida's wildlife habitat conservation system: recommendations to meet minimum conservation goals for declining wildlife species and rare plant and animal communities. Florida Game and Fresh Water Fish Commission, Tallahassee, Florida.

Dickson, J. G., editor. 2001. Wildlife of southern forests: habitat and management. Hancock House Publishers, Blaine, Washington.

Dueser, R. D. and H. H. Shugart. 1978. Microhabitats in a forest-floor small mammal fauna. Ecology 59:89–98.

Dunwiddie, P. W. 1991. Comparisons of aboveground arthropods in burned, mowed and untreated sites in sandplain grasslands of Nantucket Island. American Midland Naturalist 125:206–212.

Erhardt, A. 1985. Diurnal Lepidoptera: sensitive indicators of cultivated and abandoned grasslands. Journal of Applied Ecology 22:849–861.

Fitzgerald, S. M. and G. W. Tanner. 1992. Avian community response to fire and mechanical shrub control in south Florida. Journal of Range Management 45:396–400.

Florida Fish and Wildlife Conservation Commission (FWC). 2005. Florida's comprehensive wildlife strategy. Florida Fish and Wildlife Conservation Commission, Tallahassee, Florida.

Gerberg, E. J. and R. H. Arnett. 1989. Florida Butterflies. Natural Science Publications, Baltimore, Maryland.

Giuliano, W. M., A. K. Accamando, and E. J. McAdams. 2004. Lepidoptera-habitat relationships in urban parks. Urban Ecosystems 7:361–370.

Glassberg, J. 1999. Butterflies through binoculars: a field guide to the birds of eastern North America. Oxford University Press, New York.

Glitzenstein, J., D. R. Streng, and W. J. Platt. 1995. Evaluating the effects of season of burn on vegetation in longleaf pine savannas. Florida Game and Freshwater Fish Commission, Tallahassee, Florida.

Hendrix, S. D. and J. F. Kyhl. 2000. Population size and reproduction in *Phlox pilosa*. Conservation Biology 14:304–313.

Higgins, K. F., K. J. Jenkins, G. K. Clambey, D. W. Uresk, D. E. Naugle, J. E. Norland, and W. T. Barker. 2005. Vegetation sampling and monitoring. Pages 524–553 *in* C. E. Braun, editor. Techniques for wildlife investigations and management. The Wildlife Society, Baltimore, Maryland.

Kremen, C. 1992. Assessing the indicator properties of species assemblages for natural areas monitoring. Ecological Applications 2:203–217.

Launer, A. E. and D. D. Murphy. 1994. Umbrella species and the conservation of habitat fragments: a case of a threatened butterfly and a vanishing grassland ecosystem. Biological Conservation 69:145–153.

Mapstone, B. D. 1995. Scalable decision rules for environmental impact studies: effect size, type I, and type II errors. Ecological Applications 5:401–410.

Nelson, S. M. and D. C. Anderson. 1994. An assessment of riparian environmental quality by using butterflies and disturbance susceptibility scores. Southwestern Naturalist 39:137–142.

New, T. R. 1991. Butterfly Conservation. Oxford University Press, Oxford, United Kingdom.

———. 1993. Conservation biology of Lycaenidae (butterflies). IUCN, Gland, Switzerland.

———. 1997. Are Lepidoptera an effective 'umbrella group' for biodiversity conservation? Journal of Insect Conservation 1:5–12.

Oates, M. R. 1995. Butterfly conservation within the management of grassland habitats. Pages 98–112 *in* A. S. Pullin, editor. Ecology and Conservation of Butterflies. Chapman and Hall, London, United Kingdom.

Opler, P. A. 1998. A field guide to eastern butterflies. Houghton Mifflin, New York, New York.

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

Robbins, L. E. and R. L. Myers. 1992. Seasonal effects of prescribed burning in Florida: a review. Tall Timbers Research Station Miscellaneous Publication No. 8, Tallahassee, Florida.

Robertson, P. A., S. A. Clarke, and M. S. Warren. 1995. Woodland management and butterfly diversity. Pages 113–122 *in* A. S. Pullin, editor. Ecology and Conservation of Butterflies. Chapman and Hall, London, United Kingdom.

Rudolph, D. C. and C. A. Ely. 2000. The influence of fire on Lepidopteran abundance and community structure in forested habitats of eastern Texas. Texas Journal of Science 52:127–138.

Scott, J. A. 1986. The Butterflies of North America. Stanford University Press, Stanford, California.

Shepherd, S. and D. M. Debinski. 2005. Evaluation of isolated and integrated prairie reconstructions as habitat for prairie butterflies. Biological Conservation 126:51–61.

Siemann, E., J. Haarstad, and D. Tilman. 1997. Short-term and long-term effects of burning on oak savanna arthropods. American Midland Naturalist 137:349–361.

Streng, D. R., J. S. Glitzenstein, and W. J. Platt. 1993. Evaluating effects of season of burn in longleaf pine forests: a critical literature review and some results from an ongoing long-term study. Proceedings of the Tall Timbers Fire Ecology Conference 18:227–264.

Swengel, A. B. 1996. Effects of fire and hay management on abundance of prairie butterflies. Biological Conservation 76:73–85.

———. 1998. Effects of management on butterfly abundance in tallgrass prairie and pine barrens. Biological Conservation 83:77–89.

———. 2001. A literature review of insect responses to fire compared to other conservation managements of open habitat. Biodiversity and Conservation 10:1141–1169.

Swengel, S. R. and A. B. Swengel. 1999. Correlations in abundance of grassland songbirds and prairie butterflies. Biological Conservation 90:1–11.

SYSTAT. 2007. Statistics II, Version 12. SYSTAT Software, San Jose, California.

Tanner, G. W., J. M. Wood, R. S. Kalmbacher, and F. G. Martin. 1988. Mechanical shrub control on flatwoods range in south Florida. Journal of Range Management 41:245–248.

U.S. Fish and Wildlife Service. 1999. South Florida multi-species recovery plan. U.S. Fish and Wildlife Service, Atlanta, Georgia.

Wade, D., J. Ewel, and R. Hofstetter. 1980. Fire in south Florida ecosystems. U.S. Forest Service General Technical Report SE–17, Southeastern Forest Experimental Station, Asheville, North Carolina.

Watts, A. C. and G. W. Tanner. 2003. Fire and roller chopping have varying effects on dry prairie plant species (Florida). Ecological Restoration 22:229–230.

———, ———, and R. Dye. 2006. Restoration of dry prairies using fire and roller chopping. Pages 225–230 *in* R. Noss, editor. Land of fire and water: the dry prairie ecosystem. Proceedings of the Dry Prairie Restoration Conference, Sebring, Florida.

Willcox, E. V. 2010. Wildlife and habitat responses to prescribed burning, roller chopping, and grazing of Florida rangeland and pasture. Doctoral Dissertation, University of Florida.

Zar, J. H. 1999. Biostatistical analysis. Prentice Hall, Upper Saddle River, New Jersey.