How important is it to mimic natural fire regimes in the southeastern Coastal Plain?

Reed Noss, University of Central Florida

Backing Fire
Oil on canvas
by Philip Juras

Only recently has the idea emerged that conservation of entire fire-adapted floras and ecosystems depends on understanding historical fire regimes and on managing human fire regimes so that they mimic historical fire regimes.

Platt et al. (2015)

Why It is So Important to Get Fire Management "Right" in the Coastal Plain

Global Biodiversity Hotspot #36

Diversity and Distributions, (Diversity Distrib.) (2015) **21**, 236–244

ion Biogeography

BIODIVERSITY VIEWPOINT

How global biodiversity hotspots may go unrecognized: lessons from the North American Coastal Plain

Reed F. Noss[1*], William J. Platt[2], Bruce A. Sorrie[3], Alan S. Weakley[3], D. Bruce Means[4], Jennifer Costanza[5] and Robert K. Peet[6]

- 1816 endemic plants, plus high endemism in many other groups
- **ca. 85% of endemic plants are associated with fire-dependent pine savannas/woodlands and embedded communities**
- ca. 86% of original vegetation and 96% of savannas and woodlands highly altered or converted

Components of a fire regime, which might be mimicked

- Frequency
- Seasonality
- Intensity/Severity
- Extent/Size
- Heterogeneity/Patchiness

Evidence for a long evolutionary history of fire in a region

- Charcoal in sediments
- Paleoclimate proxies (e.g., sediment layers) showing dry/wet annual seasonal cycles typical of savannas
- Ancient fossils of plants we know today are fire-adapted
- Ancient fossils of vertebrates associated with savannas and other usually fire-maintained habitats
- High endemism in fire-prone ecosystems
- High incidence of fire-adaptive traits among extant species

Fire-dependent Ecosystems

Three of the Biggest Controversies among Fire Ecologists and Managers

- The influence of native Americans on fire regimes prior to European settlement, and how they may have altered selective pressures
- The importance of fire seasonality (vs. just fire frequency)
- Pyrodiversity begets biodiversity?

Did Indians change fire regimes in the Coastal Plain enough to alter the evolutionary environment?

- Humans are most likely to change fire regimes in regions that contain vegetation susceptible to burning, but are **ignition-limited** (Pinter et al., 2011, *Quat. Sci. Rev*.)
- Not the case here – landscapes possibly **saturated with fire** due to frequent lightning ignitions
- Indians used fire for many purposes, but unequivocal first-hand reports of **landscape-scale burning** are lacking prior to late 1700s (unlike some other regions)

George Catlin, *Prairie Meadows Burning*

Lightning vs. Humans as Igniters of Fires in the Holocene Eastern U.S.

Journal of Sustainable Forestry, 34:30–48, 2015
Copyright © Taylor & Francis Group, LLC
ISSN: 1054-9811 print/1540-756X online
DOI: 10.1080/10549811.2014.973605

Taylor & Francis
Taylor & Francis Group

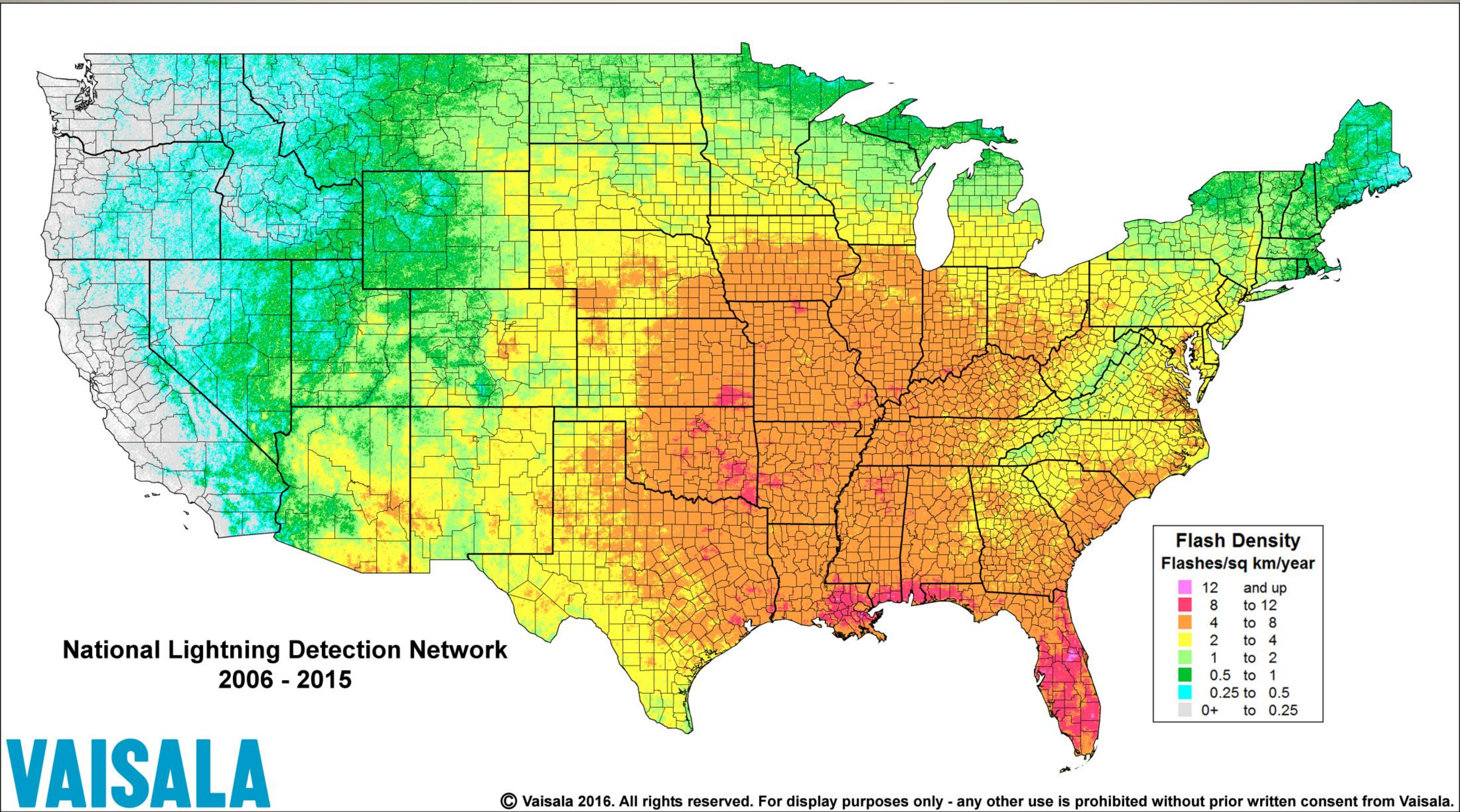
Exploring the Early Anthropocene Burning Hypothesis and Climate-Fire Anomalies for the Eastern U.S.

MARC D. ABRAMS[1] and GREGORY J. NOWACKI[2]
[1]*Department of Ecosystem Science and Management, Penn State University, University Park, Pennsylvania, USA*
[2]*USDA Forest Service, Eastern Regional Office, Milwaukee, Wisconsin, USA*

Climate dominated human activity as a control of fire regimes and vegetation during the early and middle Holocene. During the late Holocene, humans became the main source of fires in the northern and central regions.

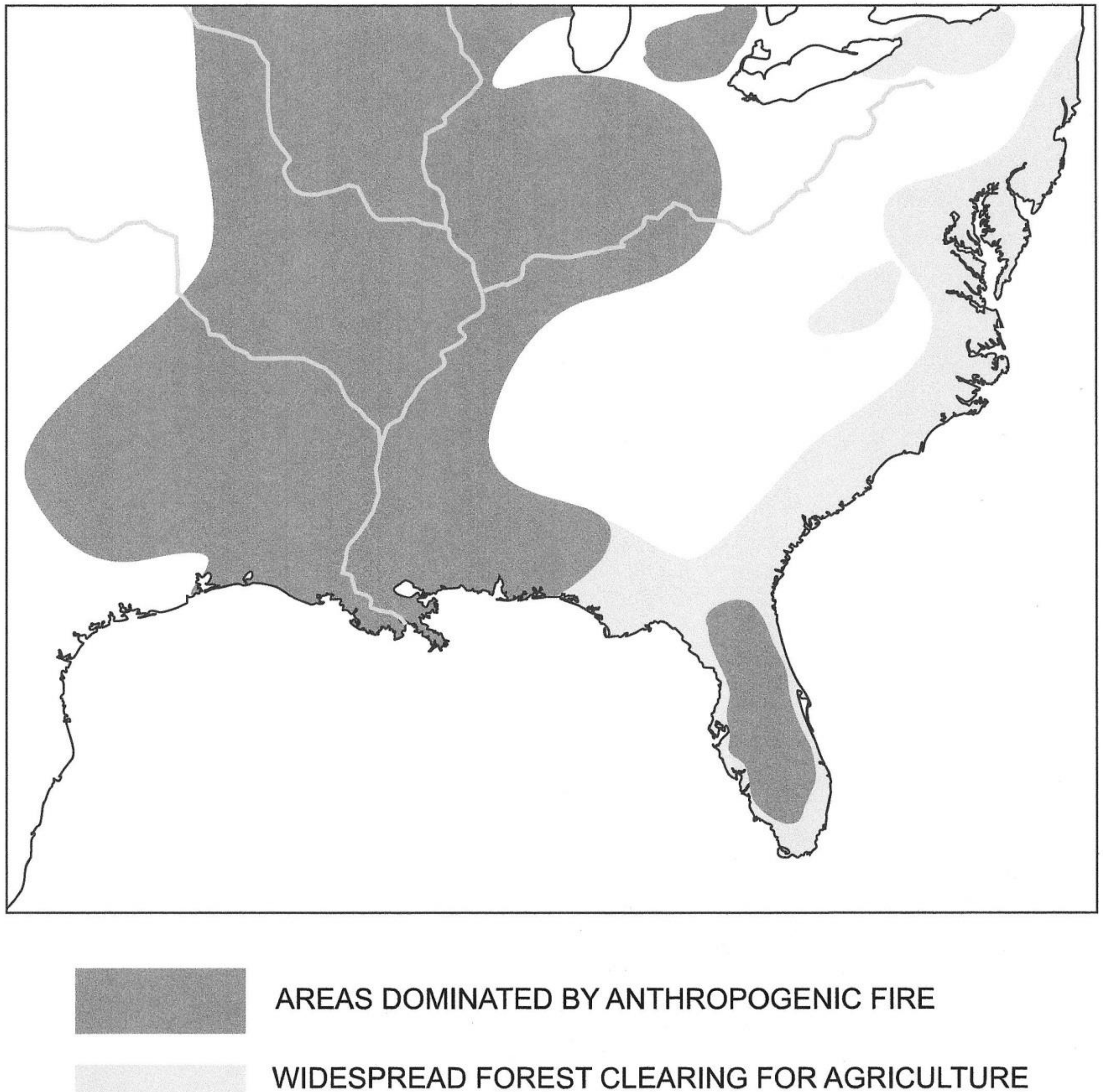
“The southeastern Coastal Plain appears to be one region where frequent natural lightning fires, facilitated by the occurrence of dry lightning, may have been adequate to sustain pyrogenic vegetation…with or without Indian burning.“

Lightning frequency in the Southeastern Coastal Plain, combined with highly combustible vegetation, is more than enough to explain dominance of the region by fire-dependent ecosystems



© Vaisala 2016. All rights reserved. For display purposes only - any other use is prohibited without prior written consent from Vaisala.

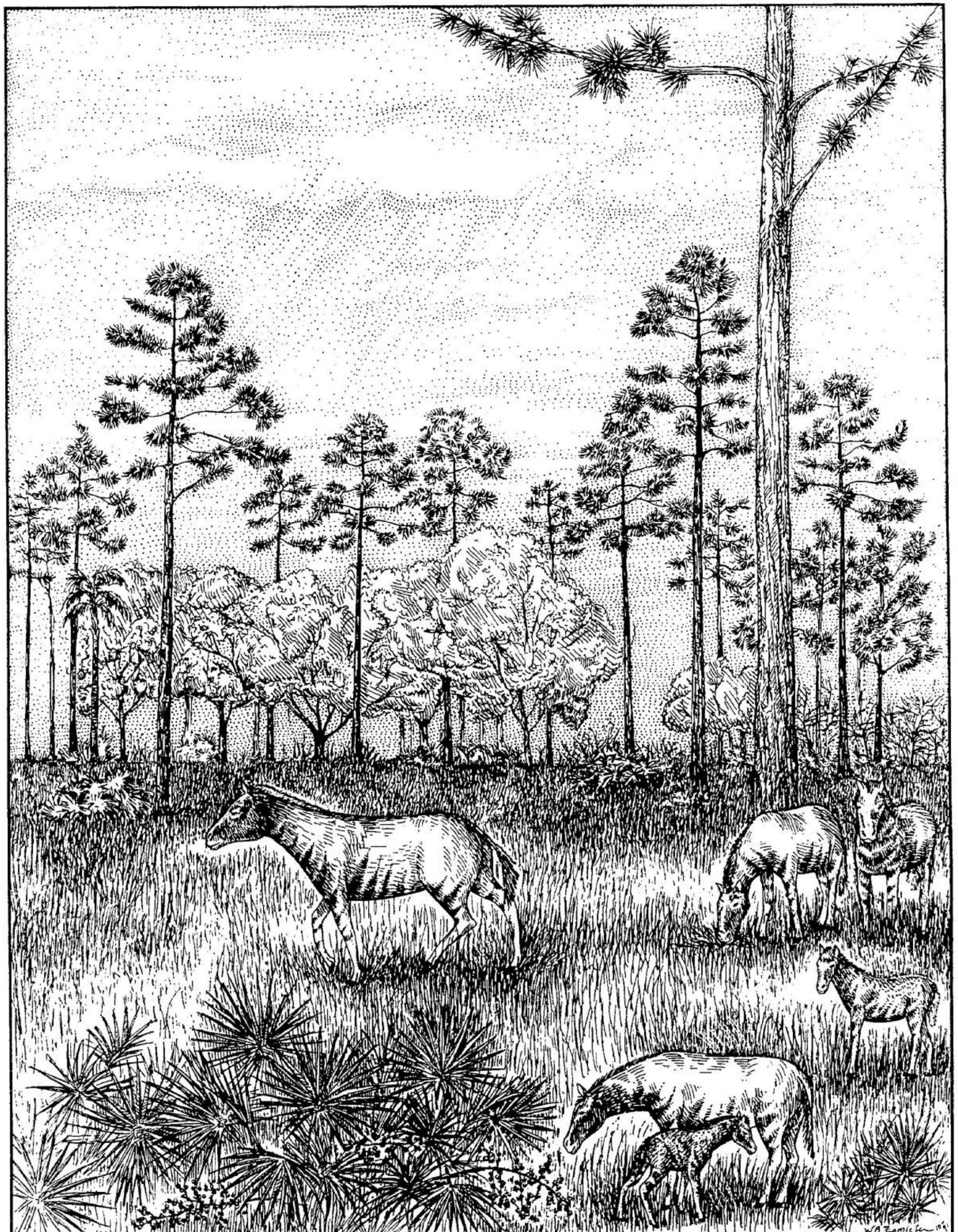
Humanized landscapes prior to European settlement, as imagined by Charles Mann (2005; *1491: New Revelations of The Americas before Columbus*) – <u>based on no data</u>



Vegetation in the Coastal Plain has not changed all that much for millions of years

Graham (1999) describes vegetation in the Coastal Plain from the Middle Eocene (ca**. 45 Ma**; Claiborne Formation, western KY and TN) much like that in Florida today: "On sandy flats, but removed from the tidal influence, *Pinus* and an understory of *Sabal-Serenoa*-type palms and *Ephedra* were present (early sand pine scrub association)."

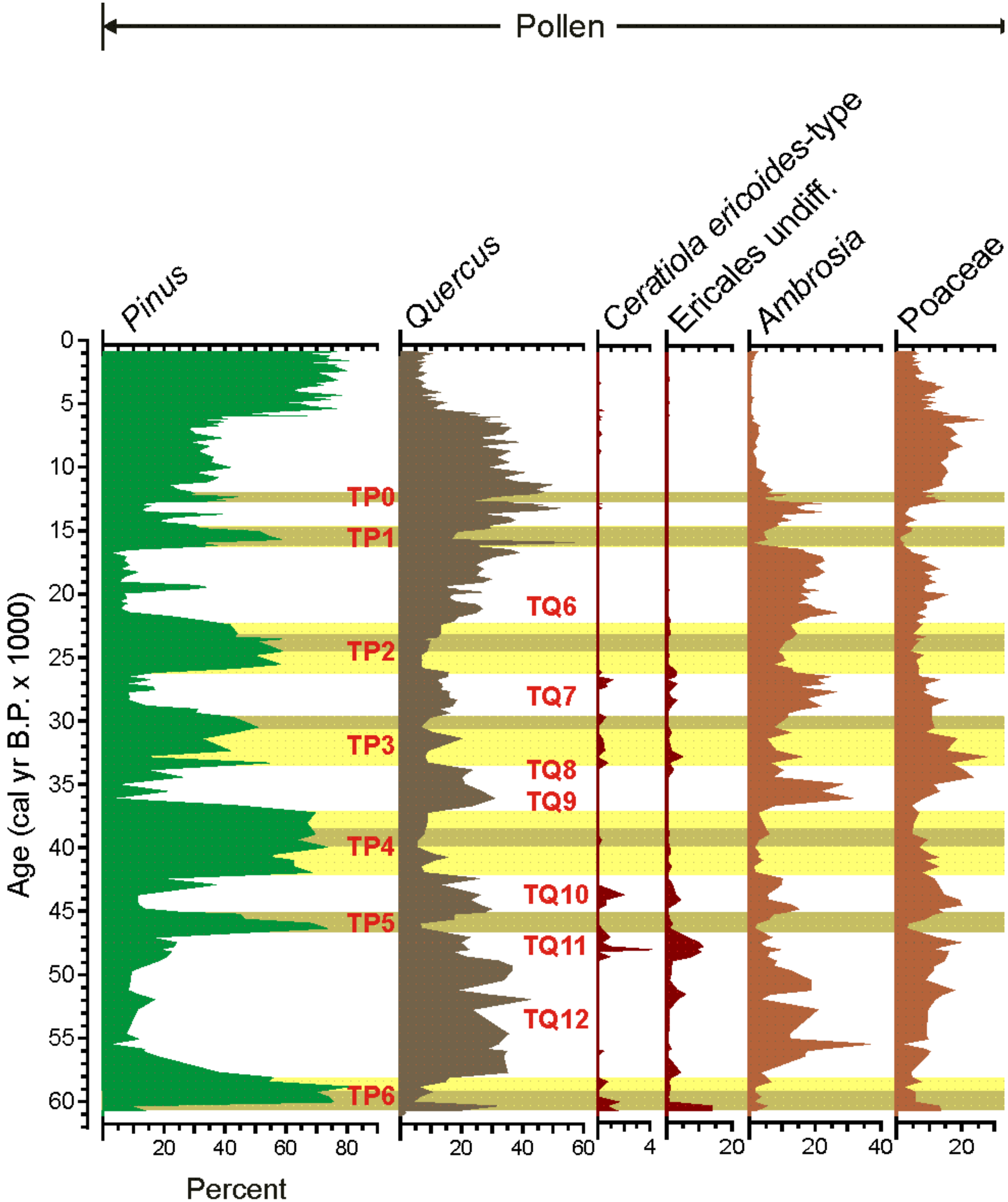
Serenoa repens present range



Savanna in the Southeastern Coastal Plain goes way back!

Reconstruction of pine savanna with *Parahippus leonensis*, a three-toed horse, from the Early Miocene (ca. 18 Ma) Thomas Farm site in northern peninsular Florida.

From MacFadden (1992)



Paleoecology:

Pine-oak cycles over 61,000 years in Central Florida (Lake Tulane)

Pine in wet, warm periods
Oak in dry, cool periods

Grasses (and hickory) covary with oak (scrub vs. dry prairie or oak savanna)

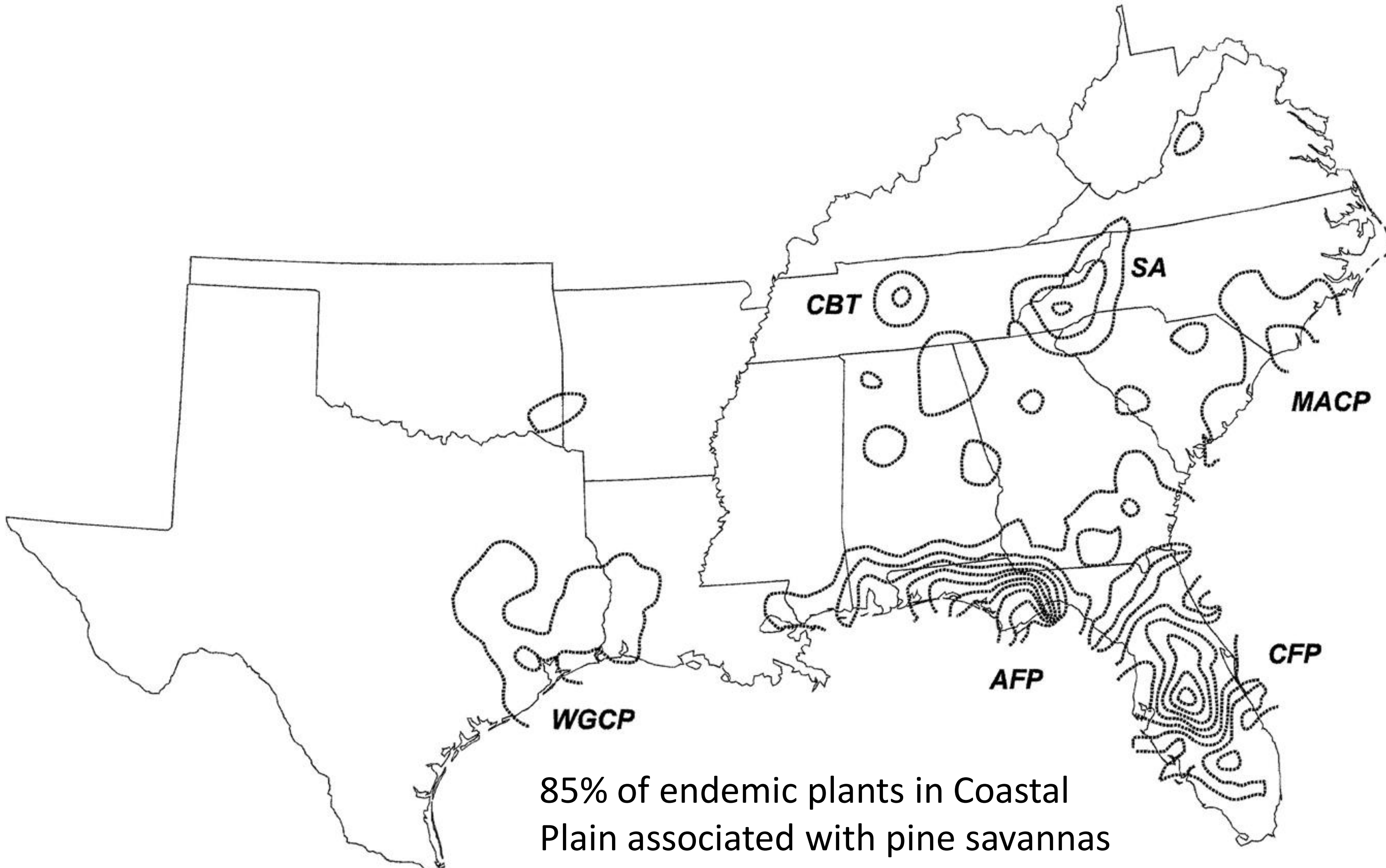
Source: E. Grimm
Adapted from Grimm et al. (2006, *Quat Sci Rev*)

Picoides borealis
Red-cockaded Woodpecker

Found in Pleistocene deposits
In Florida 180,000-120,000 BP
(Platt 1999, Means 2006)

Evidence of antiquity: Centers of plant endemism

Plants associated with **fire-dependent ecosystems** make up the majority of the endemic taxa, and many of these taxa are ancient. From Estill and Cruzan (2001)



85% of endemic plants in Coastal Plain associated with pine savannas or embedded communities

Fire-adaptive traits

"Adaptive traits are those that provide a fitness advantage in a given environment. There are many plant traits that are of adaptive value in the face of recurrent fire and these vary markedly with fire regime."

(Keeley et al. 2011, *Trends Plant Sci*)

Species are not adapted to fire *per se* but rather to specific fire regimes that they experience during their evolutionary histories

Heading Fire
By Philip Juras

Types of fire regimes

- **Stand-maintaining fires:** usually low-severity surface fires; if they occur frequently enough, they maintain a stand in a characteristic grassland or open-canopy savanna or woodland condition.
- **Stand-replacing fires:** usually high-severity fires that burn through the canopy or "crown" of the vegetation. These fires topkill or complete-kill many or most of the canopy trees and shrubs, which then must be "replaced" by resprouting, germination of seeds in the soil seed bank, reseeding from a canopy seed bank (e.g., from serotinous cones), or dispersal from outside the stand.

Types of fire regimes (cont.)

- **Smoldering fires:** ground fires that burn organic soils, often over an extended period of time. These fires typically occur in wetlands.
- **Rare or infrequent fire:** characteristic of moist, topographically protected sites that uncommonly burn under natural conditions, except along their edges or more completely during extreme drought. This fire regime overlaps with the stand-replacing fire regime.

Thick bark offers protection from damage by surface fires

<u>Fire-protective thick bark in *Pinus* arose in the Cretaceous, ca. 126 Ma.</u>

- By 89 Ma **two alternative strategies** in *Pinus*:

1) thick bark and branch shedding
2) serotiny with branch retention

He et al. (2012, *New Phytologist*)

Bark of blackjack oak (*Quercus marilandica*), comprising over half of the basal diameter (bark:wood = 0.55). Bark is thickest at base, within the flame zone.

Hammond et al. (2015, *Ecosphere*)

Resprouting after fire: an ancestral trait

"Topkill" of woody plants is followed by mobilization of carbohydrates stored in roots and underground storage organs for growth of new stems and leaves - greater for dormant season fires than growing-season fires

Robertson and Hmielowski (2014, *Oecologia)*

Saw palmetto (*Serenoa repens*) rhizome - Monotypic genus endemic to Southeastern Coastal Plain

Additional fire-adaptive traits

- Heat and smoke stimulate germination of plants from seed bank (e.g., via karrikins produced by burning plant material)
- Underground storage organs form underground forests

Bejaria racemosa
- a geoxyle (underground tree)

Longleaf pine (*Pinus palustris*) grass stage (extended seedling, 5-15 years)


Rapid "bolting" stage of longleaf pine growth
- Quickly escape the flame zone!

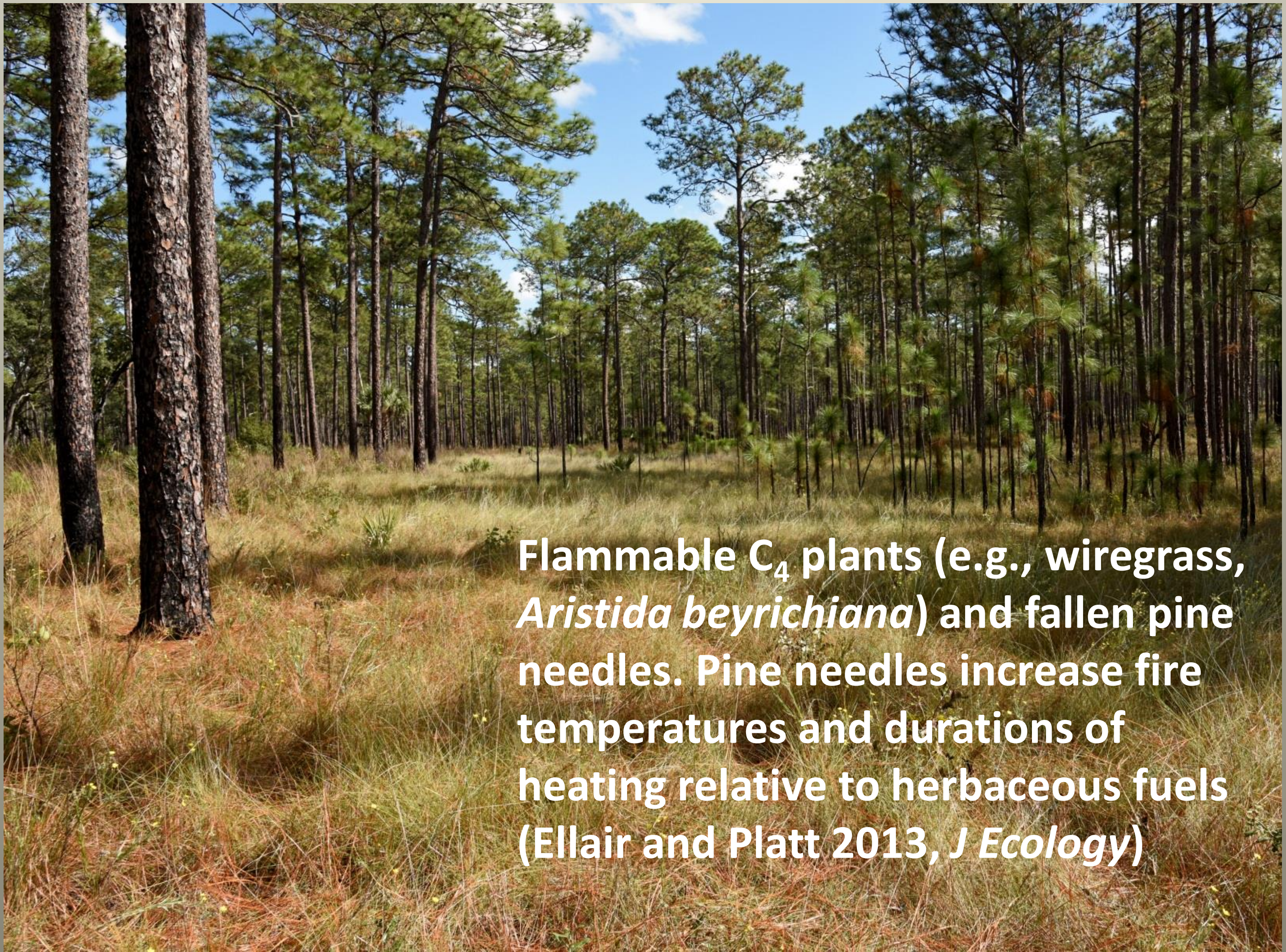
Pond pine well adapted to variable fire regime (ca. 3-30 year interval)

Pinus serotina
with epicormic branching after fire
(also resprouting from root collar, serotinous cones, medium-thick bark)

Promoting and Facilitating Fire:

Pyrogenicity and Niche Construction

Natural selection by fire for plant traits that increase flammability favors plants with such traits over others more sensitive to fire (Mutch 1970, *Ecology*)



Promoting and Facilitating Fire

Photo by Jean Huffman

Cabbage palm (*Sabal palmetto*) - Carry fire into the canopy, spread fire through flaming firebrands, torch out nearby trees, and create open space for regeneration

Ground-nesting birds in fiery habitats typically re-nest when nests are destroyed by fire (analogous to resprouting in plants) – and require fire to maintain habitat

Bachman's Sparrow (*Peucaea aestivalis*)

Fire management for the Florida Grasshopper Sparrow

The FGSP prefers dry prairie burned during the current or previous year, with no successful reproduction known for sites unburned for > 24 months

(Ammodramus savannarum floridanus)

Many amphibians are also adapted to frequent fire – and require it

Journal of Herpetology, Vol. 49, No. 3, 364–370, 2015
Copyright 2015 Society for the Study of Amphibians and Reptiles

Juvenile Recruitment of Oak Toads (*Anaxyrus quercicus*) Varies with Time-Since-Fire in Seasonal Ponds

Clay F. Noss[1,2] and Betsie B. Rothermel[1]

[1]*Archbold Biological Station, Venus, Florida, USA*

In seasonal ponds burned 4 mo, 3-4 yrs, and 11 yrs in the past, mean survival was significantly higher In the most recently burned ponds.

Survival was significantly positively associated with pH, which was highest in the most recently burned ponds.

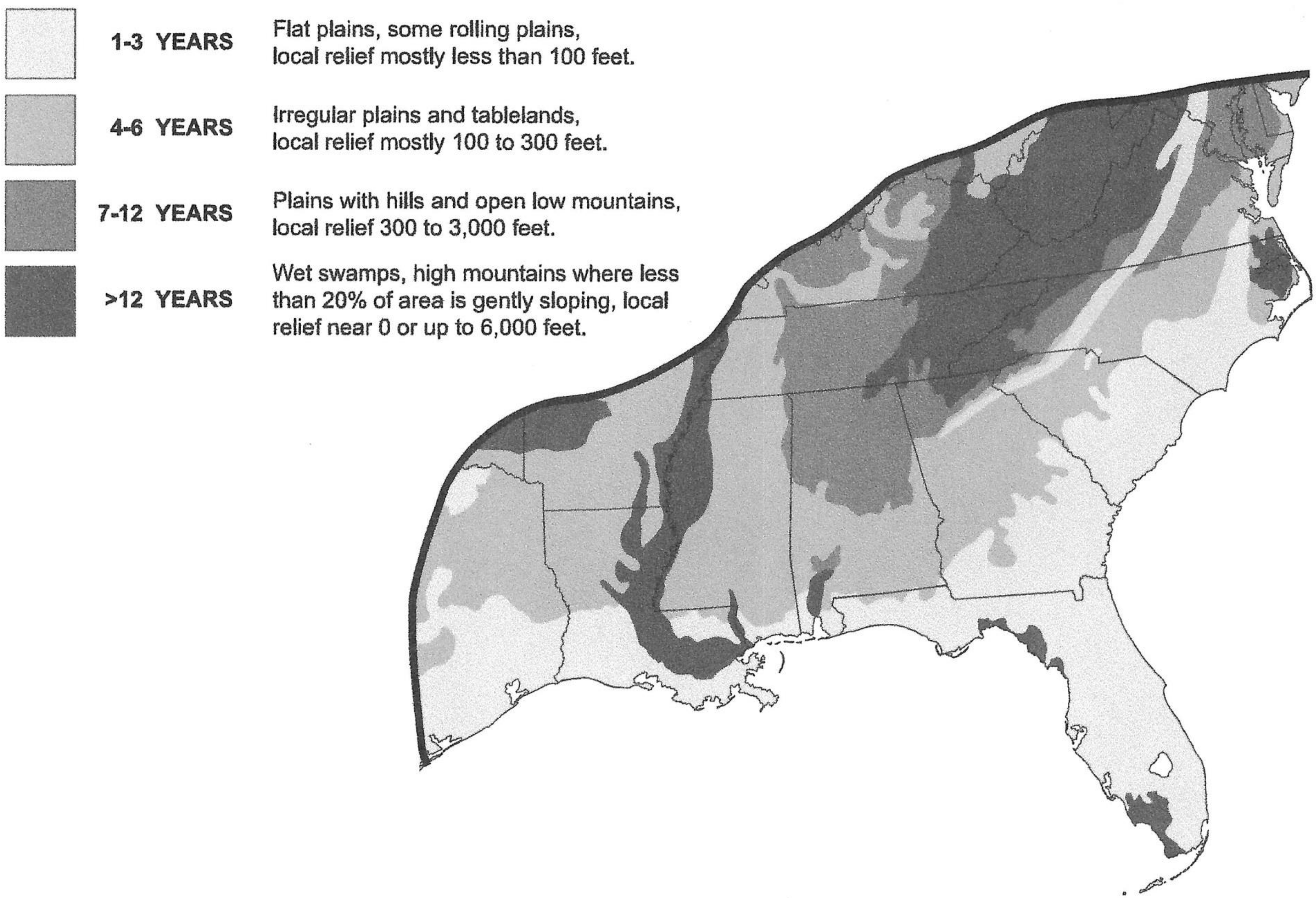
Photo by Clay Noss

What do evolutionary history, patterns of endemism, fire-adaptive traits, and fire-dependent ecosystems have to do with the management question of "How often and during what times of the year should I burn the lands I am responsible for managing?"

Everything!

(if we care about maintaining and restoring native biodiversity)

Presettlement Fire Regimes (for most fire-exposed portions of the landscape)
Adapted from Frost (1995, 1998, 2006, pers. comm.)



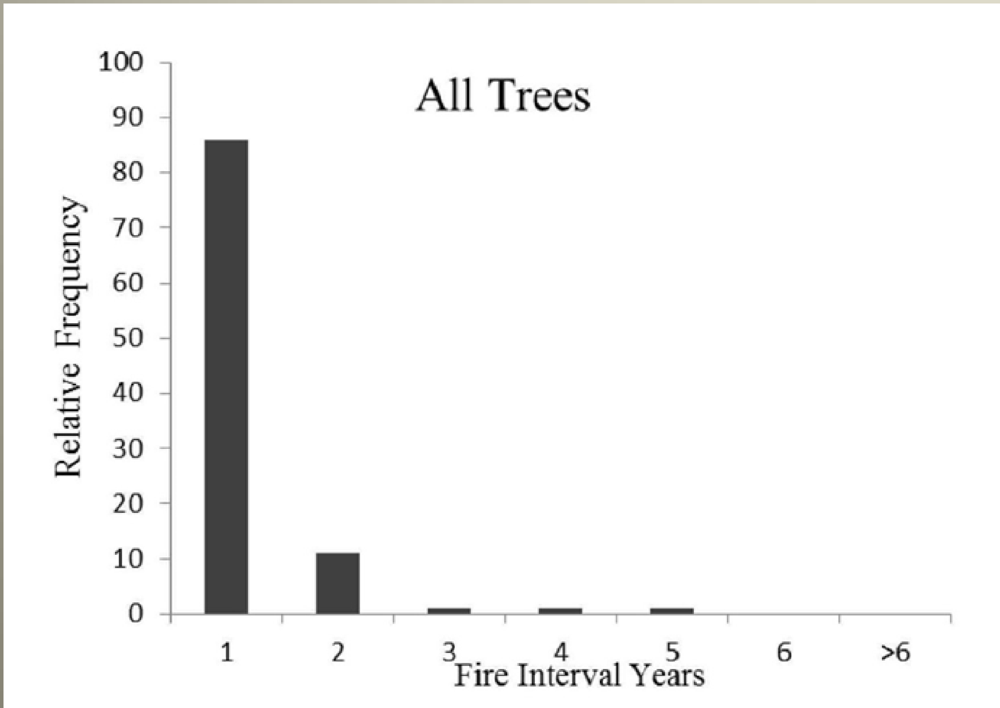
Huffman (2006, dissertation): *Historical fire regimes in southeastern pine savannas*

St. Joseph Bay Savanna:

"... 2-3 year fire return interval between 1679 and 1868. Variability in fire return intervals was low, with 92% of all fires occurring at < 5 yr intervals."

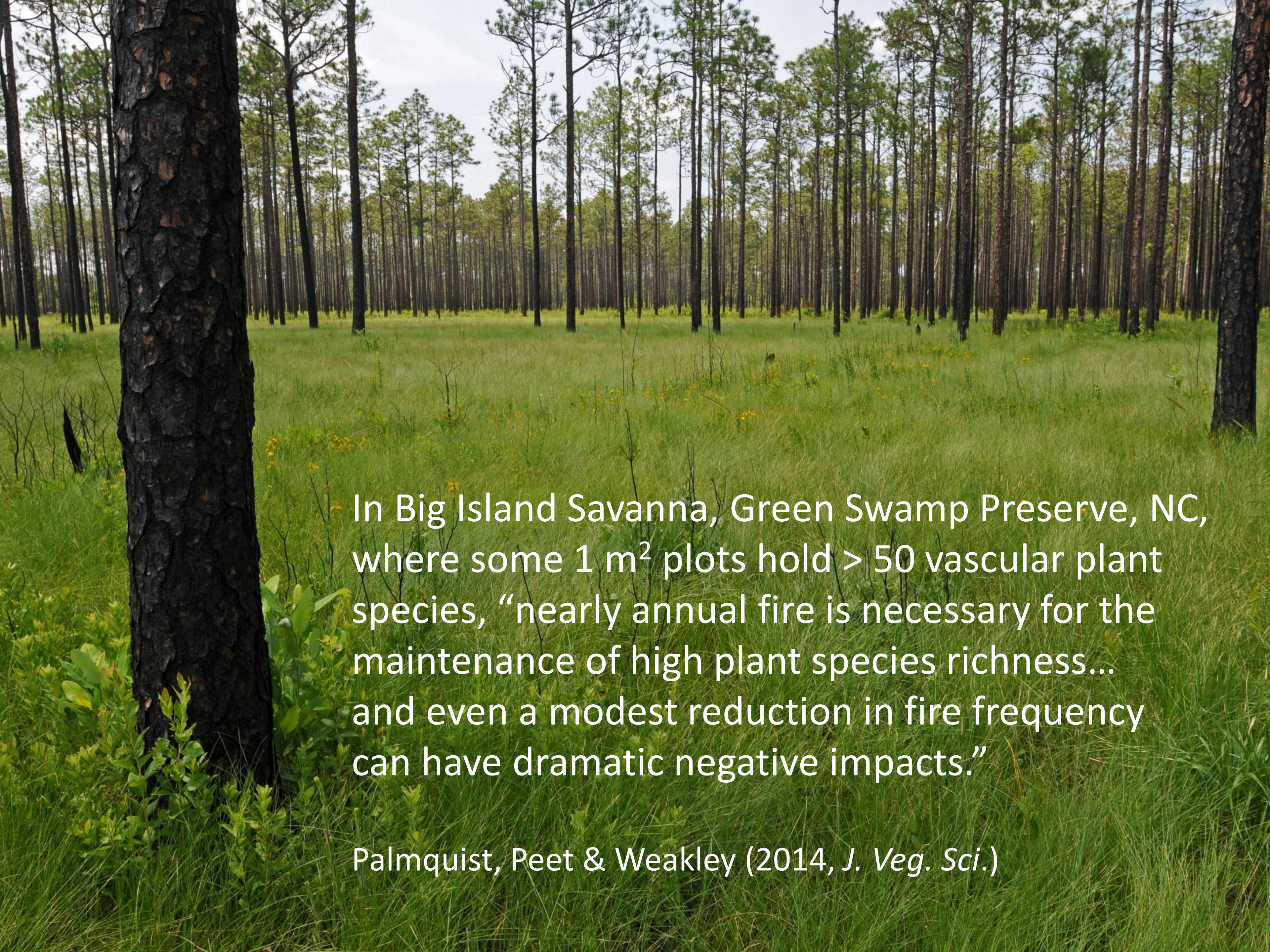
Dendropyrochronology studies at Avon Park Air Force Range

Jean Huffman, Bill Platt, Steve Orzell



Beginning year	1784
Last year	2005
Length of fire chronology	222
Total number of samples	151
Total number of fire scars	740
Total Intervals	184
Mean Fire Interval	1.19
Median Fire Interval	1
Weibull Median Interval	1.13

Huffman and Platt (2014, unpublished report)


In Big Island Savanna, Green Swamp Preserve, NC, where some 1 m^2 plots hold > 50 vascular plant species, "nearly annual fire is necessary for the maintenance of high plant species richness… and even a modest reduction in fire frequency can have dramatic negative impacts."
Palmquist, Peet & Weakley (2014, *J. Veg. Sci*.)

Active and Passive Fire Exclusion Has Reduced Fire Frequency

Fires no longer burn as frequently as they once did in the Coastal Plain due to two kinds of fire exclusion:

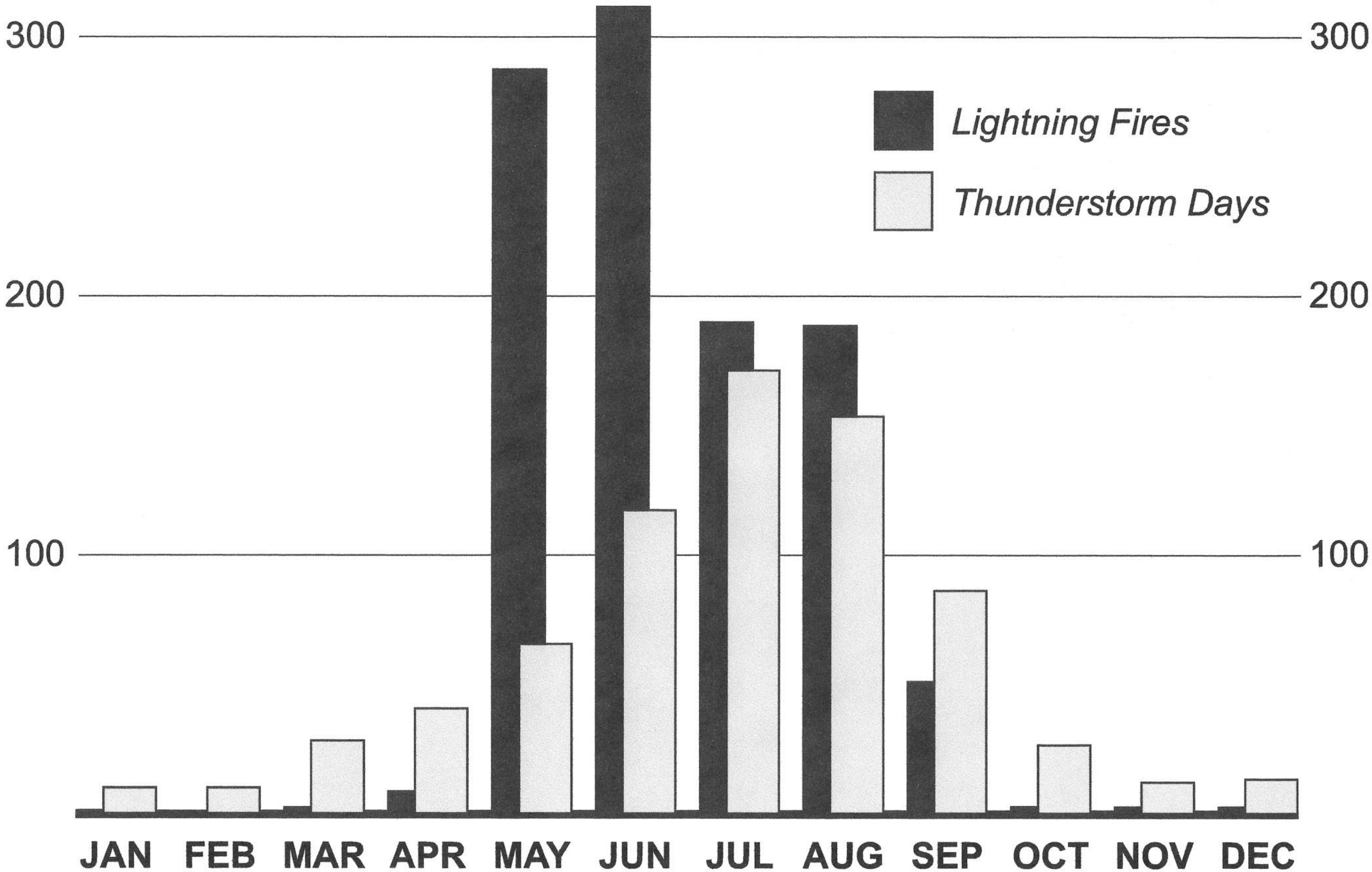
1. Active fire exclusion and suppression
2. Passive fire exclusion by landscape fragmentation, which prevents fire from flowing as it once did across huge areas (especially in the flat Coastal Plain)

Evolutionary Fire Season Hypothesis

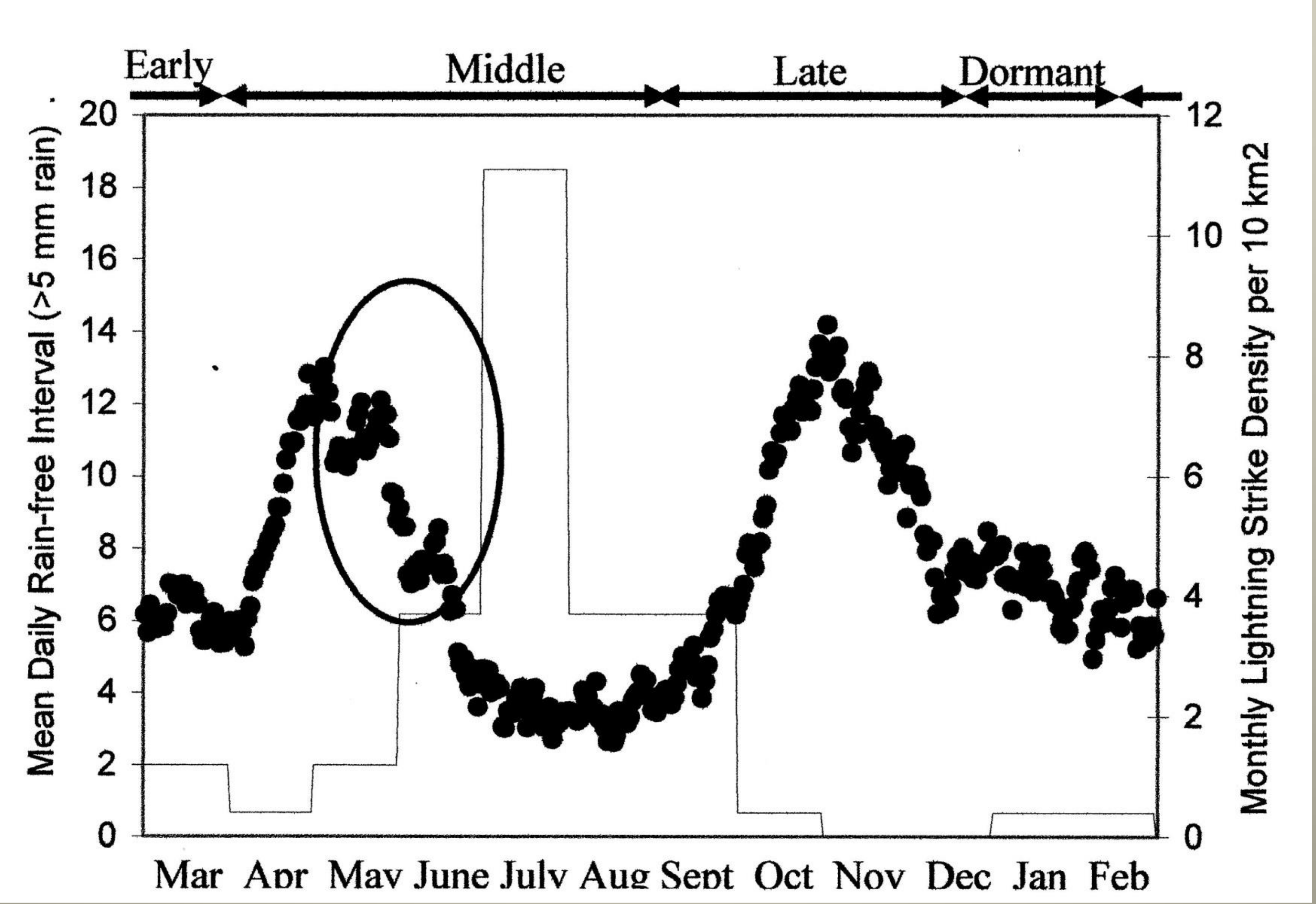
Premise: If fire is an important agent of selection, and if fires during the evolution of species in a region were concentrated in a particular season, then <u>species should have evolved mechanisms of growth and reproduction that are timed to respond to seasonal cues</u>.

Hypothesis: Burning during the evolutionary fire season provides conservation and restoration benefits – including <u>higher fitness of fire-adapted species</u> – <u>additive to those achieved by burning at the evolutionary fire frequency</u>.

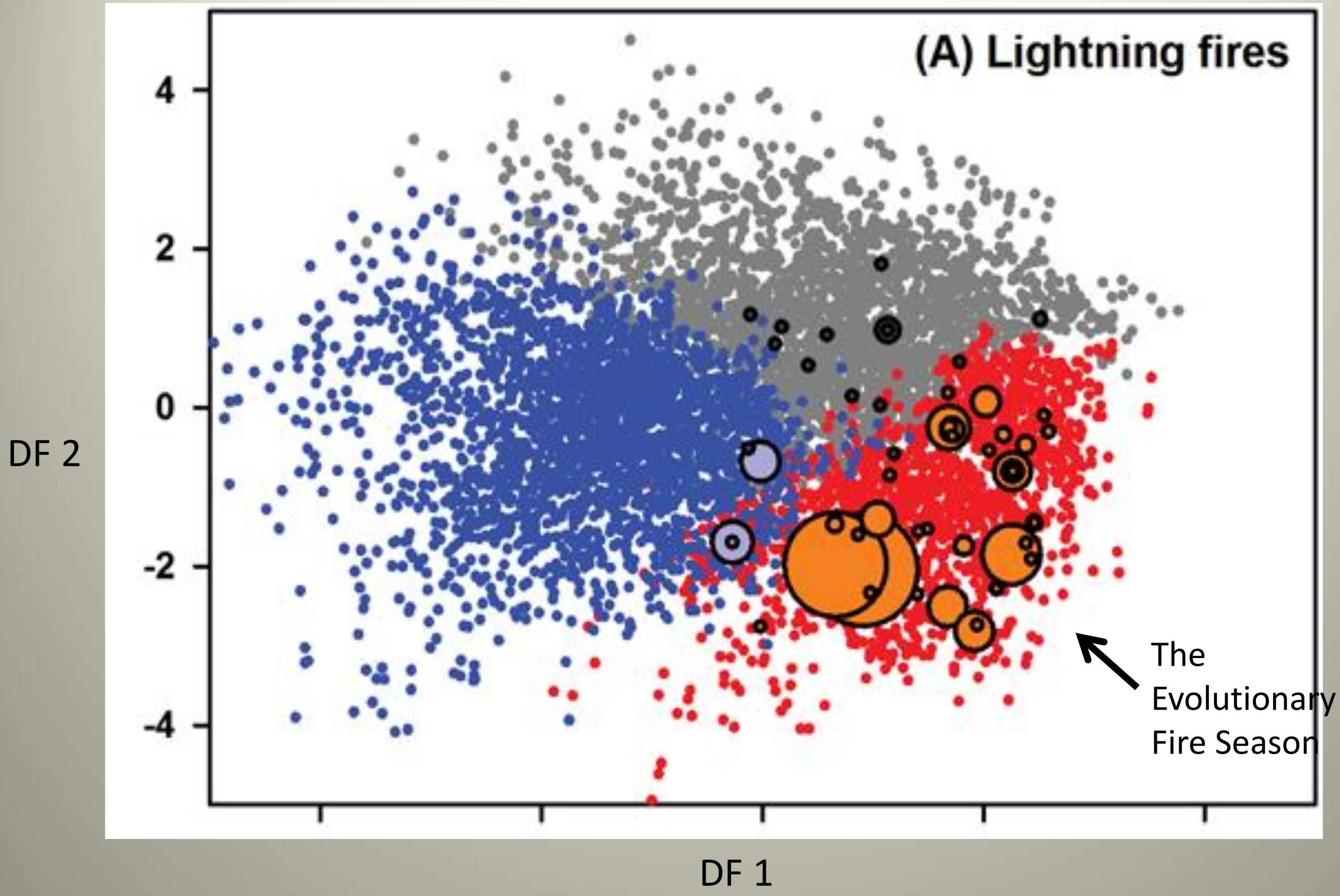
Lightning Fire Season



Adapted from Komarek (1964; data from Florida, 1962-63)

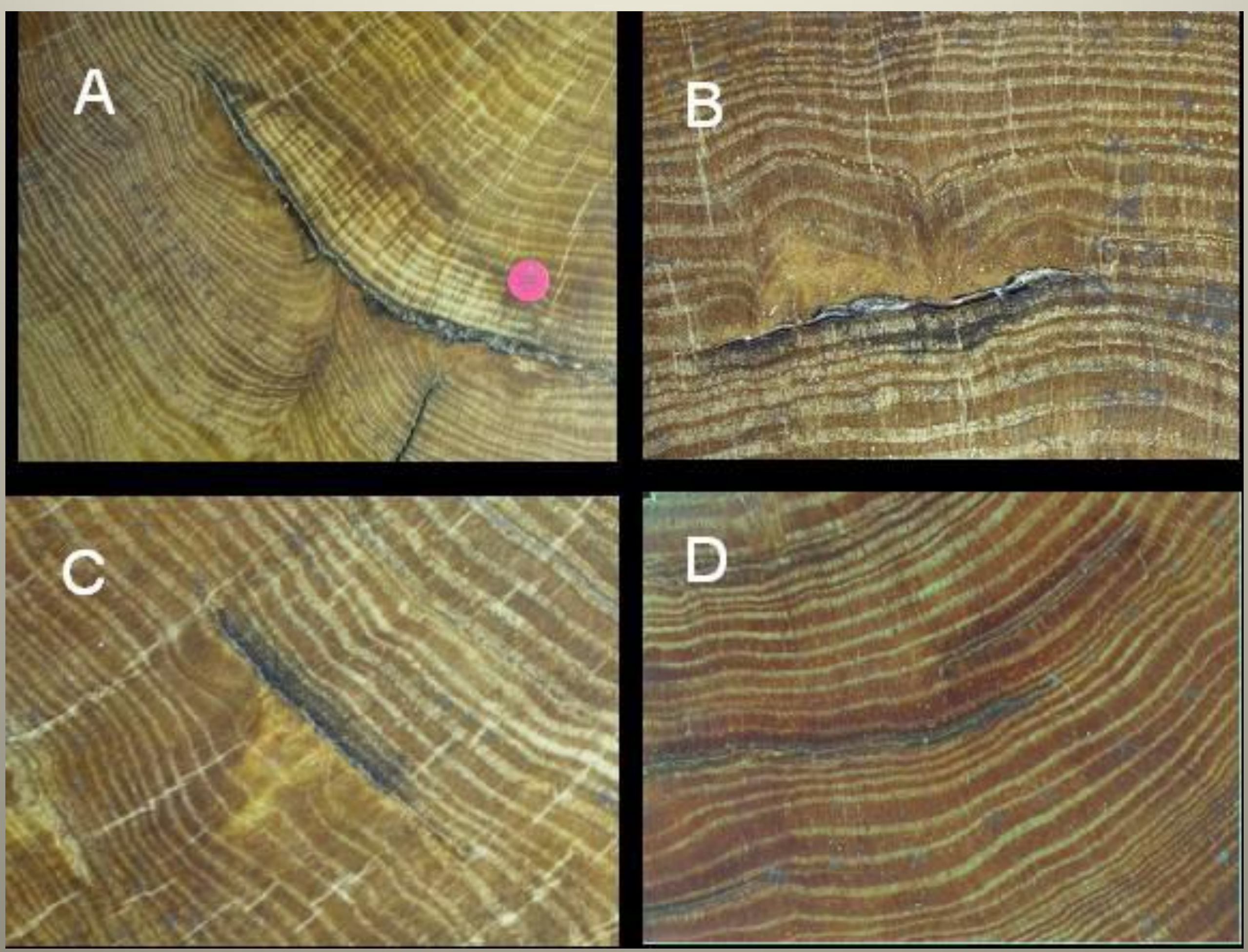


Monthly lightning strike density per 10 km2 (vertical bars) and mean number of days since last recorded precipitation >5 mm (dots) in Apalachicola, Florida.
<u>Circled area indicates when long rain-free intervals and an abundance of lightning strikes coincide</u> and lightning fires are most likely. From Huffman (2006).



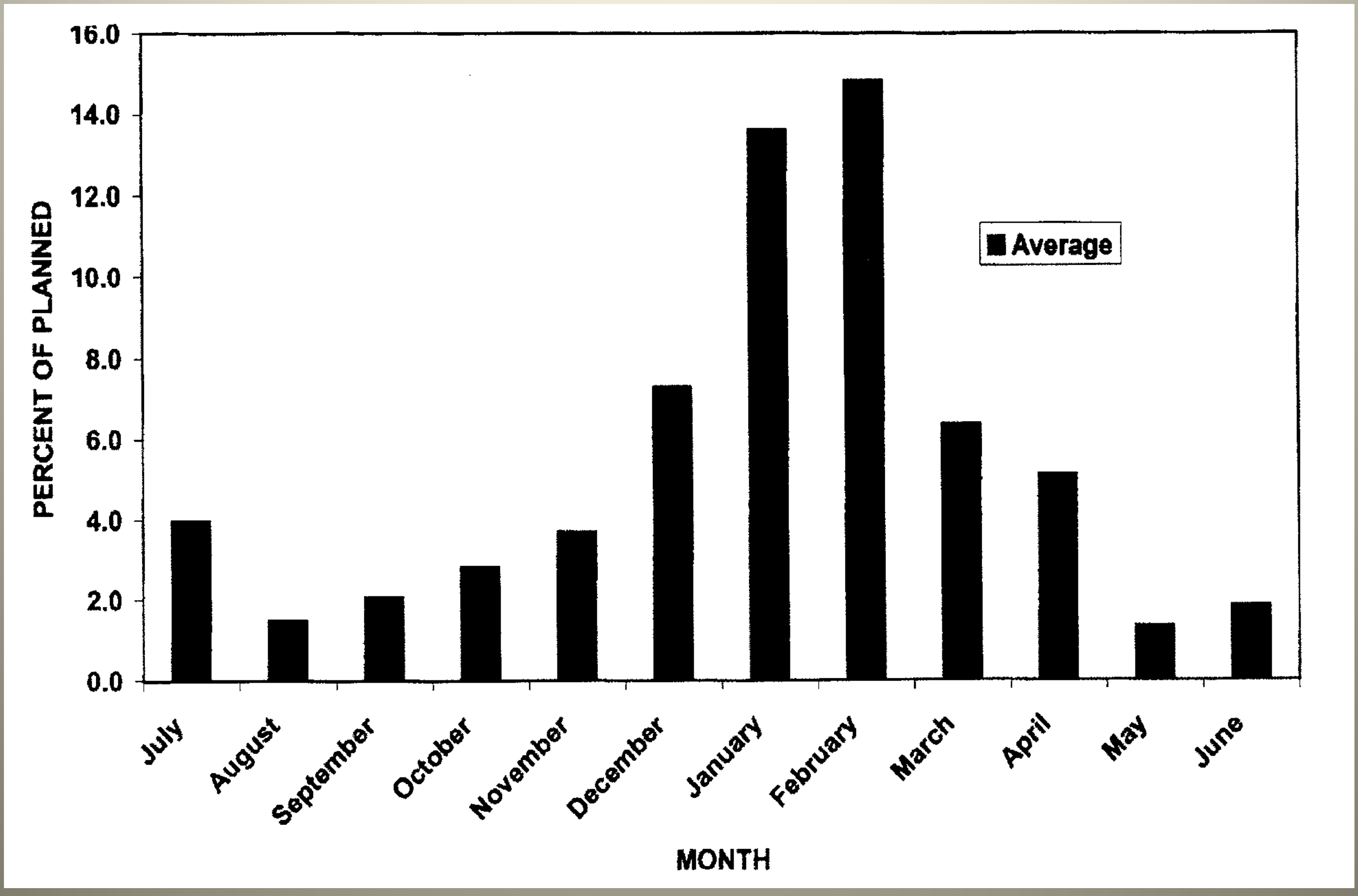
Relationship between lightning fires and climate at APAFR. Discriminant function analysis of 13 years of daily weather data: lightning fire season characterized by drought, intense solar radiation, low humidity, and warm air temperatures. Blue dots = dry season; red dots = transition season ("fire season"); gray dots = wet season. Bubbles are lightning fires (size proportioned).From Platt et al. (2015, PLOS ONE).

Lightning season fires were the only fires recorded in the annual rings of pines at the St. Joseph Bay savanna (Florida Panhandle) between 1592 and 1830. Only three fires, all after European settlement (post-1830), occurred during the dormant season.



From Huffman (2006)

Prescribed burning is opposite the natural seasonal pattern. The monthly distribution of prescribed burns accomplished in Florida's state forests as a percentage of those planned. Percentages shown are averages from fiscal year 2000-2001 to 2007-2009. From Hardin (2010).

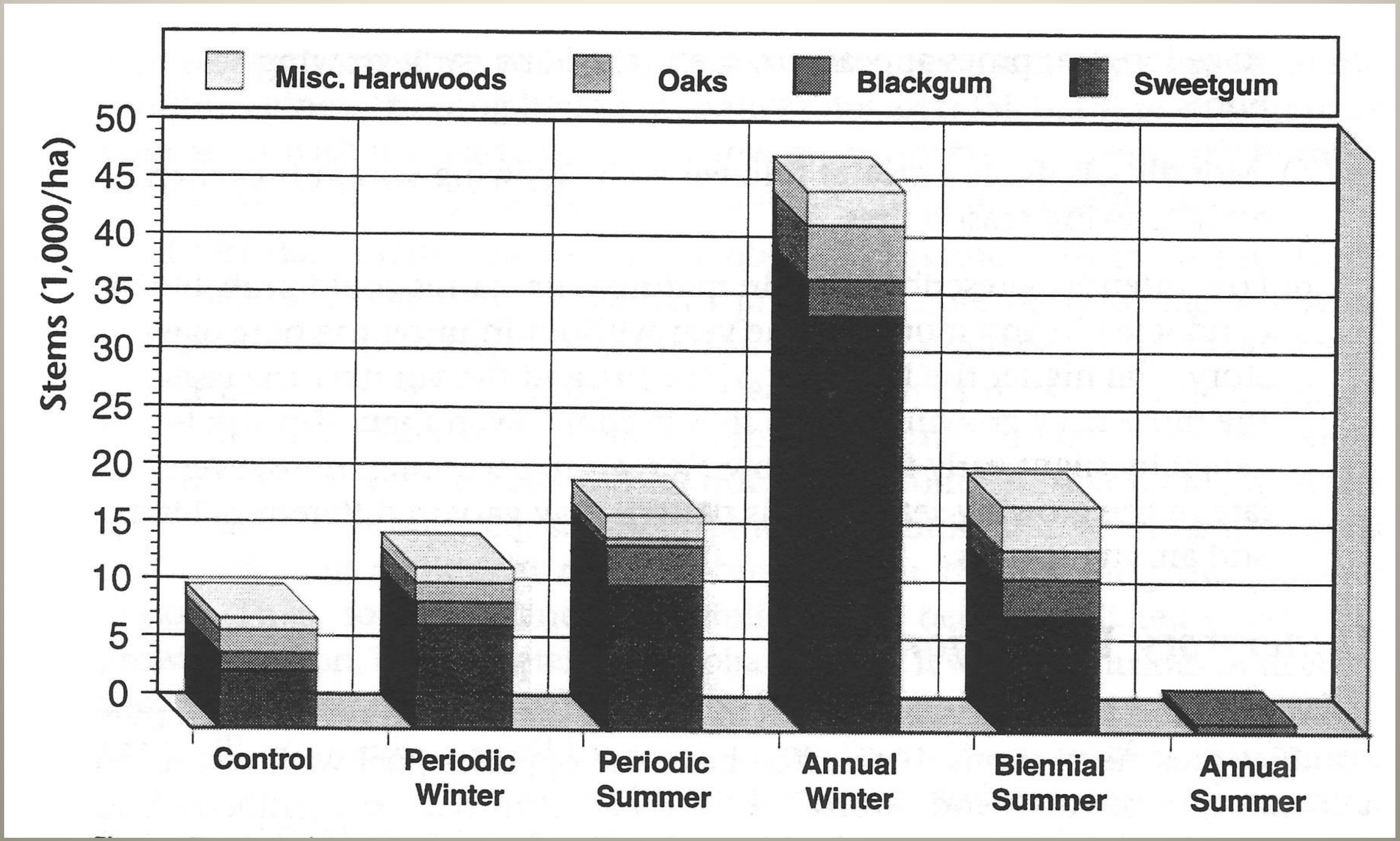


Evidence and logic in support of the biological importance of fire seasonality in the southeastern Coastal Plain

- Species have evolved adaptations to fire, and if fire varies seasonally, such <u>adaptations should include responses to seasonality</u> of fire
- A <u>distinct lightning fire season</u> (early growing or “transition” season) exists in the region and presumably has for a long time
- Many species characteristic of southeastern ecosystems, especially savannas and other grasslands, <u>respond most positively to fire in the lightning fire season</u>
- <u>Fires outside the lightning fire season have less beneficial effects</u>, and <u>sometimes negative effects</u> (less control of woody understory or midstory) on native natural communities and species of conservation concern
- Typically <u>only lightning season fires burn across wetlands</u>, reducing woody encroachment and maintaining open water

Santee Fire Plots, SC

Waldrop et al. (1987; *USDA Gen Tech Rep SE-45*)



Number of understory hardwood stems < 2.5 cm dbh after 30 years of prescribed burning in a loblolly pine plantation. Annual winter fires led to a proliferation of hardwood stems. Annual summer burns were most effective in reducing hardwood stem density.

Oecologia (2014) 174:765–776
DOI 10.1007/s00442-013-2823-4

POPULATION ECOLOGY - ORIGINAL RESEARCH

Effects of fire frequency and season on resprouting of woody plants in southeastern US pine-grassland communities

Kevin M. Robertson · Tracy L. Hmielowski

Confirms previous studies suggesting that resprouting of woody plants is less vigorous during seasons when carbohydrate reserves are low – i.e., the lightning fire season

Enhanced flowering of grasses and forbs and better control of woody species with growing season fire (St. Marks studies directed by Bill Platt)

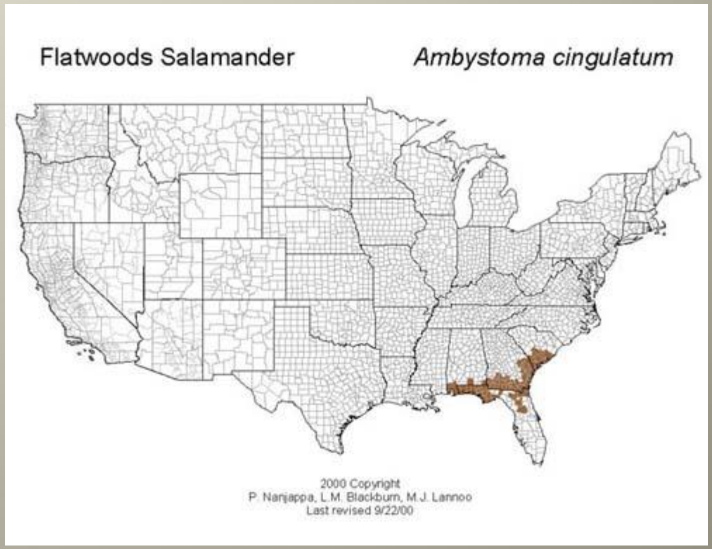
- Streng et al. (1993; *Proc Tall Timbers Fire Ecol Conf*): high rates of topkill and complete kill of midstory oaks; large positive effect on flowering and presumably seed production of dominant grasses and some forbs, no overall negative impact on pines.
- Brewer and Platt (1994; *J Ecology*): For *Pityopsis graminifolia*, floral induction and fecundity greater following May and August fires than following January fires; seedling emergence highest in May-burned plots, intermediate in August-burned plots, and lowest in January-burned plots.


Aristida beyrichiana
Wiregrass
esa
2012
ECOSPHERE
The reproductive response of an endemic bunchgrass indicates historical timing of a keystone process
JENNIFER M. FILL,† SHANE M. WELCH, JAYME L. WALDRON, AND TIMOTHY A. MOUSSEAU


The Wade Tract
Southern Georgia
Burned April 5, 2009
Burned April 24, 2009
Photo by Jim Cox, Tall Timbers Research Station

Breeding behavior of flatwoods salamanders (migration into and out of ponds) constrains burning usually in November (October-January) and March-April, when metamorphs emerge. <u>Requires lightning-season fire to maintain grassy habitat!</u>

Frosted flatwoods salamander (*Ambystoma cingulatum*)



Split by Pauly et al. (2007, *Molecular Ecology*)

Reticulated flatwoods salamander (*Ambystoma bishopi*) – **west of Apalachicola River**

Evidence and arguments in support of the <u>alternative hypothesis</u> that fire season is not important or is much less important than frequency or other variables of the fire regime

- <u>Lack of strong differences</u> in response of many species between lightning-season fires and fires in other seasons, at least if the latter are as frequent or as intense
- Evidence of <u>negative effects of lightning-season fire on particular species</u> (e.g., pines [40-50% mortality at some sites; K. Hiers, pers. comm.], game species, imperiled species), air quality, or other resources
- <u>Legal requirements</u> (e.g., ESA, Clean Air Act, burn bans) that discourage burning during the lightning season
- Other <u>practical considerations</u> (e.g., manageability, liability, fire crew safety and comfort, politics, agency culture and tradition)

Oecologia (2000) 125:521–530
DOI 10.1007/s004420000469

J. Kevin Hiers · Robert Wyatt · Robert J. Mitchell

The effects of fire regime on legume reproduction in longleaf pine savannas: is a season selective?

“Contrary to the conventional paradigm, we found a wide range of reproductive responses among dominant legumes in response to the season of burn treatments, suggesting that **a variable fire season, rather than a single season of burn, is appropriate to maintain a greater variety of native species.”**

Other arguments in favor of a variable fire regime? (seasonal pyrodiversity)

- The longleaf pine ecosystem became established in the southeastern Coastal Plain only 7,000 BP (Hiers et al. 2000 and others). **No.**
- Indigenous people exerted significant control over fire regimes within time frames capable of influencing natural selection (Hiers et al. 2000, citing others). **Perhaps in some cases but probably rarely.**
- **"Variation in amount of fuel, fuel moisture, wind speed, etc., may obscure or accentuate seasonal differences"** (Robbins and Myers 1992). **Yes.**
- <u>Intensity is more important than seasonality</u>. A good fire manager can burn at virtually any time of year and mimic a lightning season fire (K. Hiers, pers. comm.). **Maybe.**
- <u>Winter fires are critical for adding burn days, keeping fire on the ground</u>. **Yes.**

Implications for Management

- **Frequency usually trumps seasonality**, but not always, especially over the long term (e.g., as woody plants become increasingly dense)
- Many years of regularly burning outside the lightning season may have cumulative negative effects that are not evident in short term (even decadal) studies
- Although many native species may respond equally well to fires during almost any season, the foundation species of southeastern grasslands/savannas) – i.e., wiregrass and other C_4 grasses – respond most favorably to early growing season fires
- The objectives of a particular prescribed burn (e.g., restoration vs. maintenance) may dictate burning outside the lightning fire season, as will some practical concerns

What to do in the face of uncertainty?

- Follow an ecologically and evolutionarily informed precautionary principle: burden of proof is on those who would burn outside the evolutionary fire regime (frequency, seasonality, severity, etc.).
- To the extent feasible, schedule burns to mimic the lightning fire regime, but incorporating inter-annual variability.
- Variability (**pyrodiversity**) is desirable, but not beyond the probable historic (in ecological and evolutionary time) range of variability. Studies elsewhere show that maximum pyrodiversity does not promote biodiversity conservation objectives.

Smoke from Red Hill Fire, Archbold Biological Station, 7 January 2015, drifting above US 27

Courtesy of Eric Menges