



Short-Term Effects of Burn Season on Flowering Phenology of Savanna Plants

Noel B. Pavlovic

Stacey A. Leicht-Young

Ralph Grundel

Fire regime

- Frequency
- Intensity and severity
- Scale
- Seasonality
- Ignition source

State of our knowledge

- “‘Season of burn’ remains the least understood of the fire regime components.”

Gill, M., R. Bradstock & J. Williams. 2002. Fire regimes and biodiversity: legacy and vision. In *Flammable Australia*, Cambridge University Press. P432.

Why are we interested in fire season?

- At what times of year did fires occur prior to European settlement?
- What source was dominant and when was it most frequent?
- Does seasonality of prescribed burns mimic the pre-European fire conditions? And should it?
- How do species respond to fire season?

When to Burn?

- Usually burn in the dormant season
 - Either spring or fall
- Historically there may have been growing season fires, especially in drought years

Guyette et al. 2006.

Fire scars reveal variability and dynamics of eastern fire regimes.



Native American use of fire

- “The tallgrass prairies of Illinois and adjacent states were burned in the fall during that time of the year that we call ‘Indian Summer’” Also called ‘fall summer’
- Reports of lightning strikes were rare due to low observer population and difficulty of detection.

McClain and Elzinga 1994

Importance of Season of Burn

- Most studies only examine burn or not burn or contrast dormant season burns
- Could change plant community structure
- Has important implications for management practices





Growing Season Wildfire

- **Community level differences in flowering phenologies indicated that timing of fire relative to environmental cues that induced flowering was important in determining flowering synchrony among species within the ground cover of longleaf pine forests.**

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

Prairies

- In 21 years of experimental prairie plantings “summer fire best maintained richness of native, especially early-flowering species.”

Howe, H. F. (2011). "Fire season and prairie forb richness in a 21-y experiment." *Ecoscience* 18(4): 317-328.

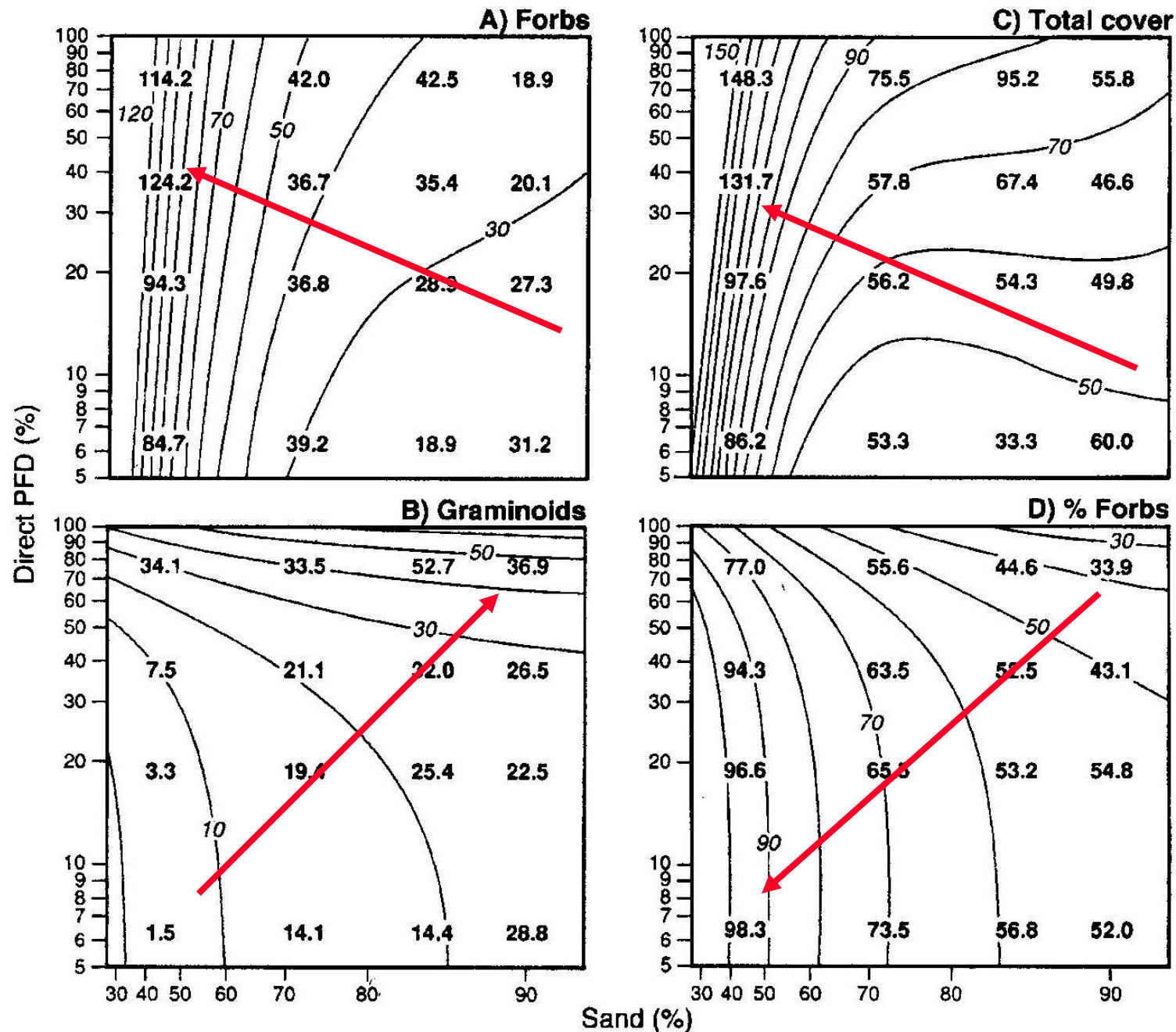


K. Frohnapple

Savannas vs prairies

- The recognition that many savannas are not “prairies with trees,” but forblands with a paucity of prairie grasses in many microsites, should improve the ability of conservationists to identify fire-suppressed sites worthy of conservation and management.

Leach & Givnish. 1999. Gradients in the composition, structure, and diversity of remnant oak savannas in southern Wisconsin. *Ecol. Monogr.* 69:353-374.



Savannas vs. Prairies

- The dry sand savanna groups share several common characteristic ground-layer species, such as huckleberry (*Gaylussacia baccata*), bracken fern (*Pteridium aquilinum*), and blueberry (*Vaccinium angustifolium* [and *pallidum*]).

Will-Wolf, S & F. Stearns. 1999. Dry soil oak savanna in the Great Lakes region. IN: Savannas, Barrens, and Rock Outcrop Plant Communities of North America. Cambridge University Press. Pp 138-140.

Importance of Burning in Oak Savannas

- Allows for reduction of litter
- Reduces woody sprouts to maintain savanna structure
- Maintains diversity of understory species



Focus on Flowers

- Flower production is important for seed production and long distance dispersal
- Influences long-term population success
- Also important for those other species that depend on flowers and fruits: pollinators (butterflies, bees), frugivores etc



Seed bank

**Number of species in the above ground vegetation
and in the seed bank from 10 oak savannas**

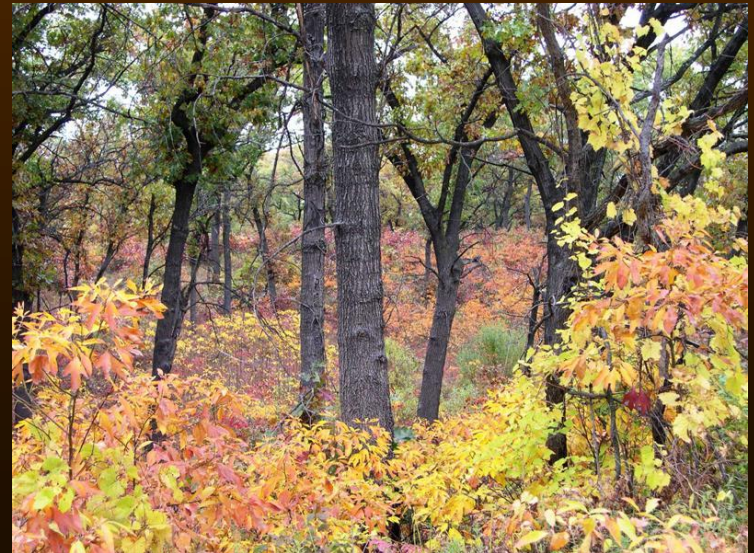
	Above ground	Seed bank
Annual/Biennial Forbs	21	5
Perennial Forbs	48	10
Graminoids	19	12
Woody Vegetation	16	0
Totals	104	27

Research Questions

- What are the phenological periods of oak savanna groundlayers?
- Does burn season affect flower abundance in oak savanna understory plant species?
- Do plants of different life forms and flowering seasons show differences in flowering depending on the season of burn?
- Does burn season affect timing of flowering?
- How are plant and inflorescence stature influenced by season of burn?

Study Site

- Miller Woods at Indiana Dunes National Lakeshore
- 420 ha. mesic oak savanna/woodland complex on sand dunes
- *Quercus velutina* (black oak), *Vaccinium* - forb understory



EASTERN PRAIRIE FOREST TRANSITION

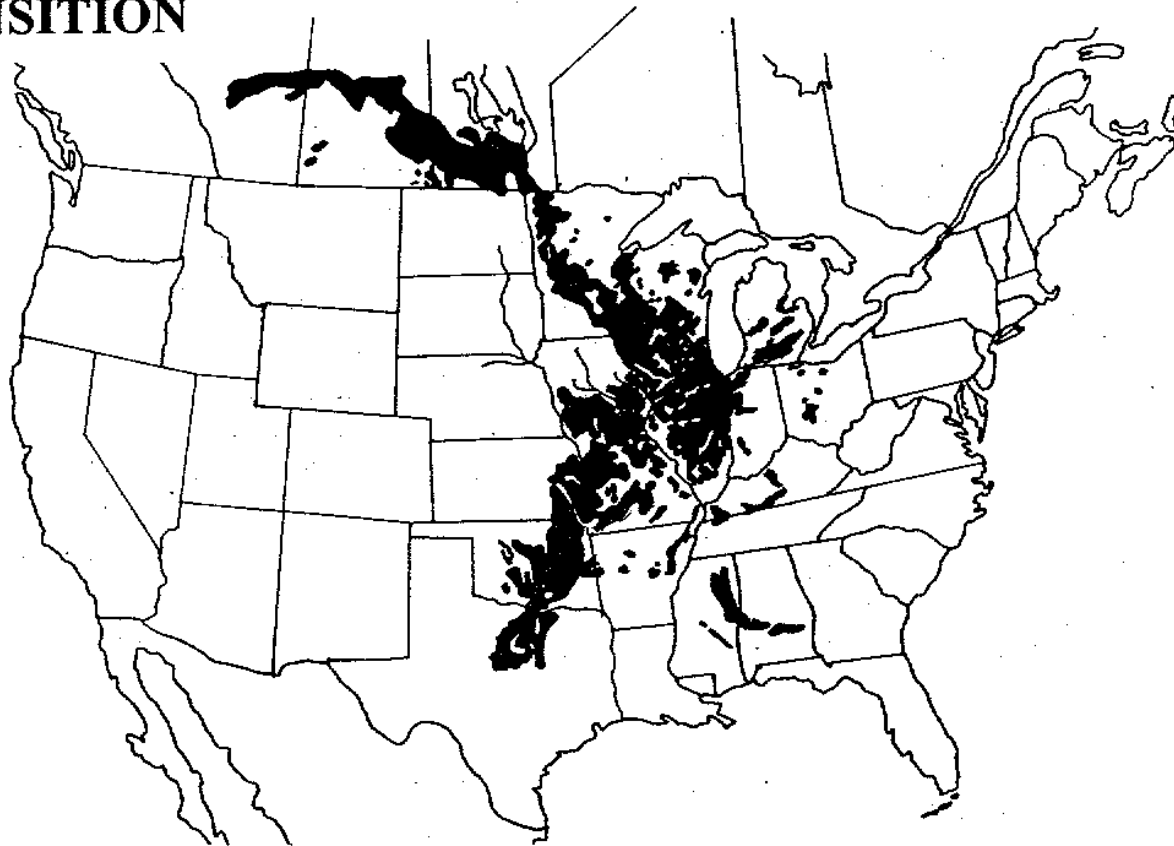
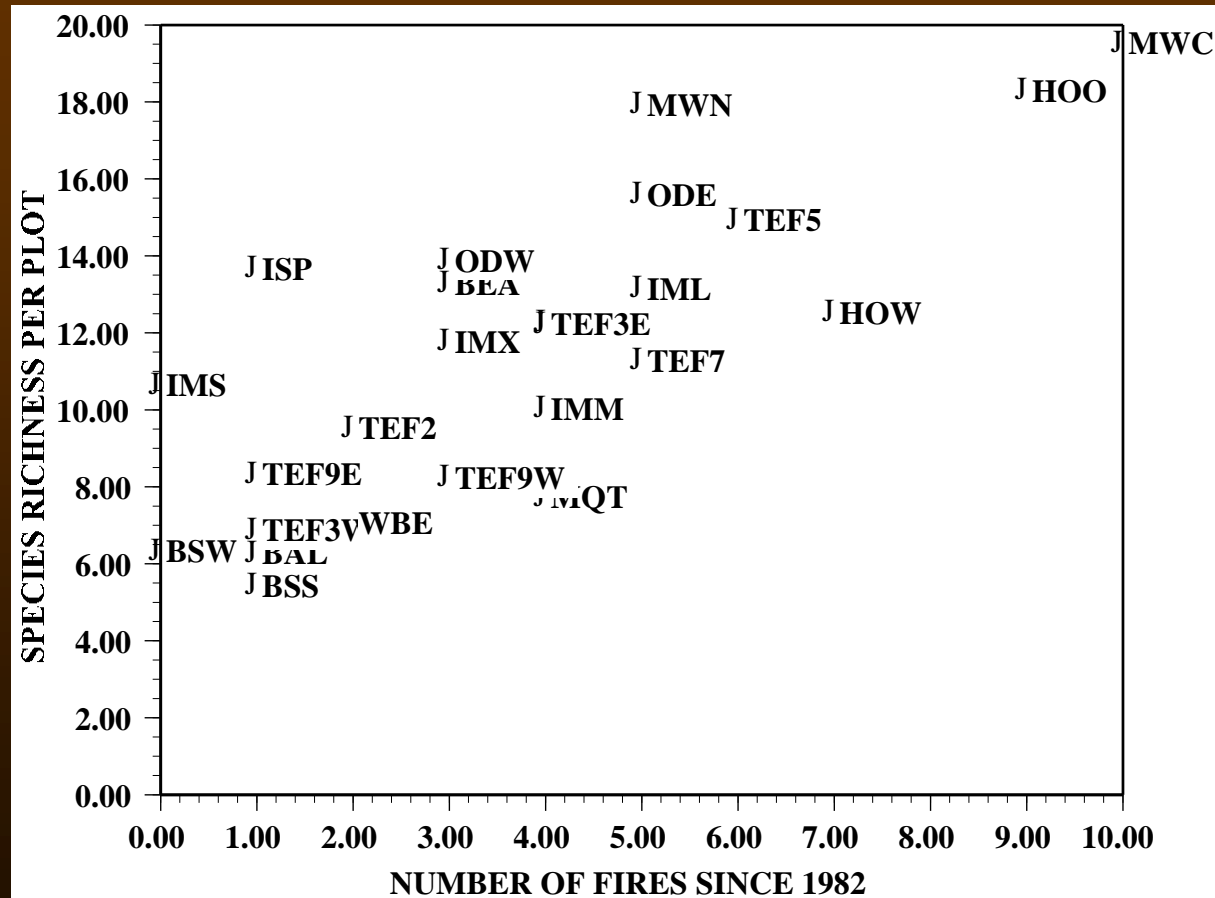


Figure 1. The eastern-prairie-forest transition extended as a broad arc along the eastern edge of the tallgrass prairie and was a mosaic of prairie, forest, and savanna (adapted from Anderson 1983 and Nuzzo 1986).

SPECIES RICHNESS VERSUS FIRE FREQUENCY



Experimental Design

- Set up eight experimental blocks in 2000
- Six burn treatments (10 X 20 m plots) in each block
 - Previous 5-yr Burn (4/1996)
 - Previous 1-yr Burn (3/2000)
 - Previous Fall Burn (11/2000)
 - Early Season Burn (4/2001)
 - Growing Season Burn (6/2001)
 - Late Season Burn (10/2001)



2000

April 1996 Wildfire

(previous 5-yr burn)

March 2000 Wildfire

(previous 1-yr burn)

May 4, 2000 Cerrado Grande fire

Early November 2000
(previous fall burn)

2001

Early April 2001
(early season burn)

Late June 2001
(growing season burn)

Early October 2001
(late season burn)

April 2002

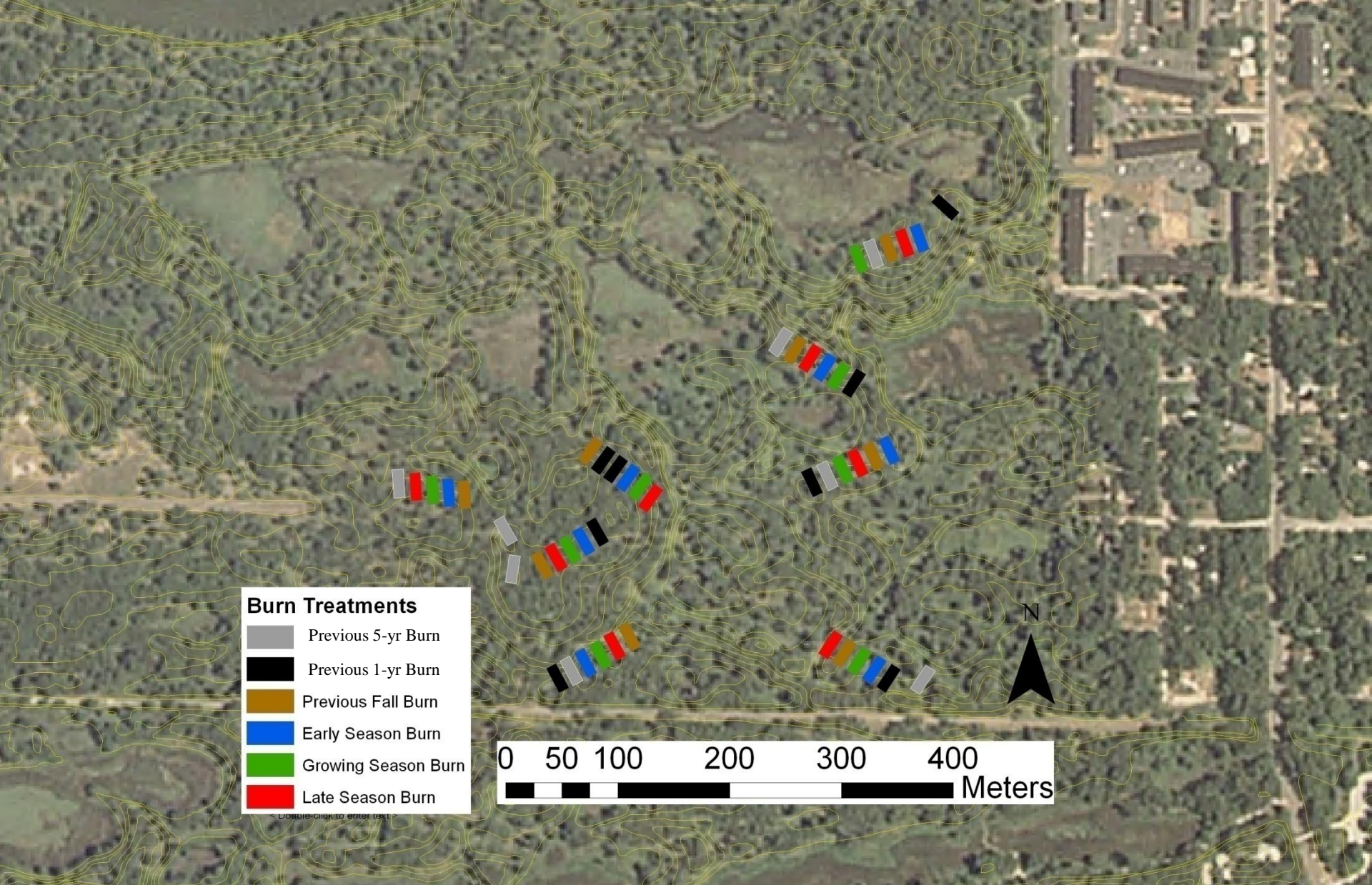
Another wildfire!

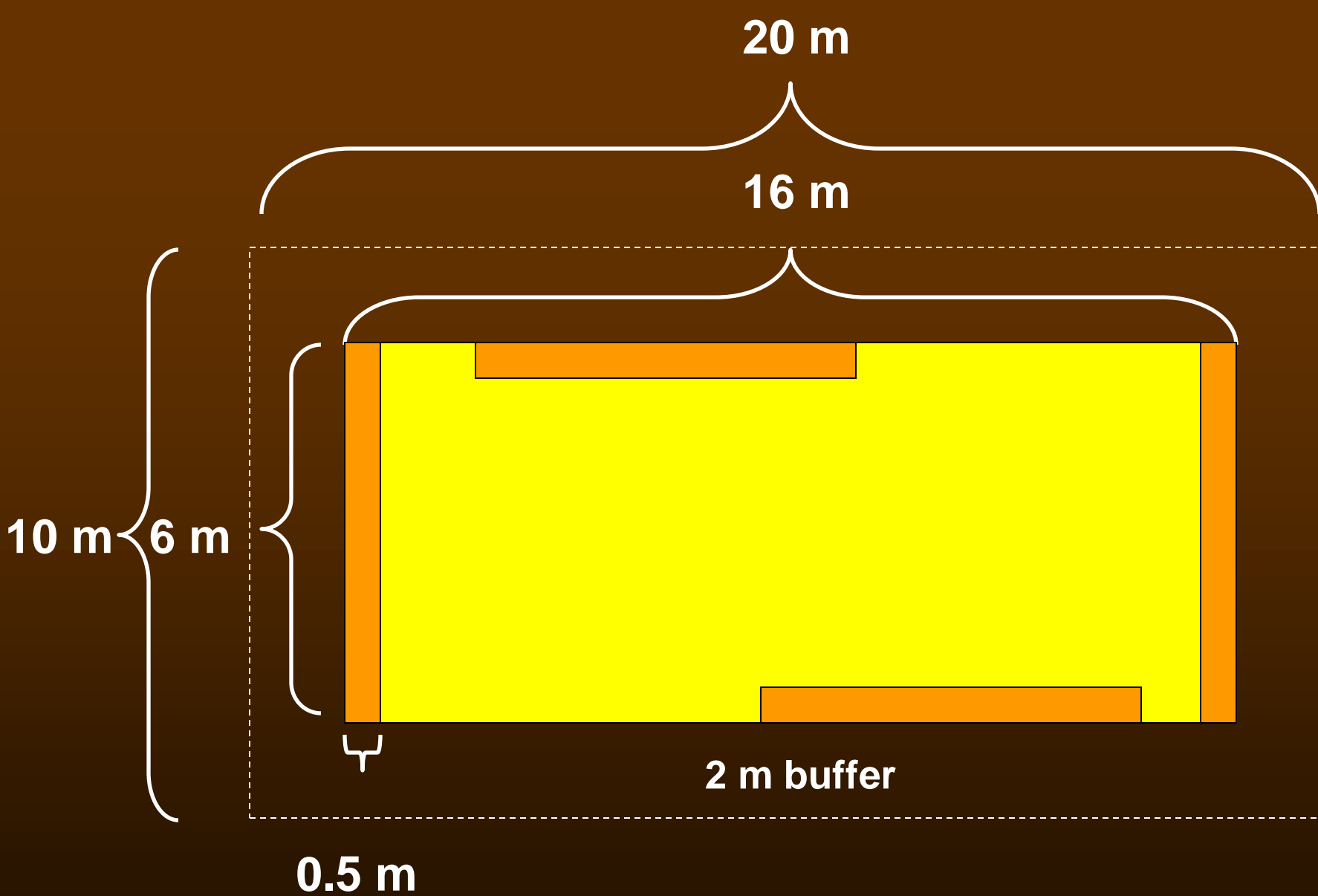
Sampling Begins
April 25, 2001

Sampled 42 times
during this interval

Sampling Ends
November 13, 2001









Growing season prescribed fire



EARLY GROWING SEASON



 **USGS** **BURNED**

UNBURNED

MID GROWING SEASON



BURNED



UNBURNED

LATE GROWING SEASON



 **USGS BURNED**

UNBURNED

Data Collection

- Collected data 42 times throughout the growing season from April 25 – November 13, 2001
- Counted number of flowering stems and flowers (flowering stems only for grasses)





Data Collection

- For *Ionactis linariifolius* (flax-leaved aster), *Solidago caesia* (blue-stemmed goldenrod) and *S. speciosa* (showy goldenrod), measured flowering height, number of flowering stems and number of flowering heads (*I. linariifolius*) or length of inflorescence (*Solidago* spp.)



Ionactis linariifolius
Flax-leaved aster
(*Aster linearifolius*)



Solidago caesia
Blue-stemmed
goldenrod



Solidago speciosa
Showy goldenrod

Data Manipulation

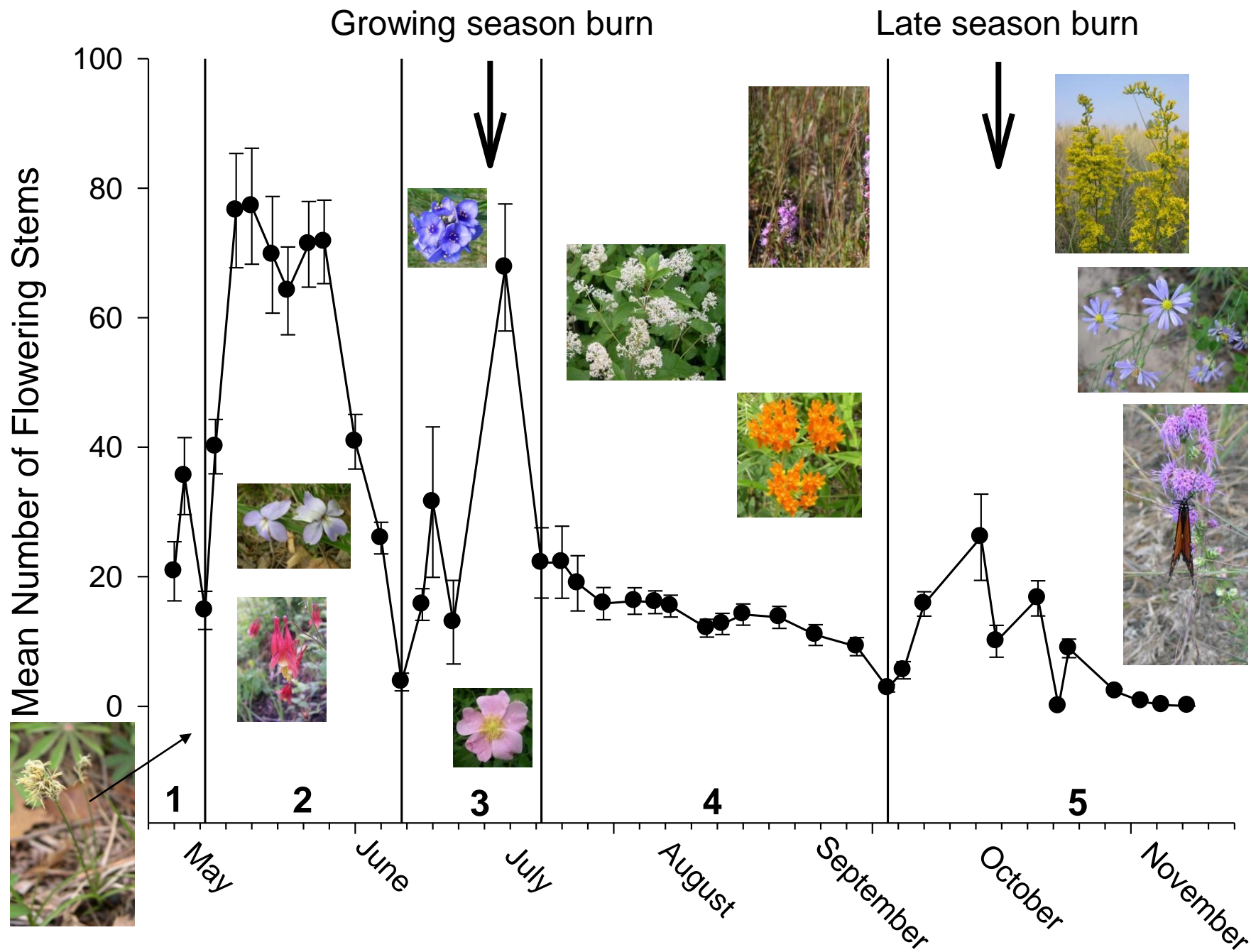
- Calculated total number of flowers and flowering stems across species by taking sum of all four sampling lanes
- Used these data for analysis



Determination of Phenoperiods

- Used mean number of flowering stems to delineate five distinct phenoperiods based on peak flowering times
- Overall analyses based on these five phenoperiods





Calculated Response Variables

- Mean number of flowering stems
- Mean number of flowers
- Flowering stems and total flowers of:
 - Perennial forbs
 - Graminoids*
 - Woody species

- Early Season (1 – 2)
- Mid Season (3 – 4)
- Late Season (5)



Data Analysis

- Analyzed overall data using randomized block ANOVA within each phenoperiod
- Flowering response ~ Burn Treatment + Block (random)
- Analyzed total stems and total flowers for the 20 species with the most flowering stems across phenoperiods

<i>Aquilegia canadensis</i>	wild columbine
<i>Arabis lyrata</i>	sand cress
<i>Carex pensylvanica</i>	Penn sedge
<i>Ceanothus americanus</i>	New Jersey tea
<i>Comandra umbellata</i> ssp. <i>umbellata</i>	false toadflax
<i>Euphorbia corollata</i>	flowering spurge
<i>Fragaria virginiana</i>	wild strawberry
<i>Helianthus divaricatus</i>	woodland sunflower
<i>Ionactis linariifolius</i>	flax-leaved aster
<i>Lithospermum caroliniense</i> var. <i>croceum</i>	hairy puccoon
<i>Lupinus perennis</i> ssp. <i>perennis</i> var. <i>occidentalis</i>	wild lupine
<i>Maianthemum canadense</i>	Canada mayflower
<i>Maianthemum stellatum</i>	starry false Solomon's seal
<i>Phlox pilosa</i>	sand prairie phlox
<i>Poa compressa</i>	Canada blue grass
<i>Poa pratensis</i>	Kentucky blue grass
<i>Solidago speciosa</i>	showy goldenrod
<i>Symphotrichum oolentangiense</i> var. <i>oolentangiense</i>	sky-blue aster
<i>Tradescantia virginiana</i>	common spiderwort
<i>Vaccinium pallidum</i>	late low blueberry

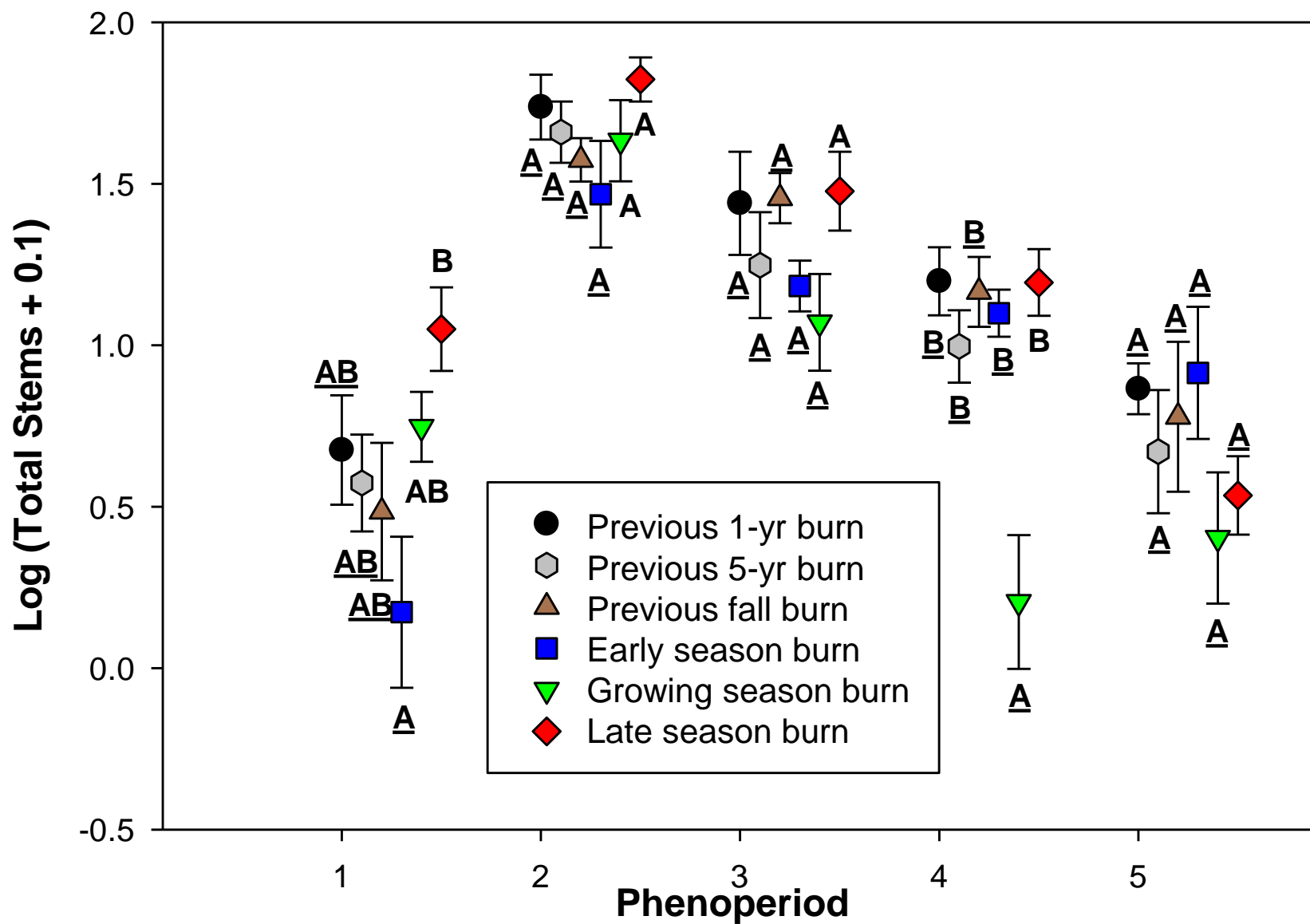
Data Analysis

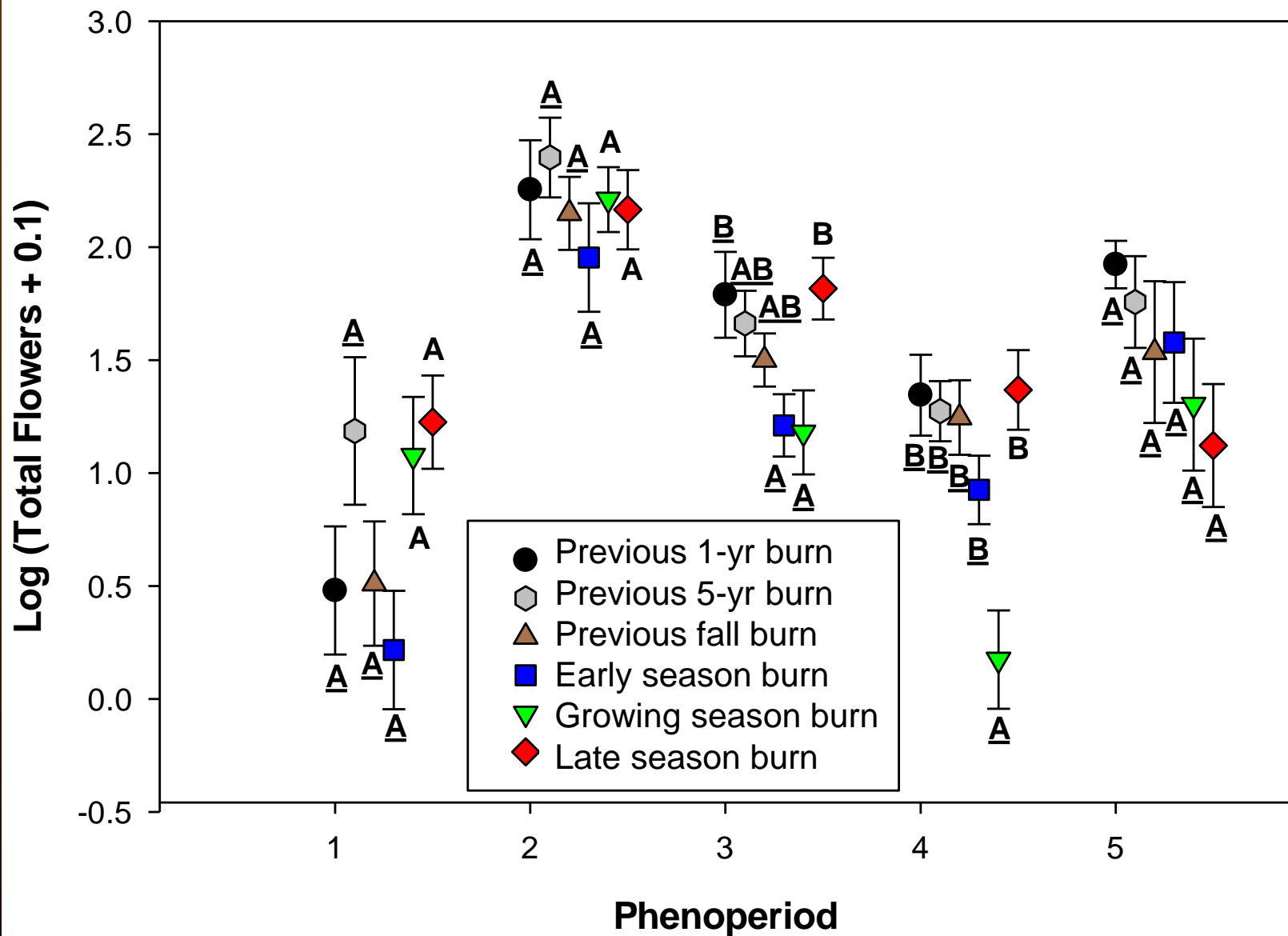
- Analyzed overall data using randomized block ANOVA within each phenoperiod
- Analyzed total stems and total flowers for the 20 species with the most flowering stems across phenoperiods
- Also examined Julian start date of flowering
- Used randomized block ANOVA to examine effects of season of burn on flowering stature of the three late blooming Asteraceae species
- Log transformed data to meet assumptions of normality

Results – Overall Flowering Data

- Collected data on 96 different plant species
- Total stems and flowers most affected by growing season burn



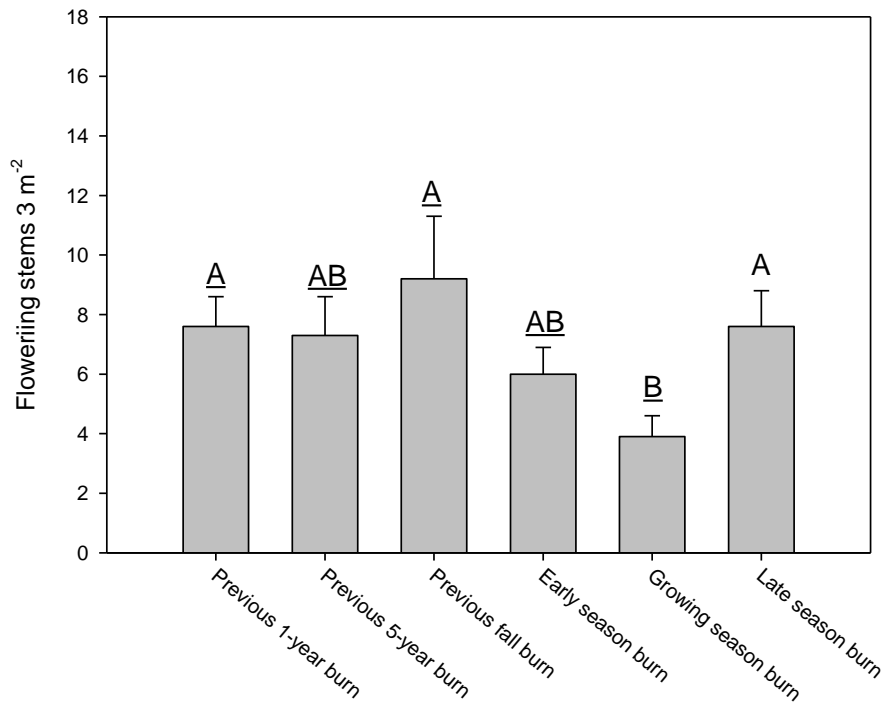




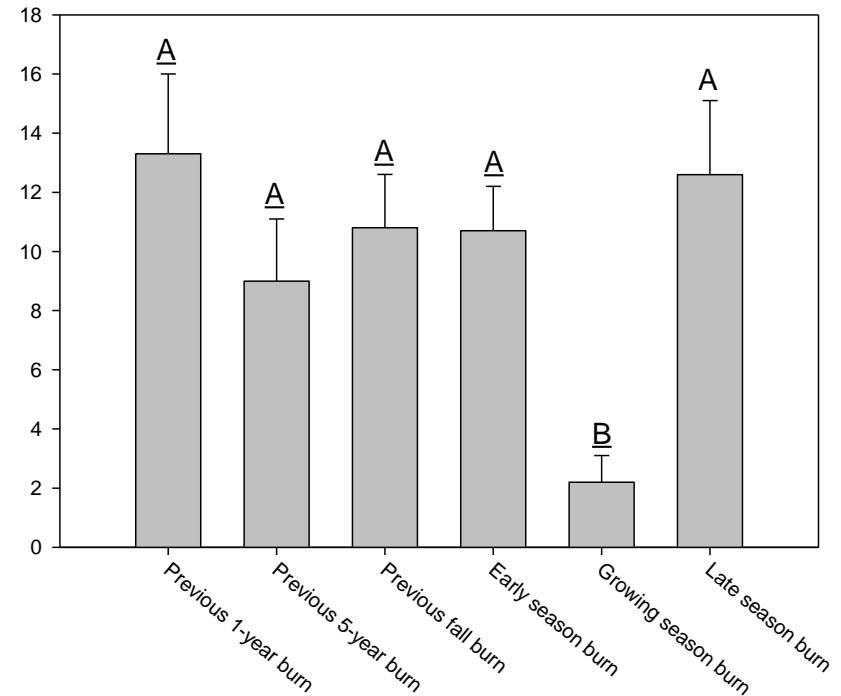
Perennial Forb Results

- Negative effect of growing season burn on perennial forbs flowering stems in phenoperiods 3 and 4

Perennial Forbs Phenoperiod 3

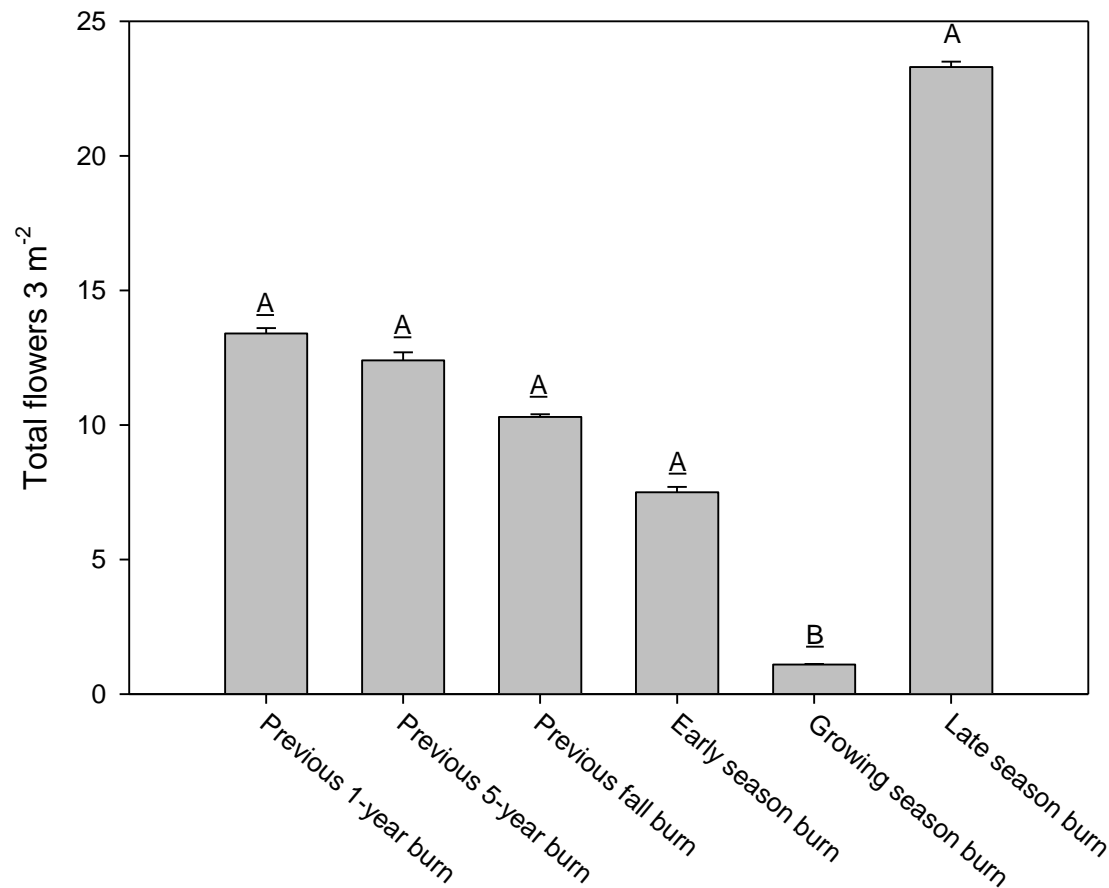


Perennial Forbs Phenoperiod 4



Perennial Forb Results

- Negative effect of growing season burn on total flowers of perennial forbs in phenoperiod 4



Graminoid Results

■ Graminoids negatively affected in phenoperiod 4 (growing season burn)

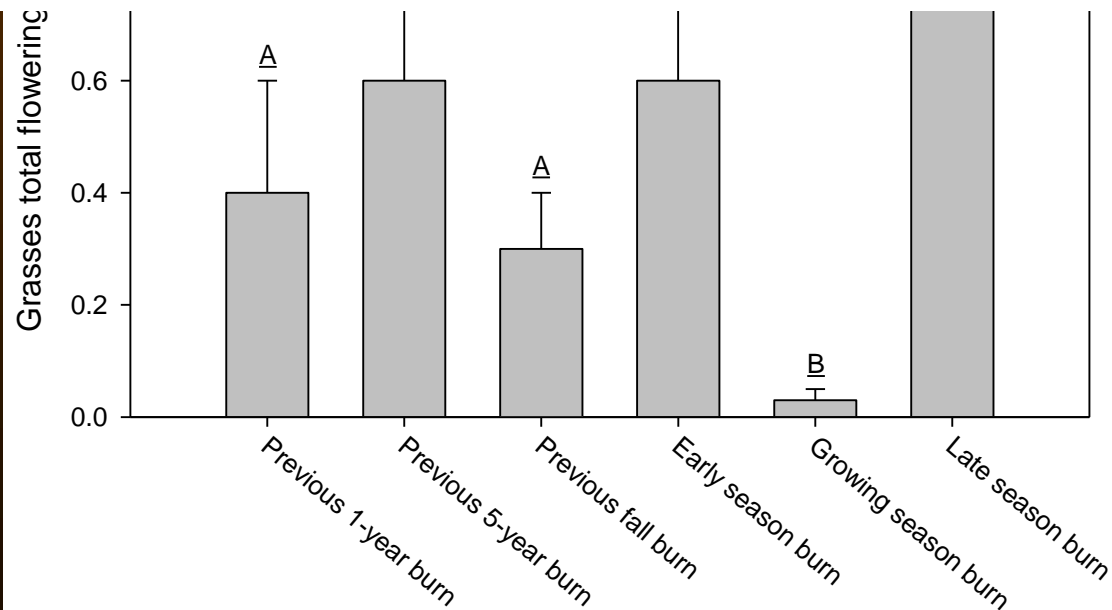
Bearded wheat grass – *Elymus trachycaulus subsecundus*

Purple love grass – *Eragrostis spectabilis*

Satin grass – *Muhlenbergia* spp.

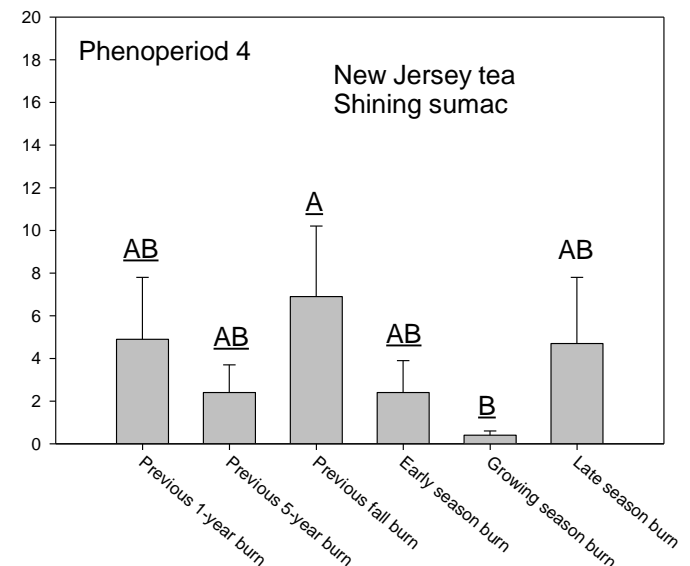
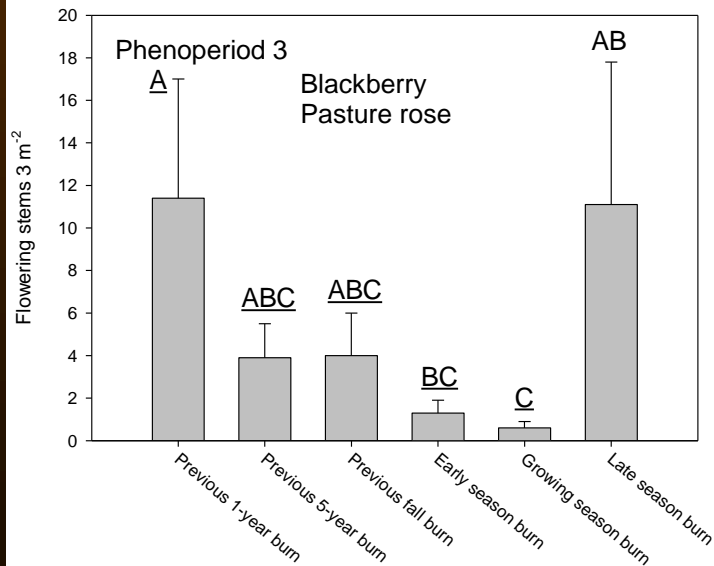
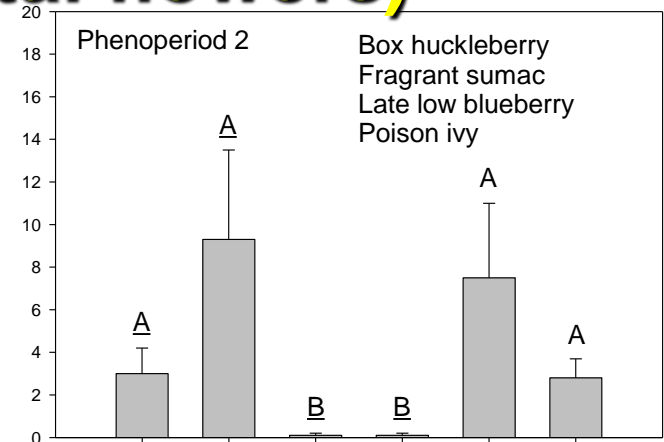
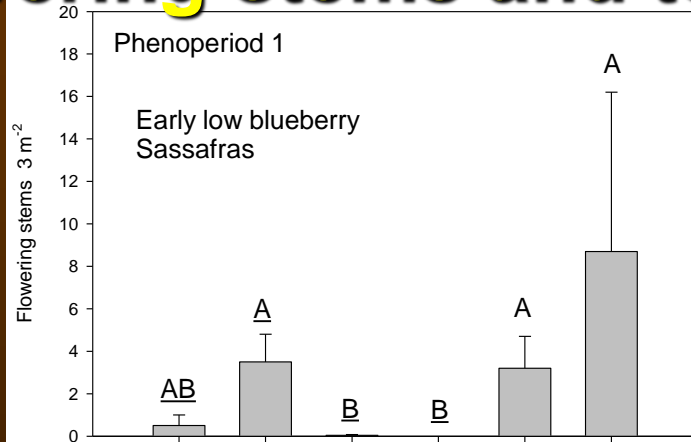
Switch grass – *Panicum virgatum*

Indian grass – *Sorghastrum nutans*



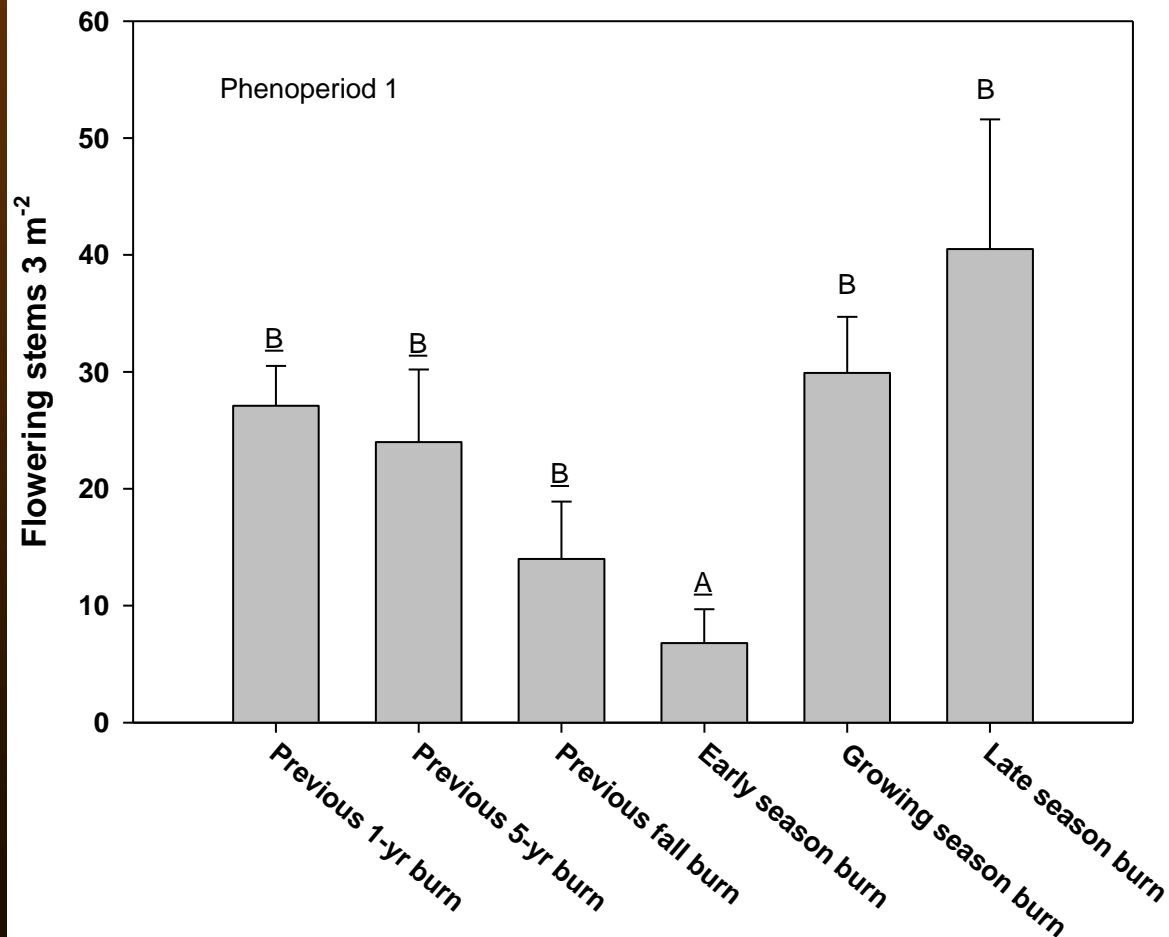
Woody Plant Results

■ Woody species negatively affected (flowering stems and total flowers)



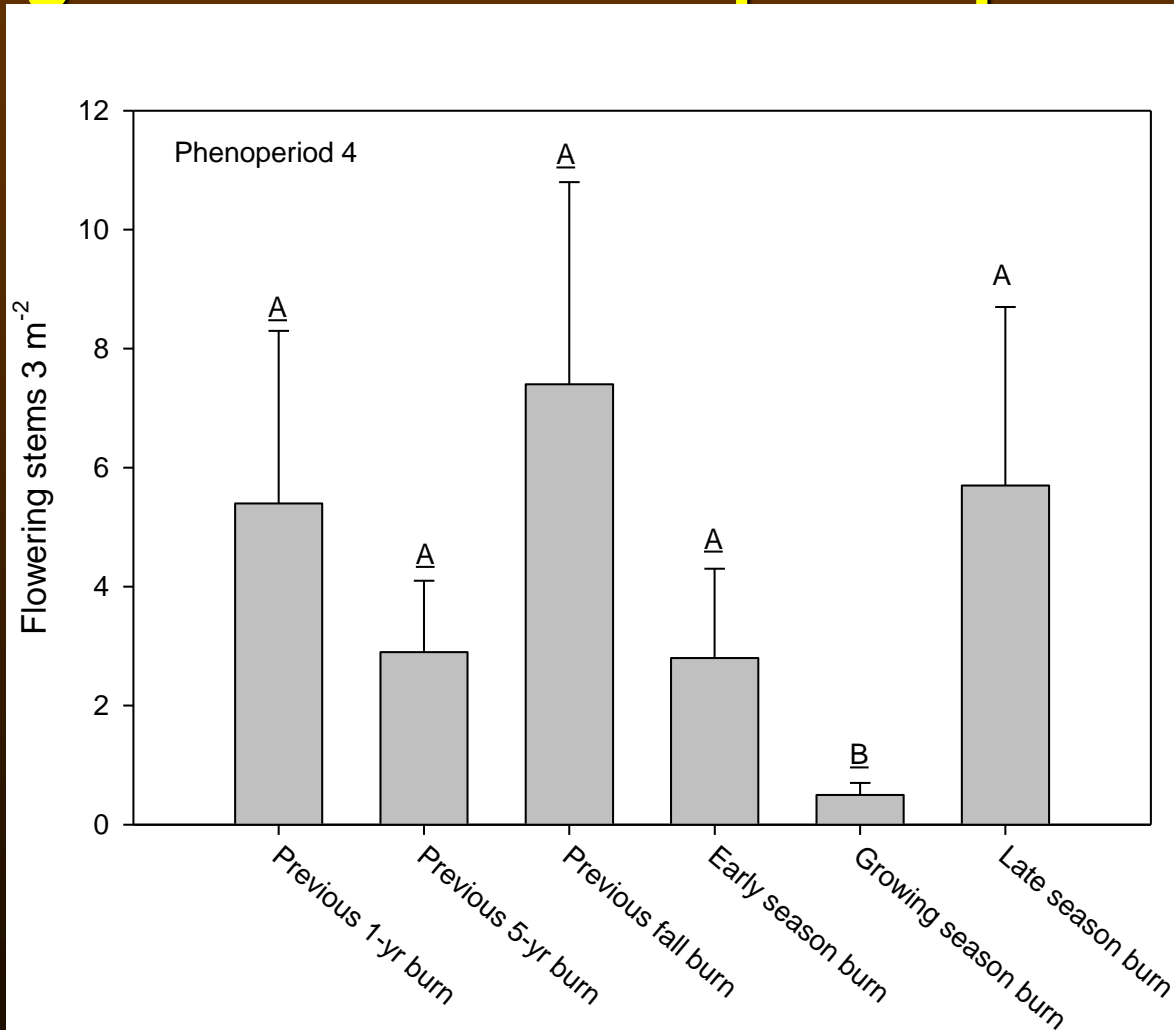
Early Flowering Season Results

- Early flowering species negatively affected by early season burn (flowering stems)



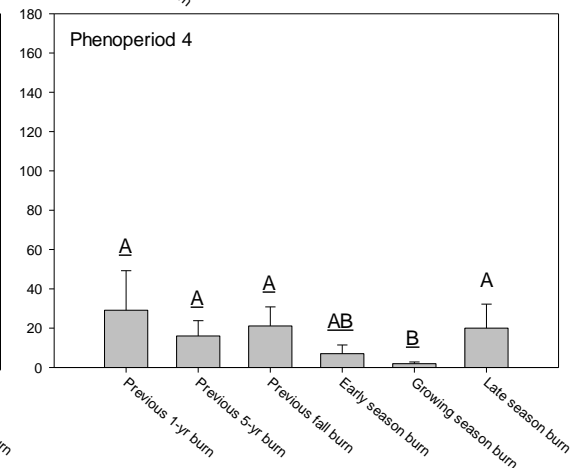
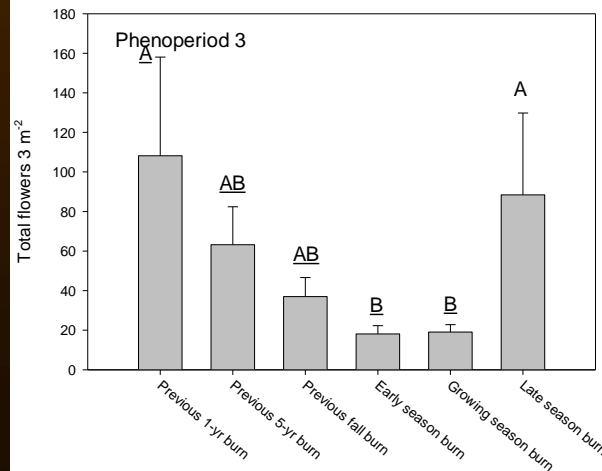
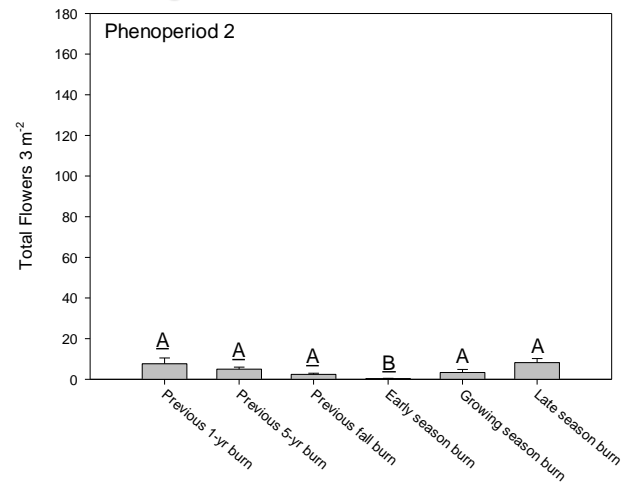
Mid-Season Flowering Results

- Mid season species negatively affected by growing season burns in phenoperiod 4



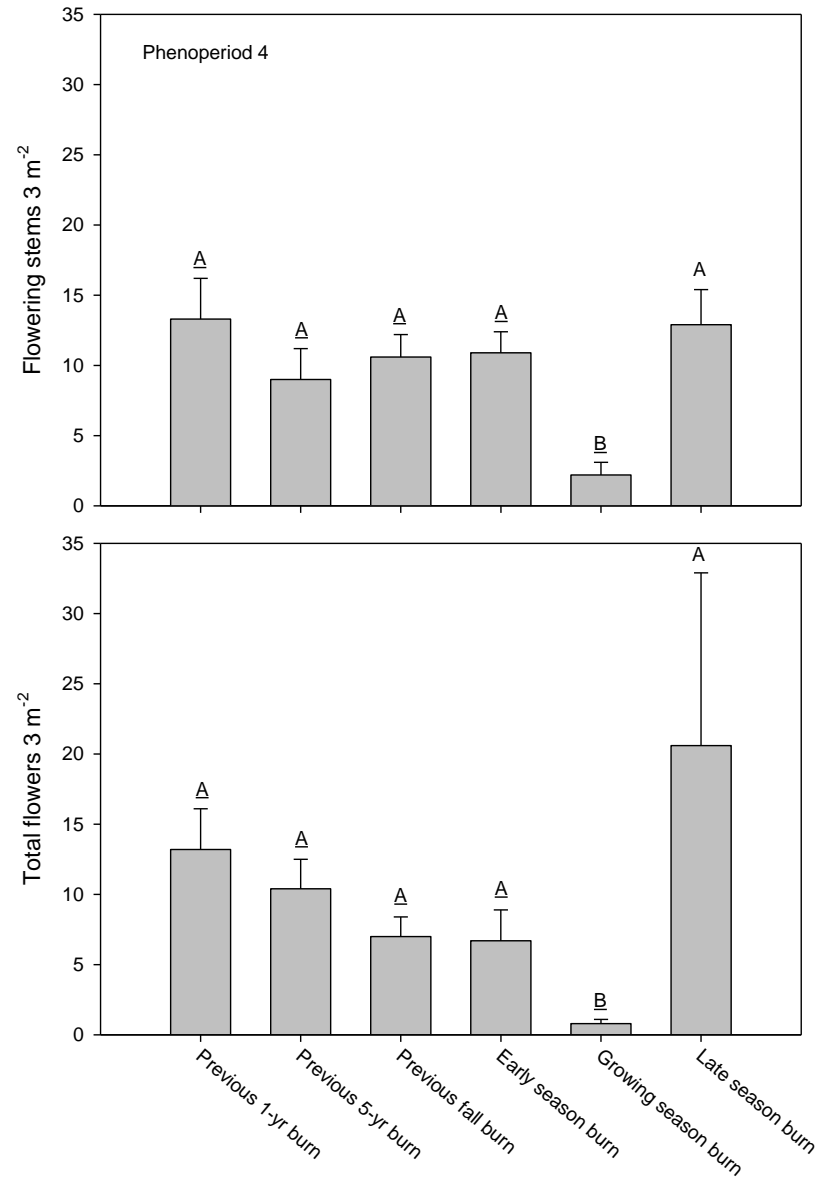
Mid-Season Total Flowers Results

- Mid-season species negatively affected by early and growing season burns in phenoperiods 2 – 4 (total flowers)



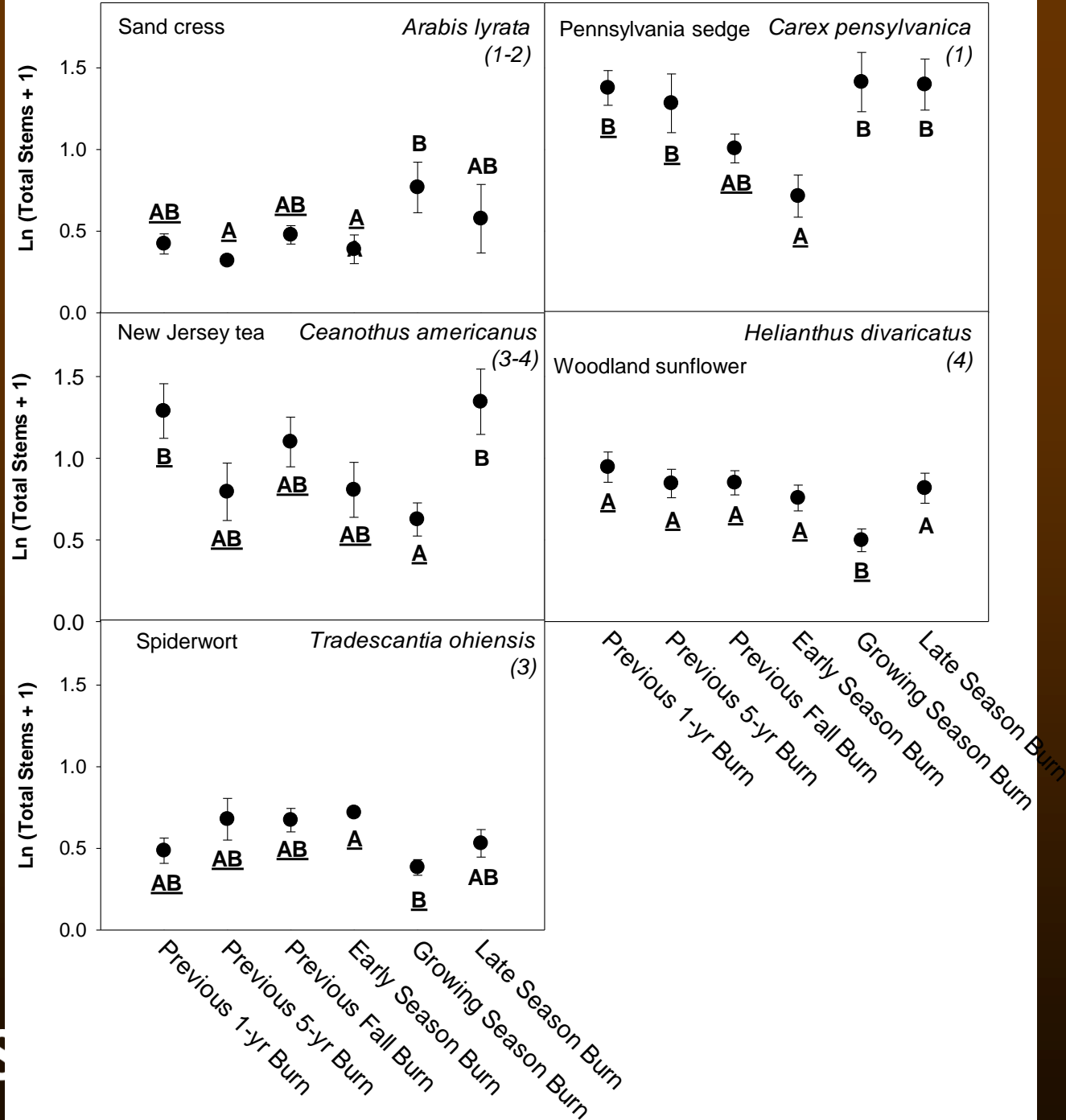
Late-Season Flowering Results

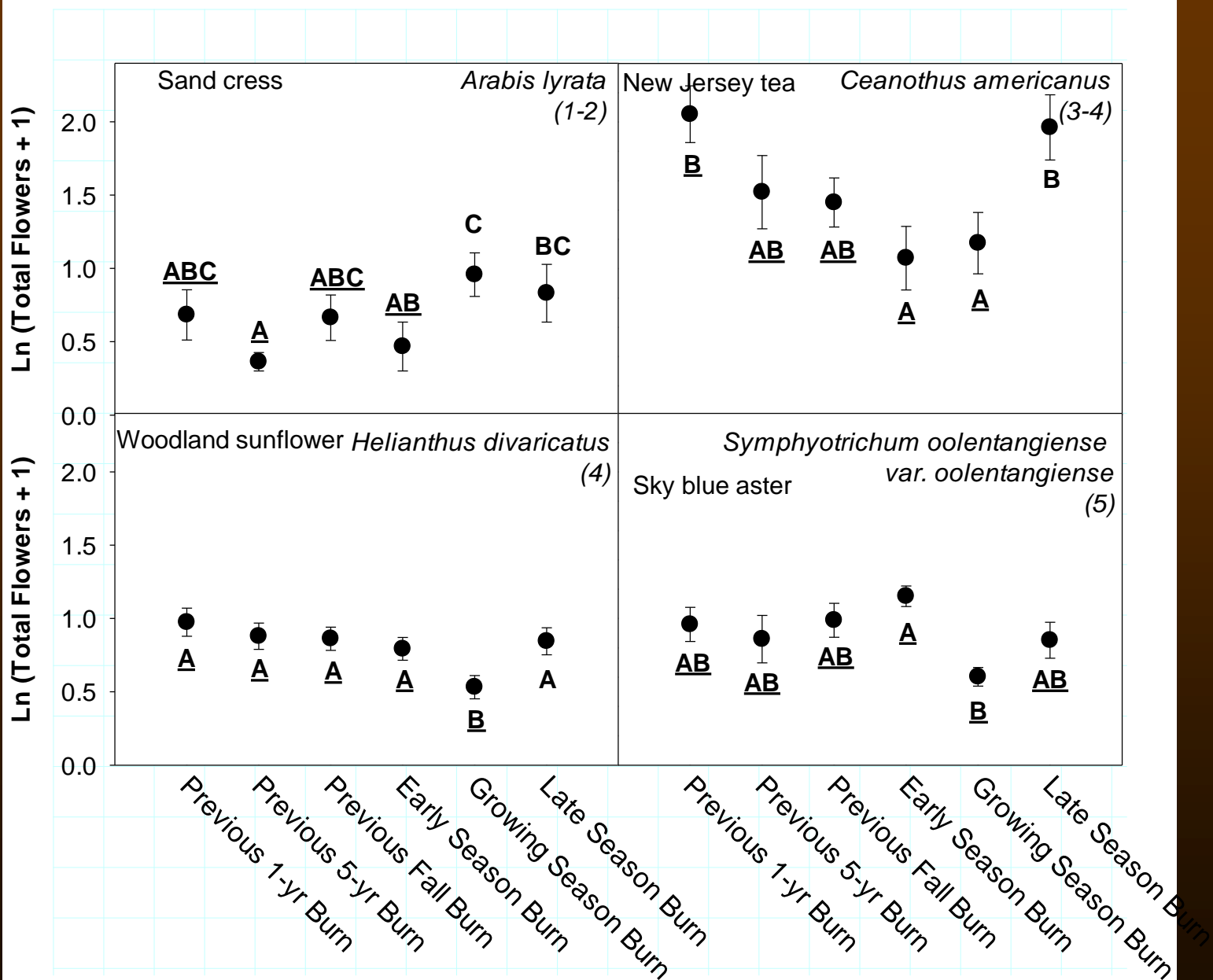
- Late blooming species negatively affected by growing season burn in phenoperiod 4 (flowering stems and flowers)



Results – Individual Species Data

- For flowering stems, only 5 species out of 20 showed a significant impact from season of burn
- For total flowers, only 4 species out of 20





Results – Individual Species Data

- For flowering stems, only 5 species out of 20 showed a significant impact from season of burn
- For total flowers, only 4 species out of 20
- Only 2 species showed a change in beginning of flowering:

Timing of Flowering



***Phlox pilosa*:**
20 day delay from
early season burn



***Tradescantia ohioensis*:**
13 day earlier bloom from
previous fall burn

Ionactis linariifolius

Flax-leaved aster

Normal



Stunted

Solidago caesia

Blue-stemmed goldenrod



Normal



Stunted

Solidago speciosa

Showy goldenrod

Normal



Stunted



Changes in flowering patterns

1. Decrease in the number of flowering stems or total flowers by a burn before the phenoperiod being examined.

Thus timing of burning will impact the species in the next flowering phenoperiod.

Changes in flowering patterns

2. Flowering was decreased as a result of two (previous fall or early) or three seasons of burn (previous 1-yr, previous fall, and early) in woody species only

This is a top killing effect not a seasonal effect. It can delay flowering for two years depending on time of floral induction.

Patterns

3. In mid- to late-flowering species, early season burning had less of an impact on flowering than the growing season burn.

These plants could flower at the usual phenoperiod. Either the plants were not up at the time of the early burn or could rapidly resprout.

Henderson 1990: plants that have a greater proportion of their biomass above ground will be damaged more.

Patterns

4. Flowering in sand cress (*Arabis lyrata*) was reduced after an early season burn.

The reduction of flowering in the same species in plots that had burned five years before was likely due to litter buildup suppressing seed germination.

Patterns

5. Some species showed delayed or expedited flowering as a result of early season burning.

Delay in prairie phlox might mean the photoperiod for flower induction can occur after the April burn.

Expedited flowering in spiderwort after a fall burn might be the result of earlier warm up of soil due to removal of leaf litter.

Discussion

- If plants normally bloom after a burn (early season burn) or during a burn (growing season burn) flower production decreases
- Blooming of woody species was strongly impacted by burning irrespective of season
- Surprisingly, did not see an increase in flowering stem density or flower density for early species from previous fall burn or late species for early season burn
- Might have seen increased flowering stem density and floral density in second year

Mechanisms for floral increase

- increased light levels; Norden & Kirkman 2004
- Physical removal of stems; McConnell & Menges 2002
- Nutrient pulses and light; Verboom et al. 2002
- Time of burn relative to photoperiod; Risberg & Granstrom 2009
- Presence of latent flower buds that survive fire; Henderson 1990

Discussion – When to burn?

- Annual burns are often performed to maintain ground layer richness and diversity at expense of woody species
- Spring and fall burns are not necessarily the “same”
- Repeated spring burning may preclude certain early season species from flowering
- May need to let plants recover so that they can flower between burns, and then burn every few years

Woody Species

- Annual burning will prevent shrubs from blooming, especially spring flowering species and those requiring flower induction on second year growth.
- Will make fruit resources for wildlife less available.
- Burns less frequently than 4 times per decade fail to control rampant resprouting of woody shrubs. Haney, A. et al. 2008. Gradient analysis of an eastern sand savanna's woody vegetation, and its long-term responses to restored fire processes. *Forest Ecology and Management* 256(8): 1560-1571.

Fire season plays out on these competing components?

- Early season forbs
- Mid-season forbs
- Late-season forbs
- Grasses (C3 vs C4)
- Shrubs
- Oak/sassafras

Phenoperiod is a good temporal criterion for determining fire effects on flowering whereas life form is a poor criterion because species with similar life forms often bloom at different times.

The effects of fire season on oak savanna groundlayer flowering and life forms suggest that prescribed burning be conducted as a mosaic in time to prevent single season burning from negatively impacting flowering and fruiting of any particular phenological suite of species.

- **A similar recommendation was made based on studies of dominant grasses in long-leaf pine savannas:**

Shepherd, B. J., D. L. Miller, et al. (2012). "Fire Season Effects on Flowering Characteristics and Germination of Longleaf Pine (*Pinus palustris*) Savanna Grasses." *Restoration Ecology* 20(2): 268-276.

Acknowledgements

- **LuAnn Forste, Lisa Schelling, Gary Glowacki, Helen Streitelemeier, Eric Garza**
- **Resource management staff of Indiana Dunes National Lakeshore (INDU)**
- **INDU fire staff**
- **Jean Adams, GLSC Statistician**

