Advances in Understanding Duff Fires in Longleaf Pine Forests

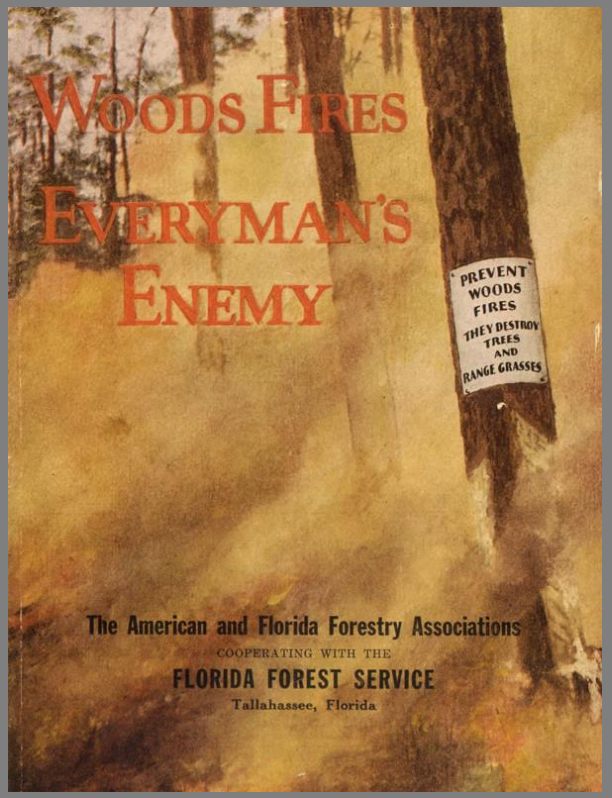
Kevin Hiers, Morgan Varner, Jesse Kreye, and Joe O'Brien

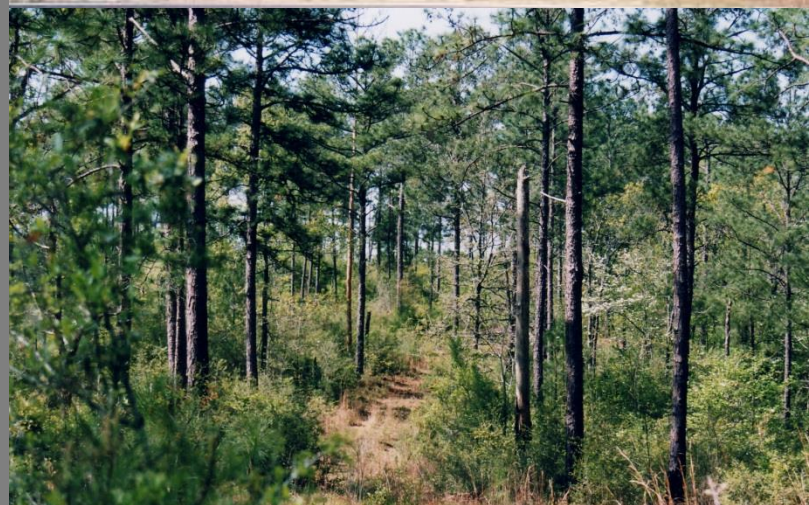
Tall Timbers Research Station & Land Conservancy

Pacific Wildland Fire Sciences Laboratory

Forest Service U.S. Department of Agriculture

Long-Unburned Longleaf Pine Forests





Longleaf Forests Without Fire

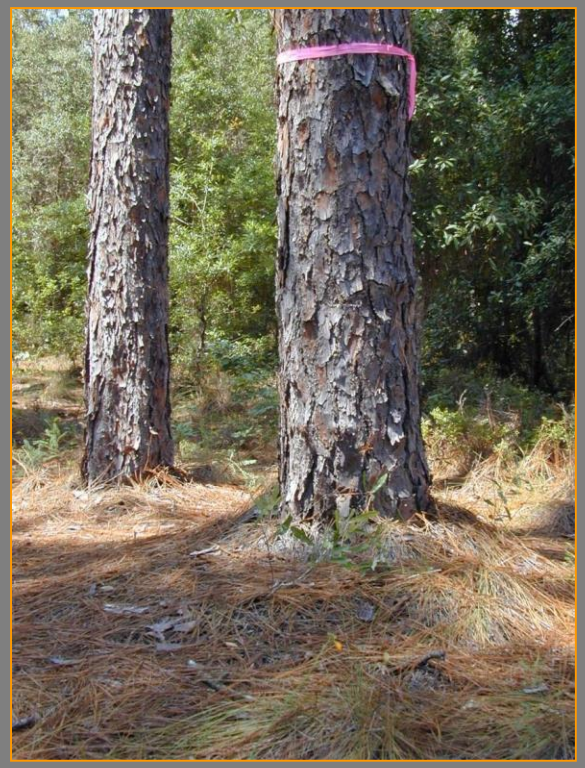
- ✓ Declines in herbaceous biodiversity
- ✓ Increase in litter accumulation
- ✓ Increase in fire sensitive trees and shrubs

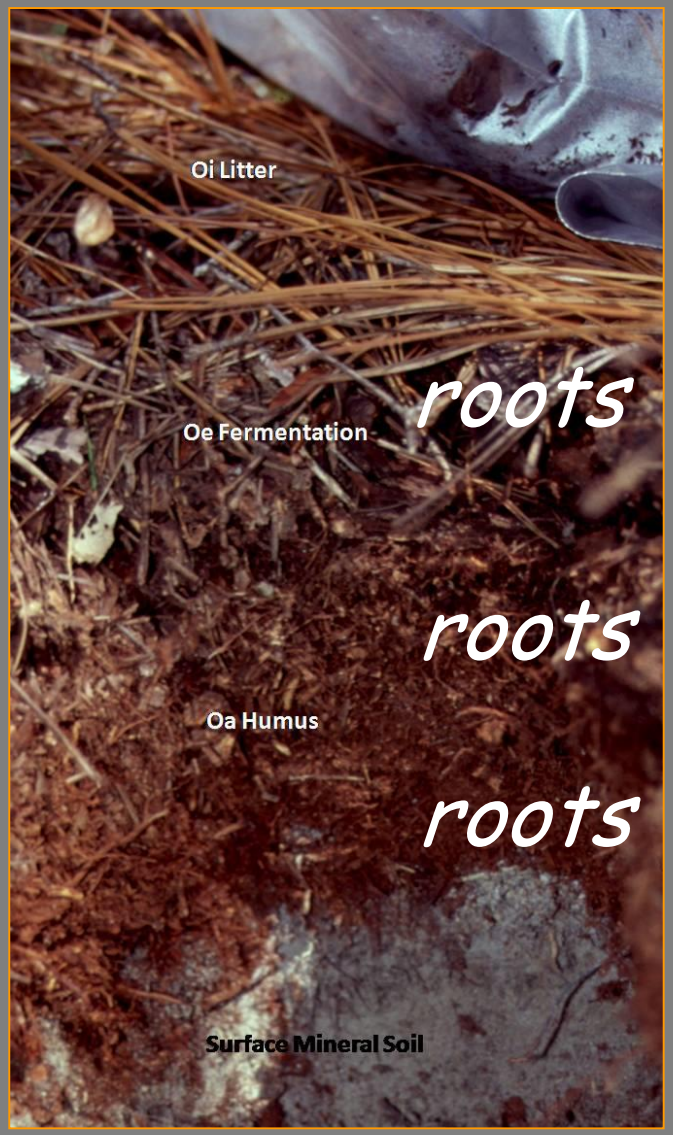

Woo-hoo!
Duff
BEER

What is Duff?

- Basal duff
  - deep mounds
  - bark slough
- Across the stand
  - discontinuous
  - needle litter

Changed Fuels: “Duff”





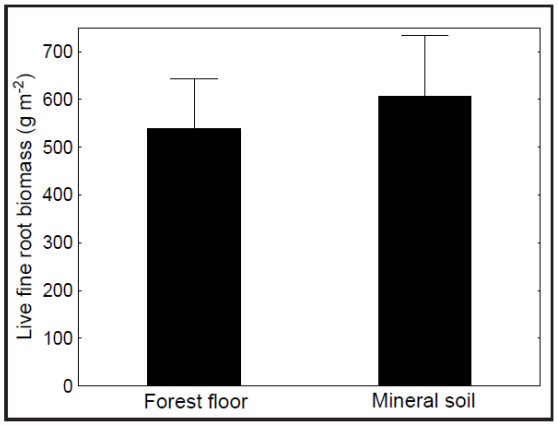


Figure 4. Mean live root dry weight in the forest floor and top 30 cm of the mineral soil in long-unburned longleaf pine forest in Georgia, USA (whiskers indicate standard error).

O’Brien et al. 2010. *Fire Ecology*

A Look at Smoldering Fire

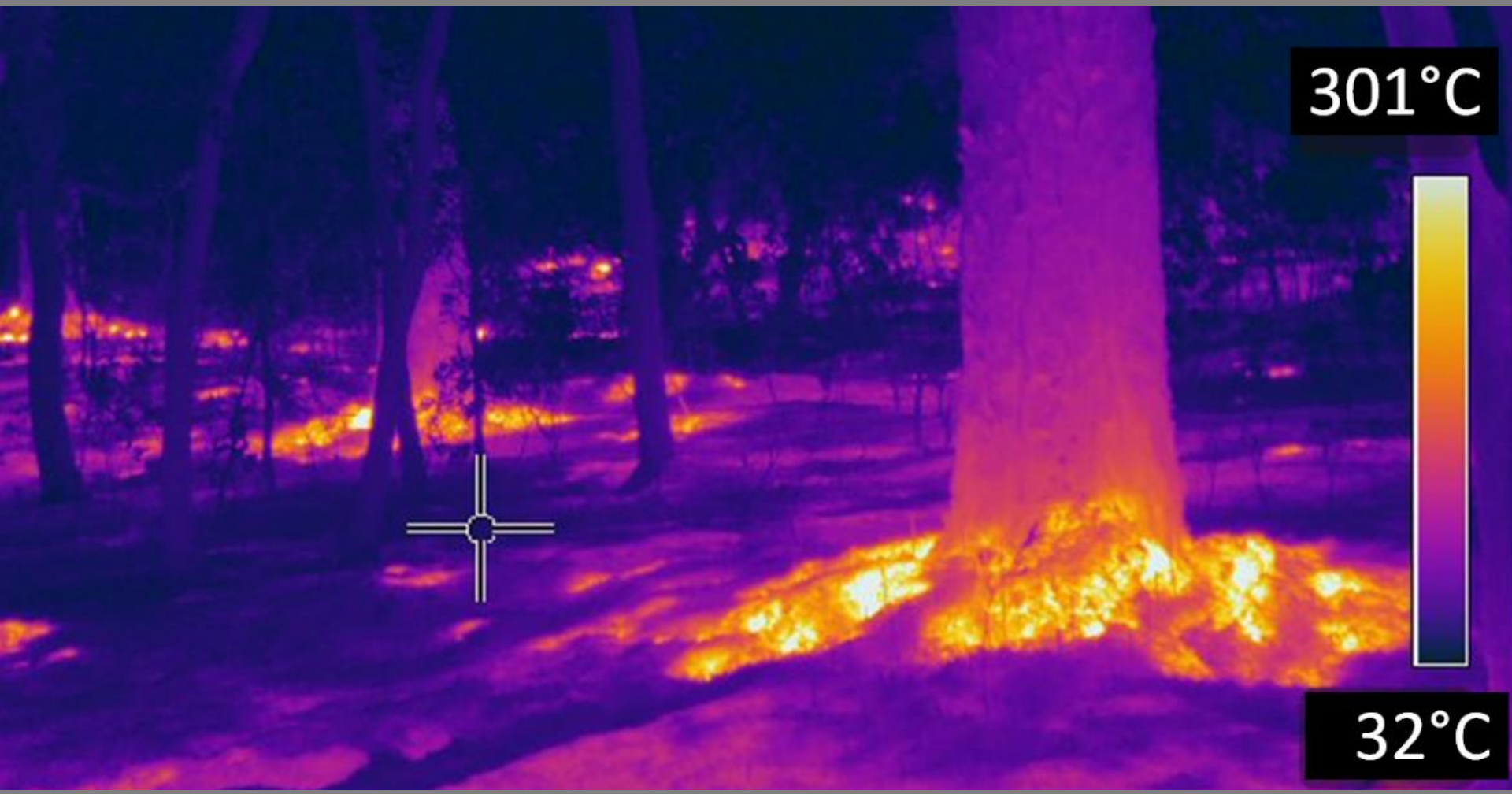


Photo by J. Kreye, Eglin AFB

Management Conundrum:

How to reduce duff
while maintaining large, old pines?

LOW *duff consumption* *HIGH*

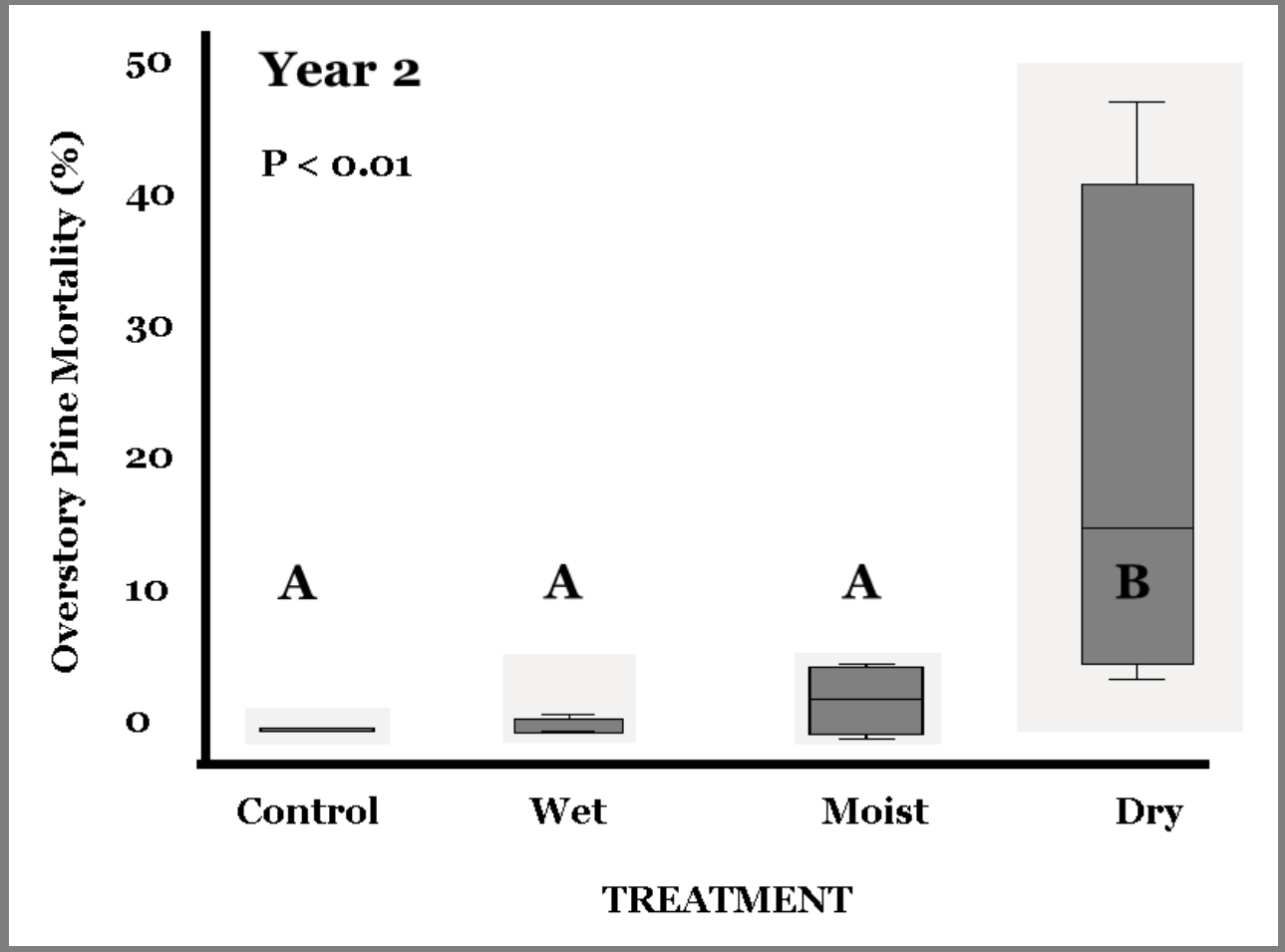
Retain large, old trees
Re-burn potential

Reduce duff fuels
Smoke hazard
Mortality

Research in Duff Consumption 2001-2015

- Quantify mortality rates when reintroducing fire to long-unburned pine ecosystems (Eglin AFB, Ordway, Moody Forest, Ft. Gordon)
- Identify threshold moisture conditions (Eglin AFB)
- Understand mechanisms of pine mortality (Ordway Preserve, Ft. Gordon, GA)
- Develop prescription guidelines

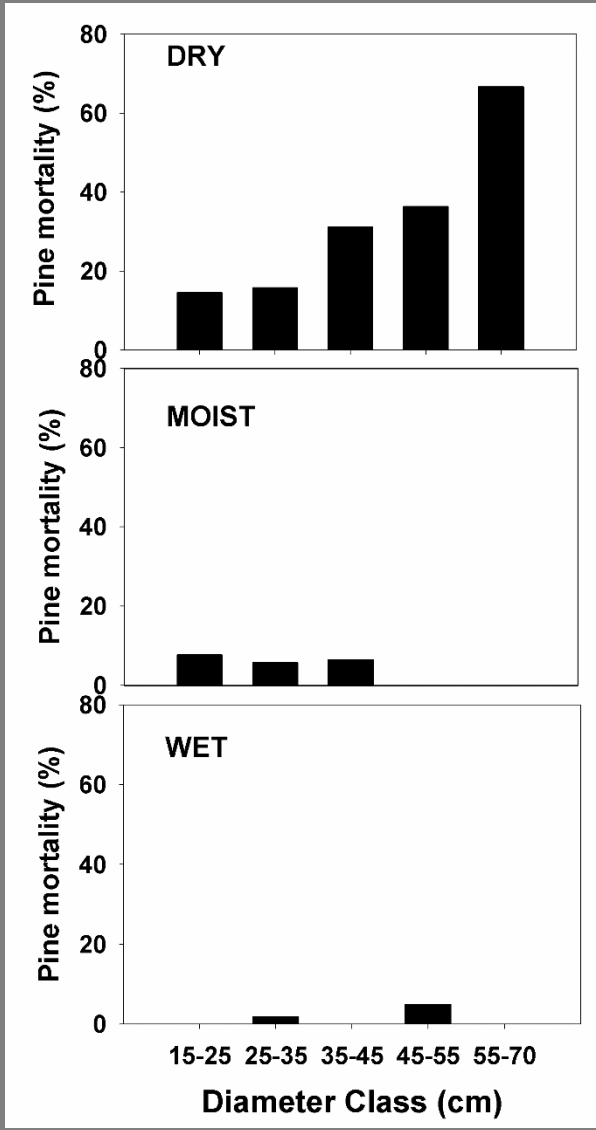
Delayed Post-fire Mortality



- Mortality delayed 18-24 months
- Mortality peaked in dry burns
- Mortality in unburned not different from moist & wet

Varner et al. 2007 *Can. J. For. Res.*

Patterns of Large Tree Mortality?



$DBH_{dead} > DBH_{surviving}$

$P = 0.002$

trees < 16” dbh: 19% mortality

trees > 16 “ dbh: **53% mortality**

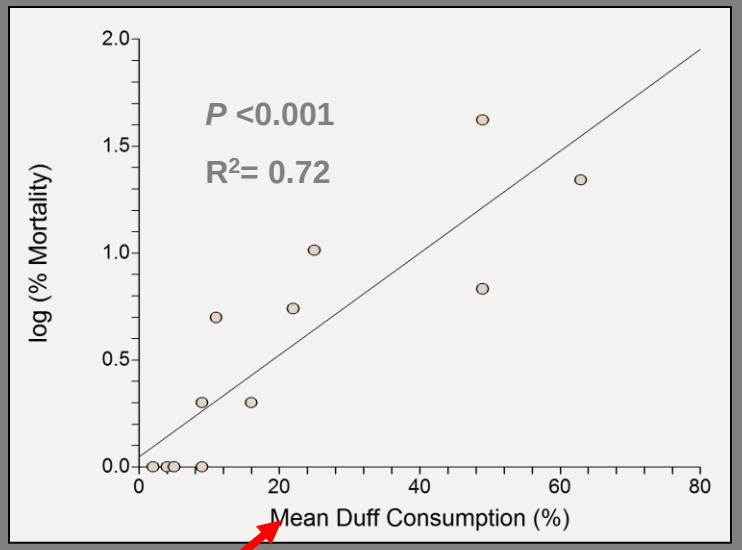
Overstory tree mortality resulting from reintroducing fire to long-unburned longleaf pine forests: the importance of duff moisture

J. Morgan Varner III, J. Kevin Hiers, Roger D. Ottmar, Doria R. Gordon, Francis E. Putz, and Dale D. Wade

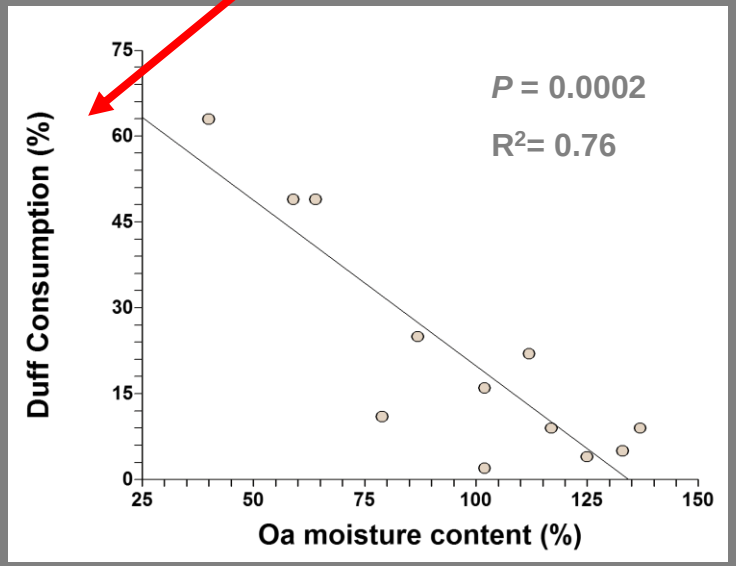
Varner et al. 2007; *Can. J. For. Res.*

Drivers of Tree Mortality?

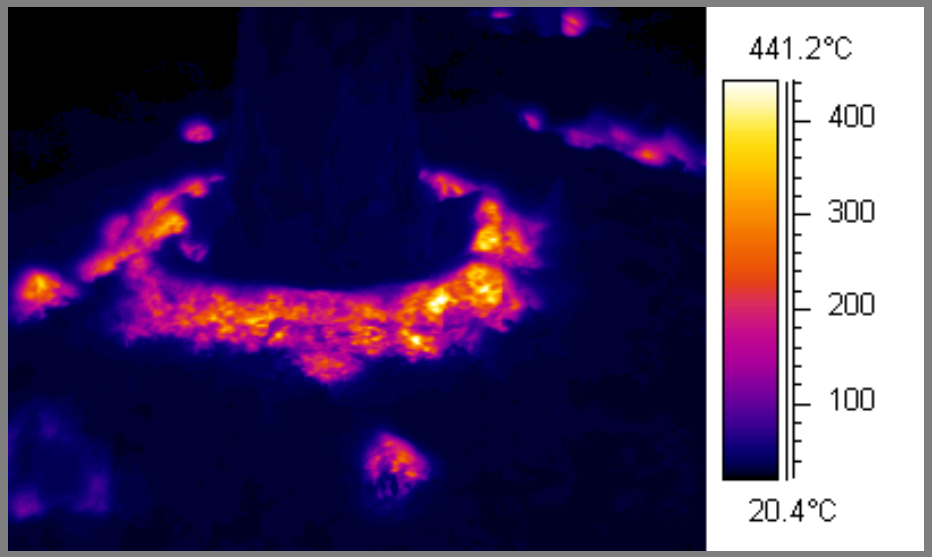
Duff consumption predicts tree death



Duff moisture predicts consumption



Mechanisms for Mortality



J. O'Brien IR image

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Post-fire tree stress and growth following smoldering duff fires

J. Morgan Varner [a,*], Francis E. Putz [b], Joseph J. O'Brien [c], J. Kevin Hiers [d], Robert J. Mitchell [d], Doria R. Gordon [b,e]

25% of burns recorded lethal

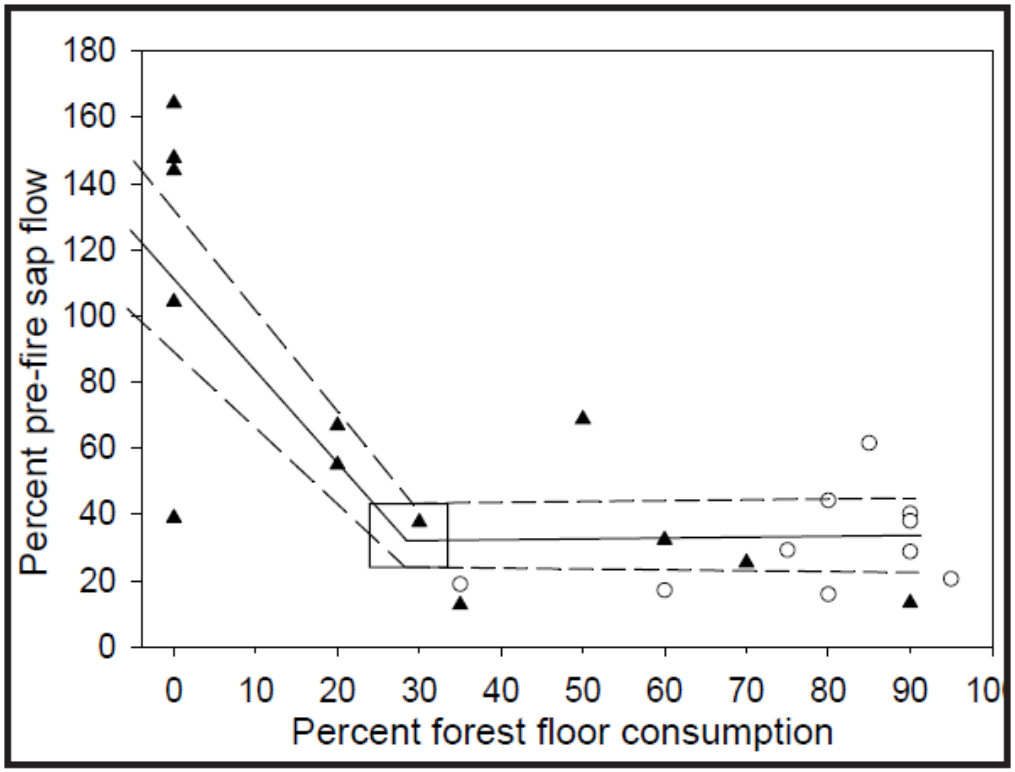
Durations of lethal heating (i.e. temperatures >60 °C) to basal bark, duff, and mineral soil during individual tree burns at the Ordway-Swisher Biological Station in northern Florida, USA.

Treatment[a]	Duration of temperatures >60 °C (min)				
	Basal bark	Basal duff	5 cm soil	10 cm soil	20 cm soil
STEM ($n=6$)	44.3 ± 77.1	42.9 ± 47.3	7.9 ± 14.1	7.3 ± 17.9	–
ROOT ($n=6$)	10.1 ± 7.0	145.6 ± 283.7	41.0 ± 90.5	4.6 ± 9.9	0.7 ± 0.8
ROOT + STEM ($n=6$)	82.2 ± 121.8	95.7 ± 187.3	56.1 ± 122.2	12.8 ± 20.9	2.1 ± 4.8
CONTROL ($n=6$)	9.4 ± 2.6	10.6 ± 24.6	2.7 ± 5.9	1.4 ± 3.5	0.2 ± 0.5
Means	36.5 ± 73.9	73.7 ± 168.8	26.9 ± 74.8	6.5 ± 14.4	0.8 ± 2.5

Loss of Roots Causes Mortality

ACUTE PHYSIOLOGICAL STRESS AND MORTALITY FOLLOWING FIRE IN A LONG-UNBURNED LONGLEAF PINE ECOSYSTEM

Joseph J. O'Brien[1,*], J. Kevin Hiers[2], R.J. Mitchell[3], J. Morgan Varner III[4], and Kathryn Mordecai[1]



O'Brien et al. 2010; Fire Ecology

Pines are sensitive to duff consumption

- Root starch
- Sap flow
- Latewood growth
- Mortality

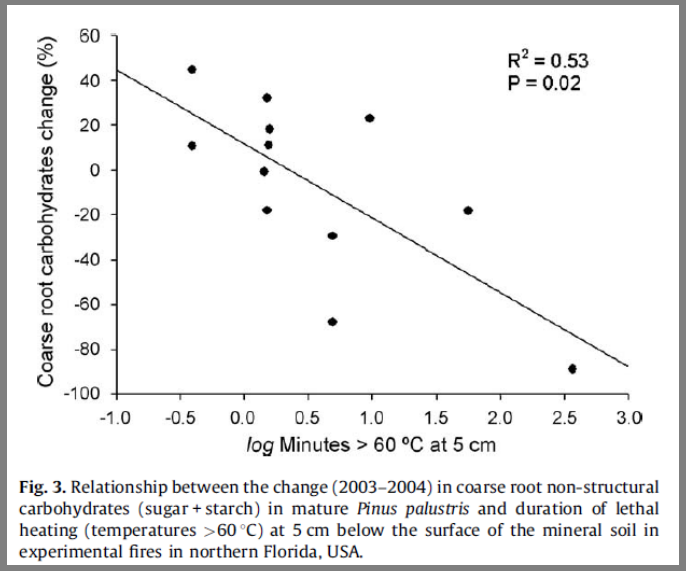


Fig. 3. Relationship between the change (2003–2004) in coarse root non-structural carbohydrates (sugar + starch) in mature *Pinus palustris* and duration of lethal heating (temperatures >60 °C) at 5 cm below the surface of the mineral soil in experimental fires in northern Florida, USA.

Varner et al. 2009; For. Ecol. & Mgmt

Consequences of Root Loss to C Assimilation

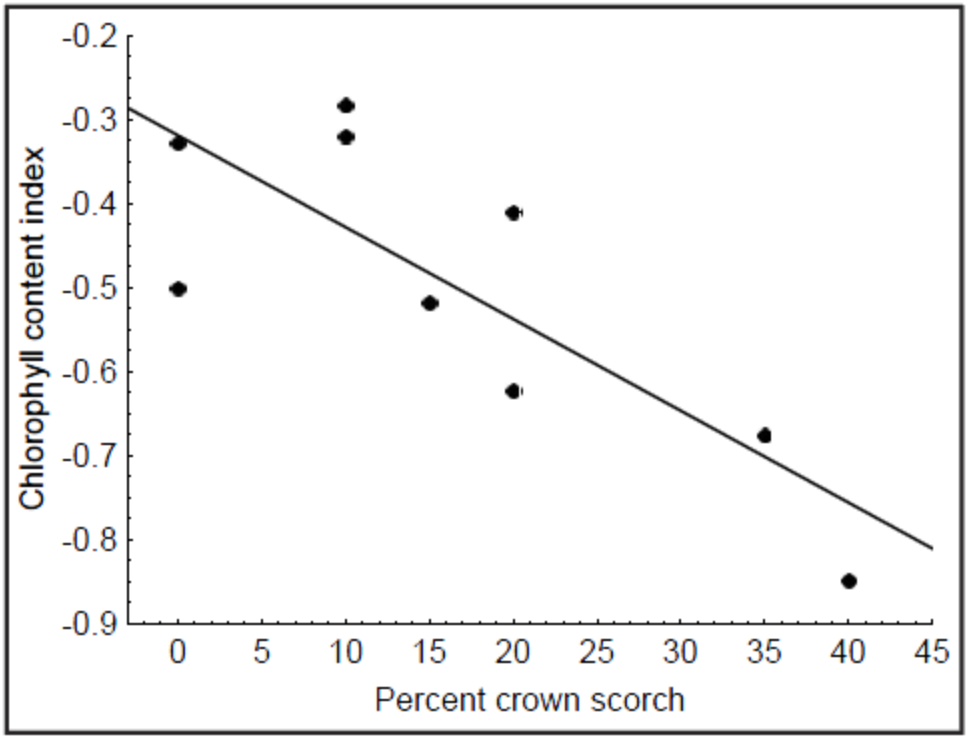


Figure 8. Linear regression of leaf chlorophyll content index and crown scorch in longleaf pines burned in a 2005 wildfire. Leaves were collected after the crowns flushed (3 months) following the fire. All pines had at least 20% forest floor consumption.

O'Brien et al. 2010; Fire Ecology

Duff ignition is complicated…

R. W. Fonda[1], Biology Department, Western Washington University, Bellingham, Washington 98225-9160

and

J. M. Varner[2], School of Natural Resources and Environment, University of Florida, Gainesville, Florida 32611-8526

Burning Characteristics of Cones from Eight Pine Species

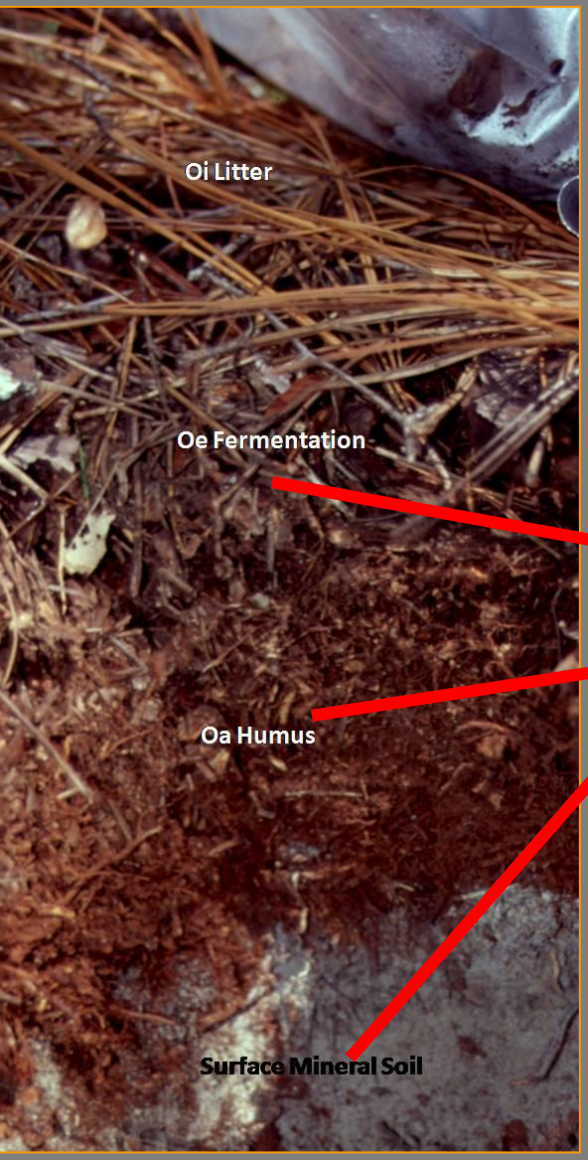
Fonda & Varner 2004 *Northwest Sci.*

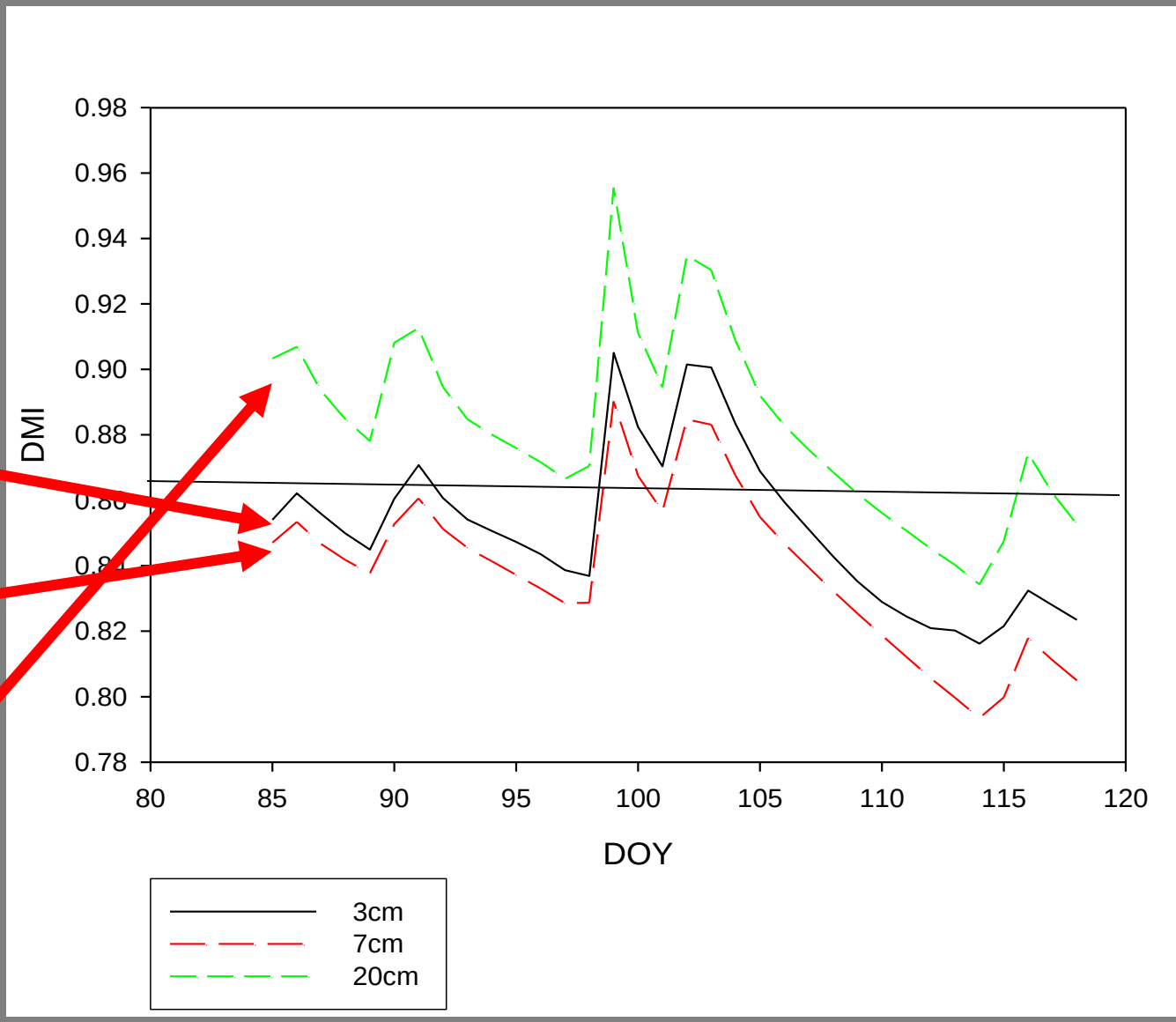
Pine cones facilitate ignition of forest floor duff

Jesse K. Kreye, J. Morgan Varner, Christopher J. Dugaw, Jing Cao, Jonathan Szecsei, and Eamon A. Engber

Kreye et al. 2013 *Can. J. For. Res.*

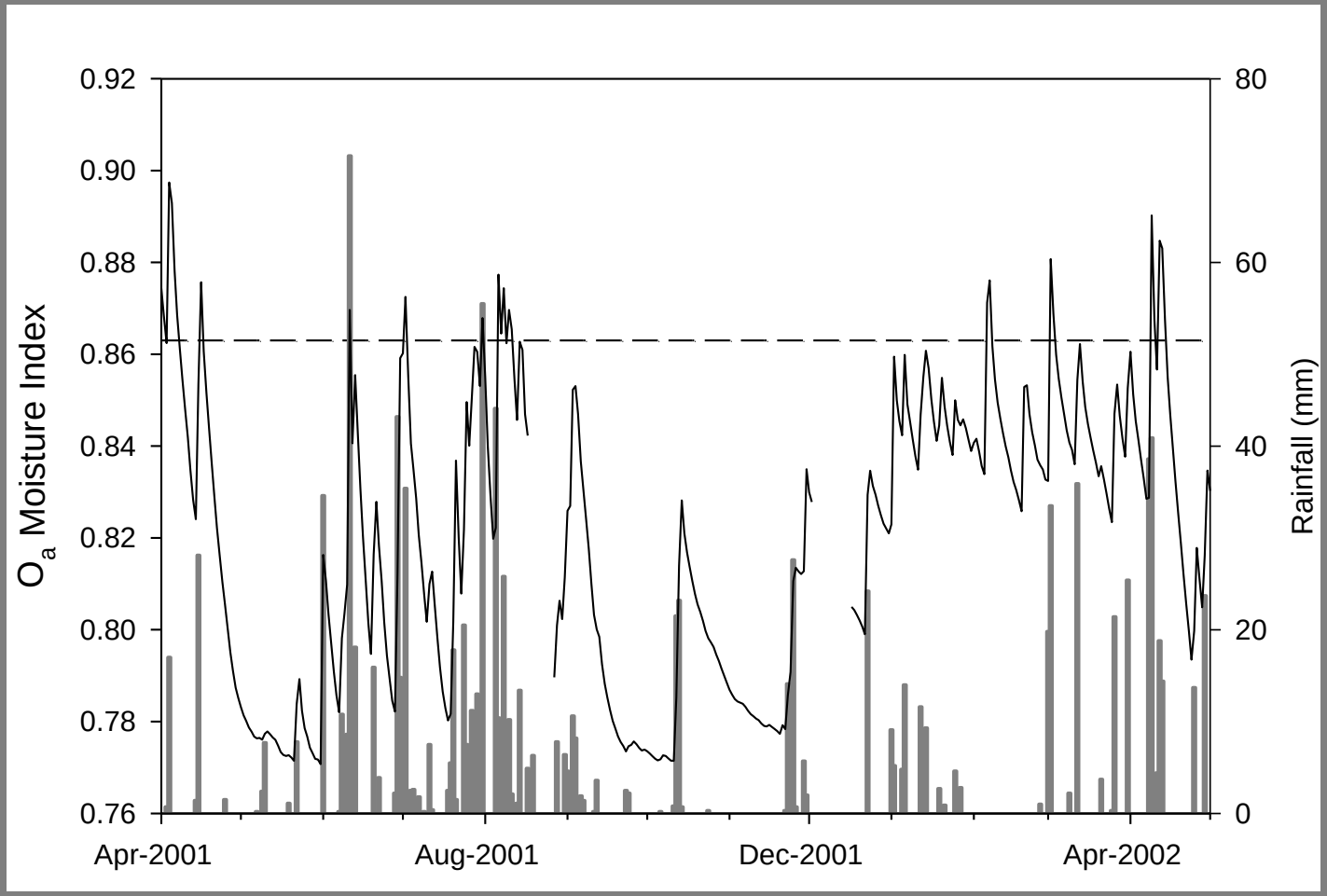
Duff Moisture Profile





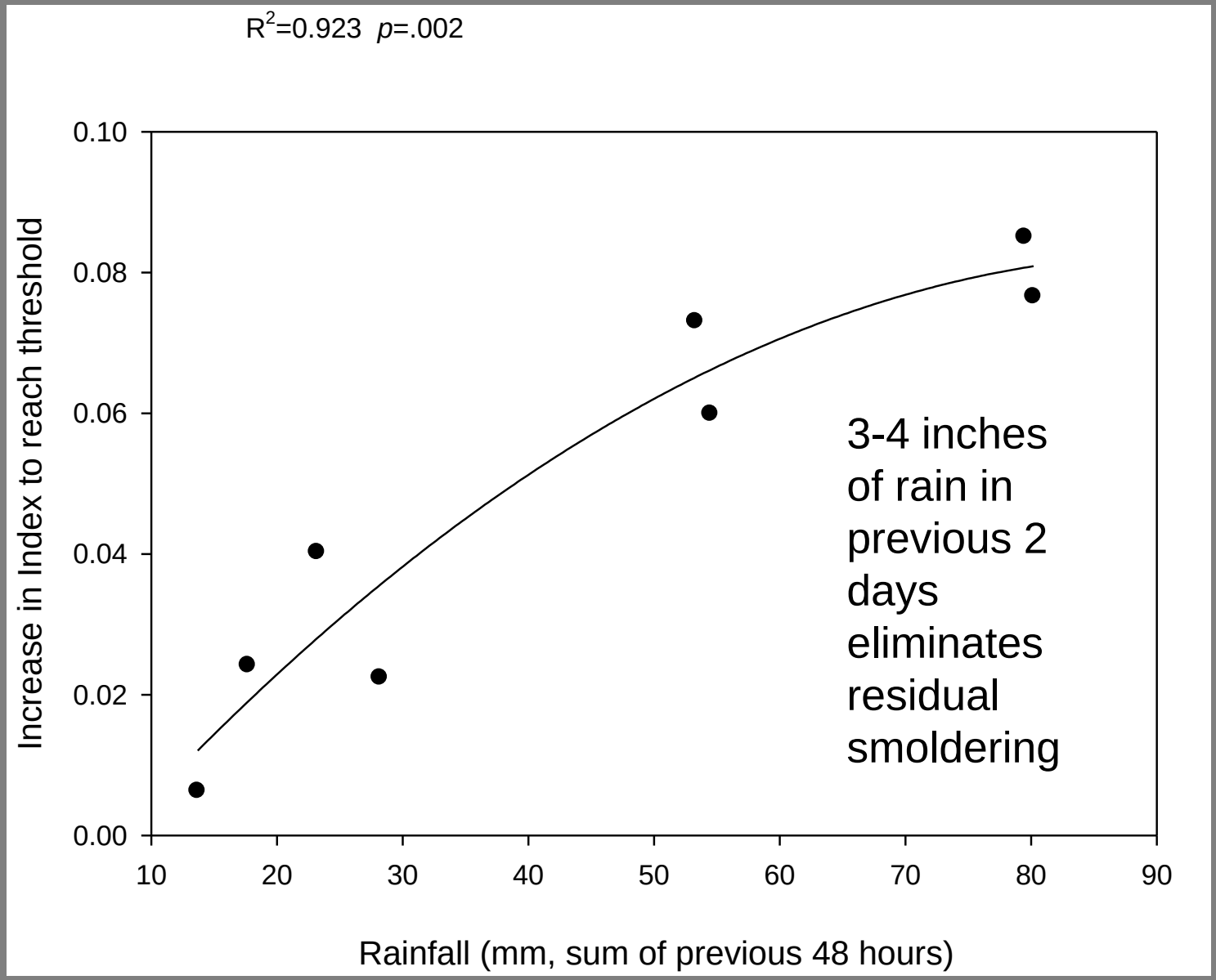
Defining Safe Burning Conditions

- ✓Safe threshold identified from actual fires
- ✓Threshold may vary by soil, duff depth and season
- ✓Cumulative rainfall is key



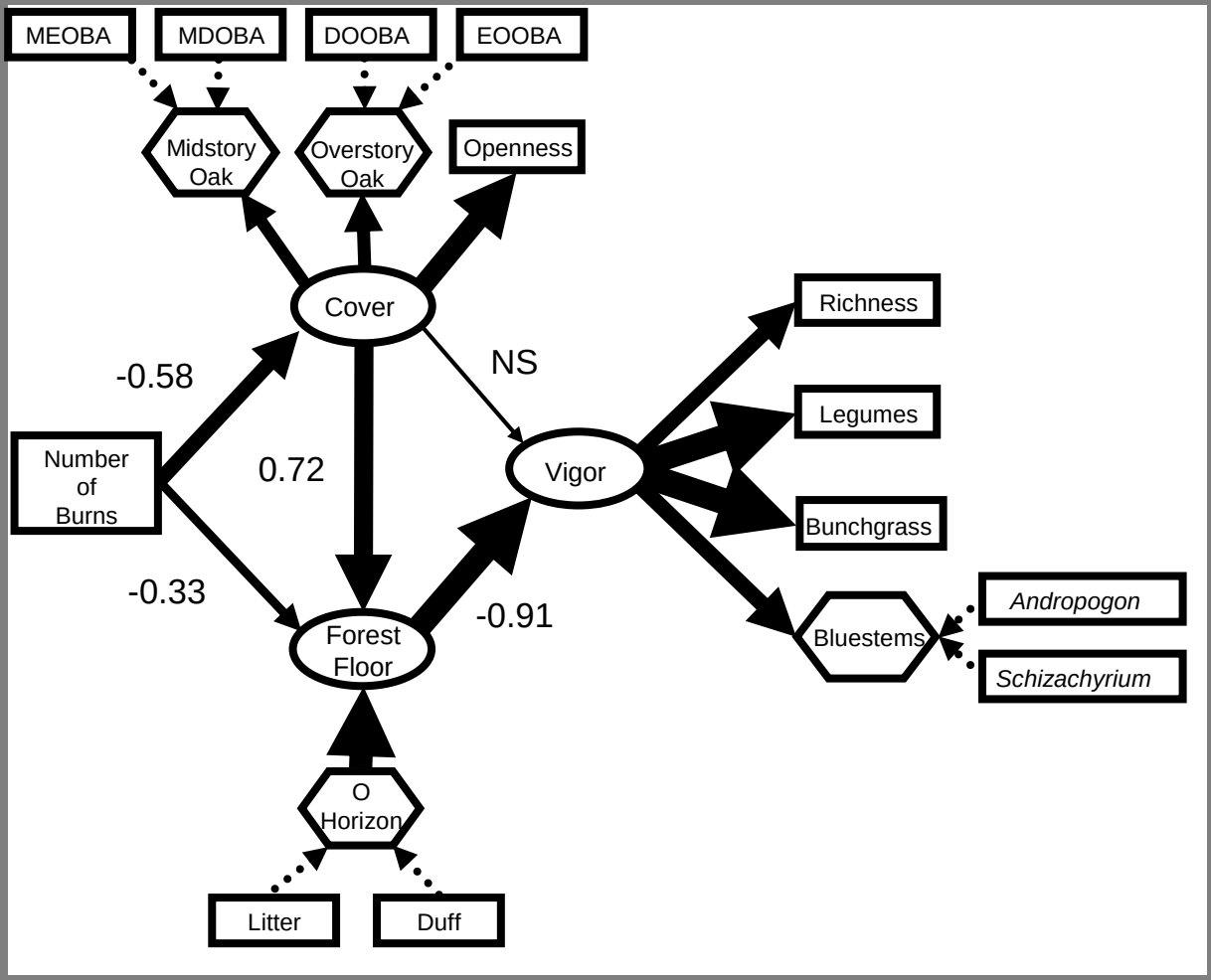
Ferguson et al 2002; Int'l Journal of Wildland Fire

Duff Saturation Curve



Forest Floor Development and Sandhill Restoration

- ✓**Restoration of Biodiversity is Duff Limited**
- ✓**Manage fuels before forest structure**
- ✓**Fuels will take time to manage**



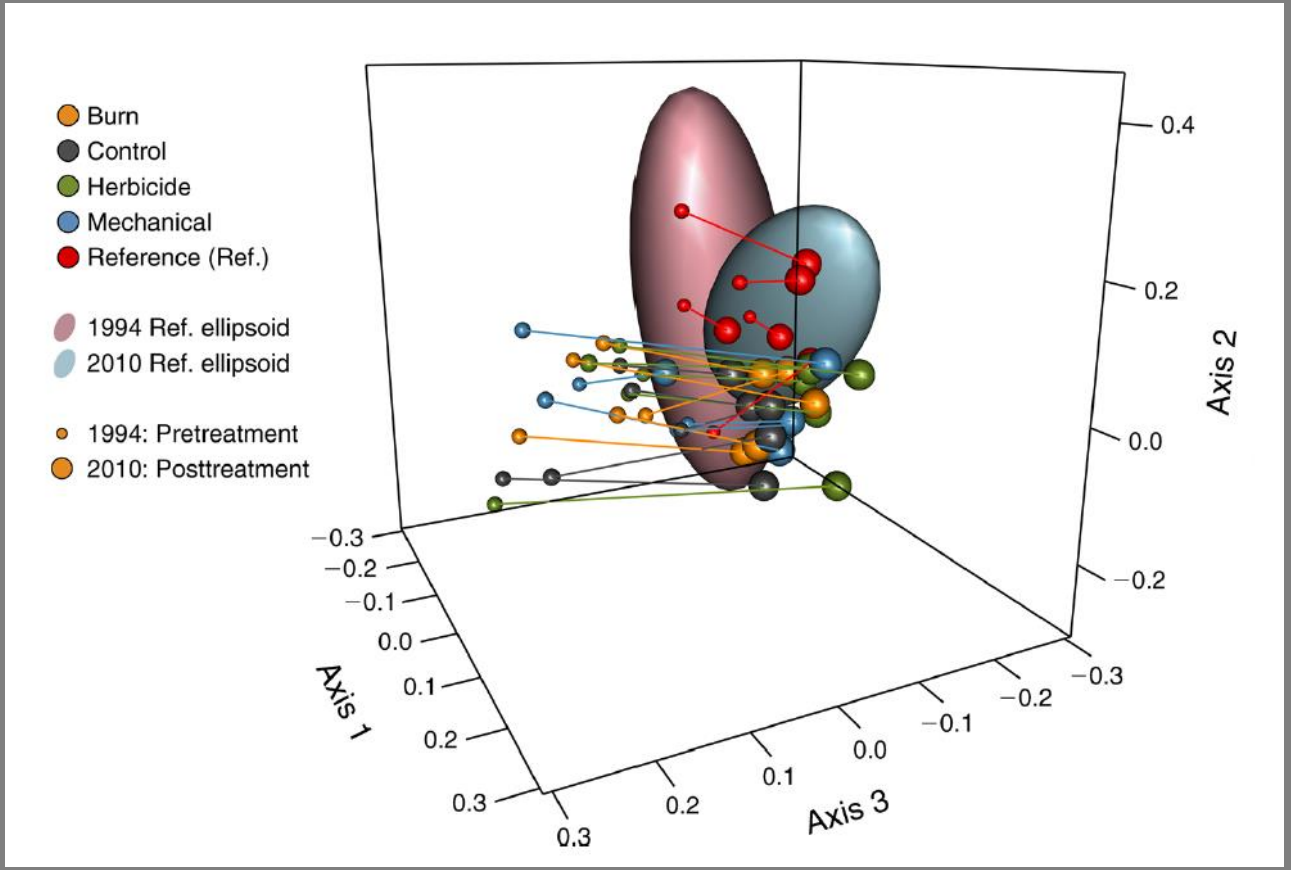
Hiers et al. 2007; Ecological Applications

Forest Floor Development and Sandhill Restoration

Recovery is fast:

✓Recovery to near reference condition observed in <20 years

✓Herbicides and mechanical treatments did not speed up recovery rates vs. fire alone



Kirkman et al 2013; Ecological Applications

Conclusions

Pine Mortality:

- ✓ Impacts from duff consumption may be delayed over 2+ yrs.
- ✓ Mortality May be extensive (>70%).
- ✓ Destruction of roots caused cascade of insults leading to tree death with <30% consumption

Safe Burning Conditions:

- ✓ Are identifiable.
- ✓ More conservative than thought.
- ✓ Varies seasonally and inter-annually.

Future Work

- ✓ **Quantify recovery of native plants in response to progressive duff removal**
- ✓ **Understand long term consequences to nutrients and soils from duff build-up and removal**
- ✓ **Refine rain prescription parameters with ET**
- ✓ **Understand mortality relative to season of burn and long-term drought.**

Collaborators & Funding

Collaborators:

Jack Putz, University of Florida

Eamon Engber and Lenya Quinn-Davidson, Humboldt State University Fire Lab

Bob Mitchell and Dali Guo, J.W. Jones Ecological Research Center

Doria R. Gordon, The Nature Conservancy & University of Florida

James Furman and Brett Williams, Eglin AFB

Steve Coates, Ordway-Swisher Biological Station

John Kush & Ralph Meldahl, Auburn University

Dale Wade, USDA-FS SRS (Athens)

Roger Ottmar, Clint Wright, and Bob Vihnanek, Pacific Wildland Fire Sci. Lab, USDA-FS PNW (Seattle)

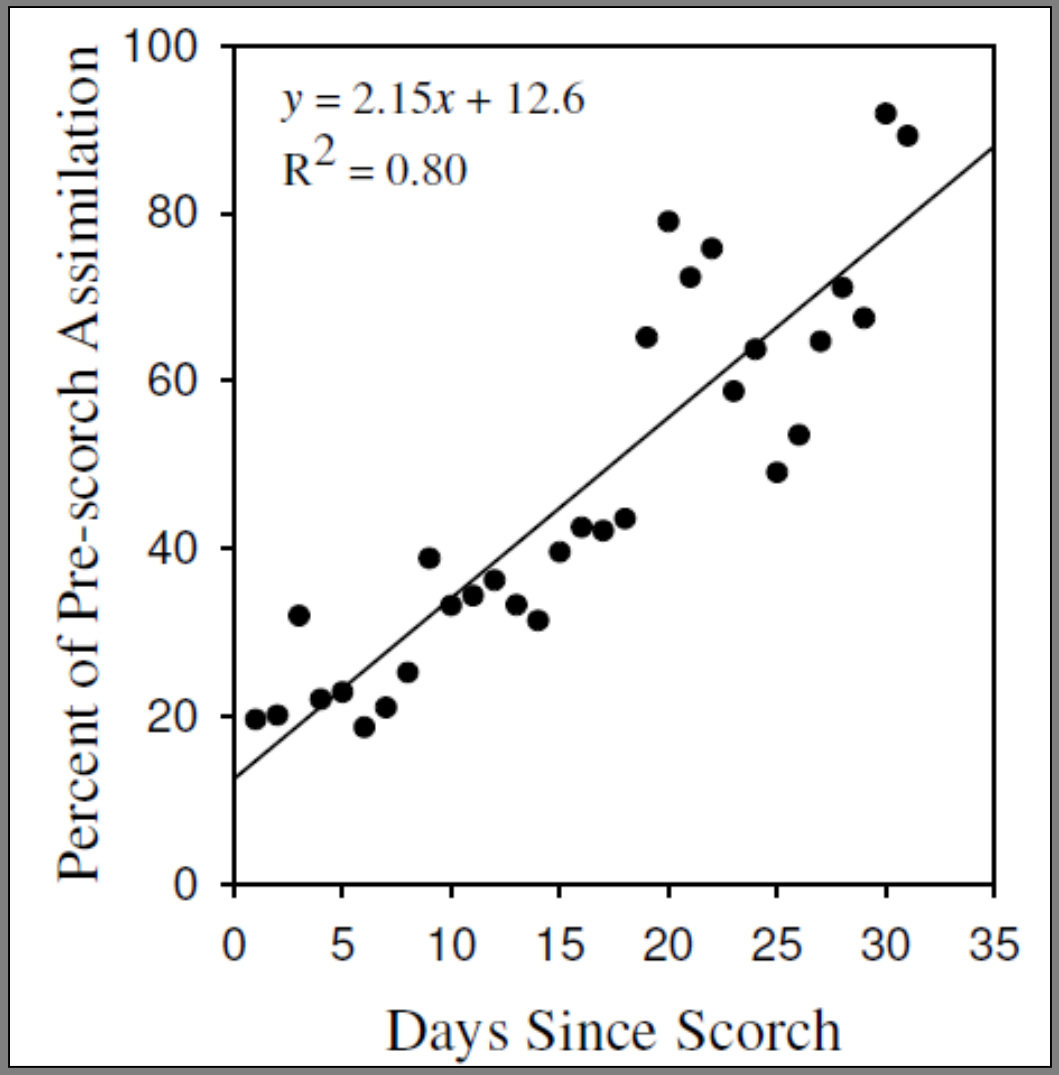
Many at Ft. Gordon, GA; The Nature [illegible] &


Questions?

A Little Light Reading…

- Ferguson et al. 2002. *International Journal of Wildland Fire* 11: 267 – 279.
- Varner et al. 2005. *Restoration Ecology* 13:536-544.
- Varner et al. 2007. *Canadian Journal of Forest Research* 37: 1349-1358.
- Hiers et al. 2007. *Ecological Applications* 17(3):806-814
- Varner et al. 2009. *Forest Ecology and Management* 258:2457-2474.
- O'Brien et al. 2009. *Fire Ecology* 6(2):1-12.
- Hiers et al. 2012. *Ecological Restoration* 30(1):27-36.

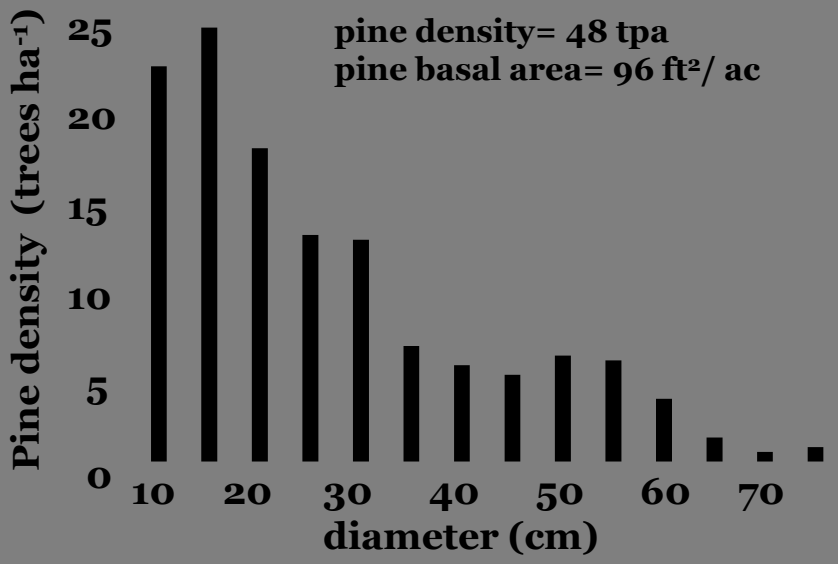
Longleaf Recovery From Scorch Quickly



Implications on stand structure

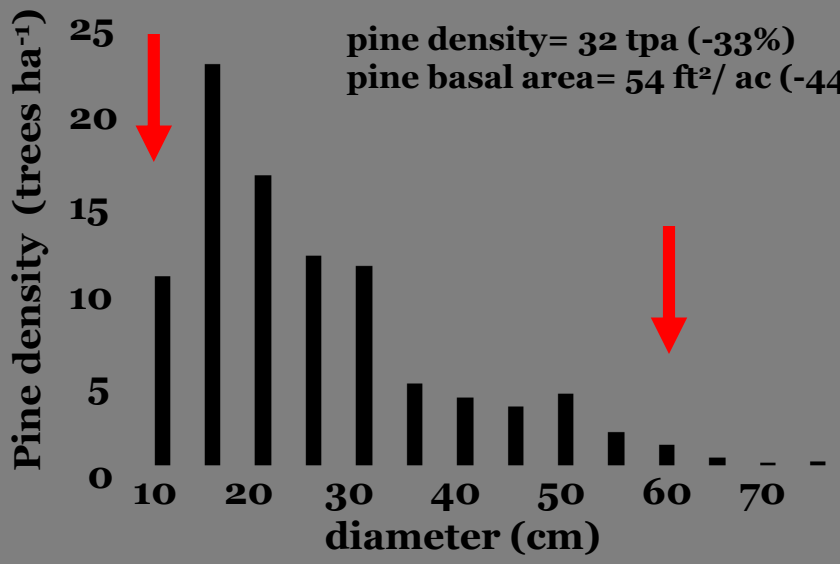
Pre-fire

pine density= 48 tpa
pine basal area= 96 ft²/ ac



Post-fire

pine density= 32 tpa (-33%)
pine basal area= 54 ft²/ ac (-44%)



Do Turkey Oaks Burn?