

ADVANCES IN UNDERSTANDING DUFF FIRES IN LONGLEAF PINE FORESTS



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TALL TIMBERS

Collaborators & Funding



Collaborators:

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Leda Kobziar, Univ. of Idaho

Eamon Engber, Lenya Quinn-Davidson & Jeff Kane, Humboldt State University Fire Lab

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

James Furman and Brett Williams, Eglin AFB

Steve Coates & Andy Rappe, Ordway-Swisher Biological Station

Roger Ottmar and Alina Cansler, Pacific Wildland Fire Sci. Lab (Seattle)

Many at Ft. Gordon, GA; The Nature Conservancy of Florida & Georgia



Degraded Remnant Longleaf Pinelands

Fire exclusion across 1/2 of area (Outcalt 2000)

- **Results of exclusion:**
 - **Structural changes**
 - **Compositional shifts**
 - **Fauna extirpation**
 - **Advent of forest floor**



Results of restoration with fire?

- **Heavy large tree mortality**
- **Long-duration heating**
- **Smoke**



Heavy overstory mortality at the Flomaton Natural Area, Alabama

Restoring Fire to Long-Unburned *Pinus palustris* Ecosystems: Novel Fire Effects and Consequences for Long-Unburned Ecosystems

J. Morgan Varner, III,^{1,2,3} Doria R. Gordon,^{4,5} Francis E. Putz,⁵ and J. Kevin Hiers⁶

Varner et al. 2005 *Restoration Ecology*

J. Kush photos

Changed Fuels: "Duff"

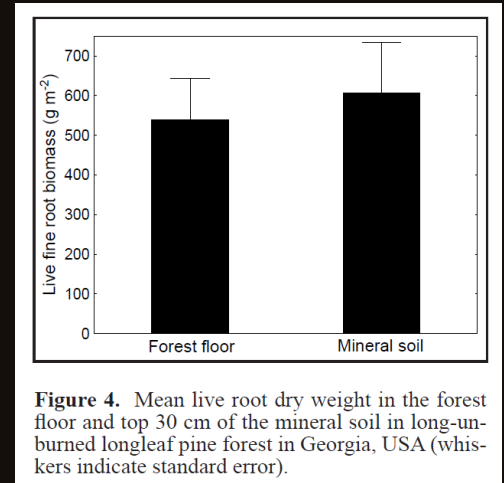
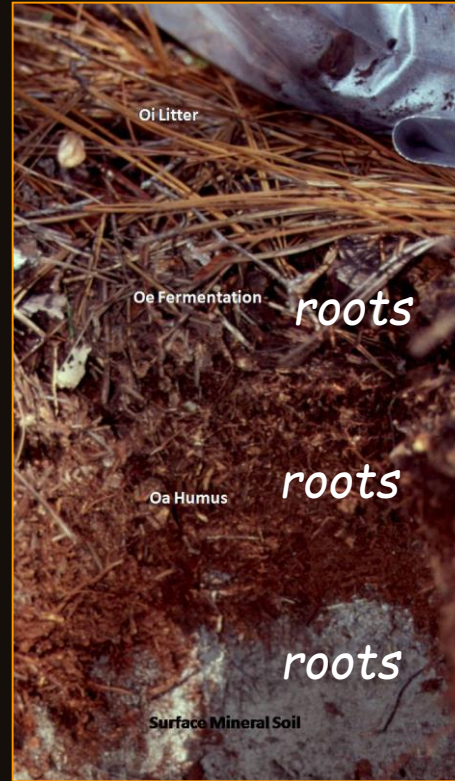
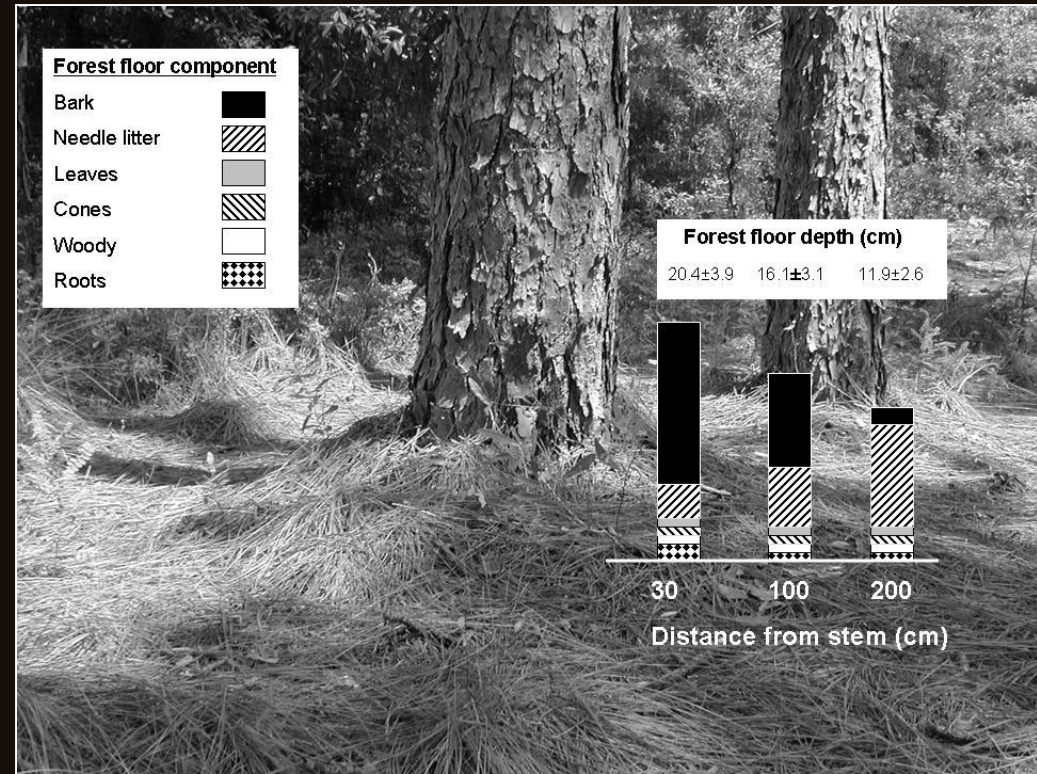


Figure 4. Mean live root dry weight in the forest floor and top 30 cm of the mineral soil in long-unburned longleaf pine forest in Georgia, USA (whiskers indicate standard error).

What is duff?

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



Varner et al. 2016. *Proc Biennial So Silv Conf.*

Management Conundrum:

*How to reduce duff
while maintaining large, old pines*



Retain large, old trees

High survival = residual duff hazard

Reduce duff fuels

Reduce duff = high mortality

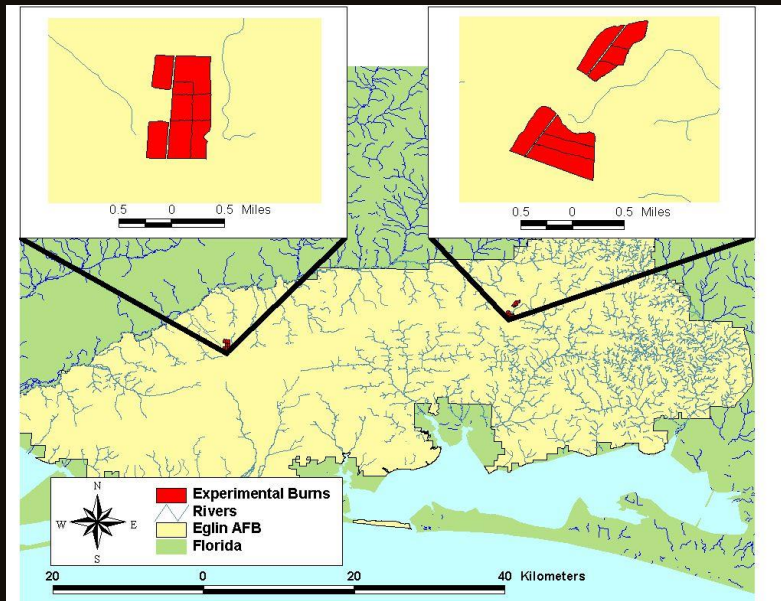
What are the patterns in large pine mortality?

Operational-scale Rx Fire Experiment

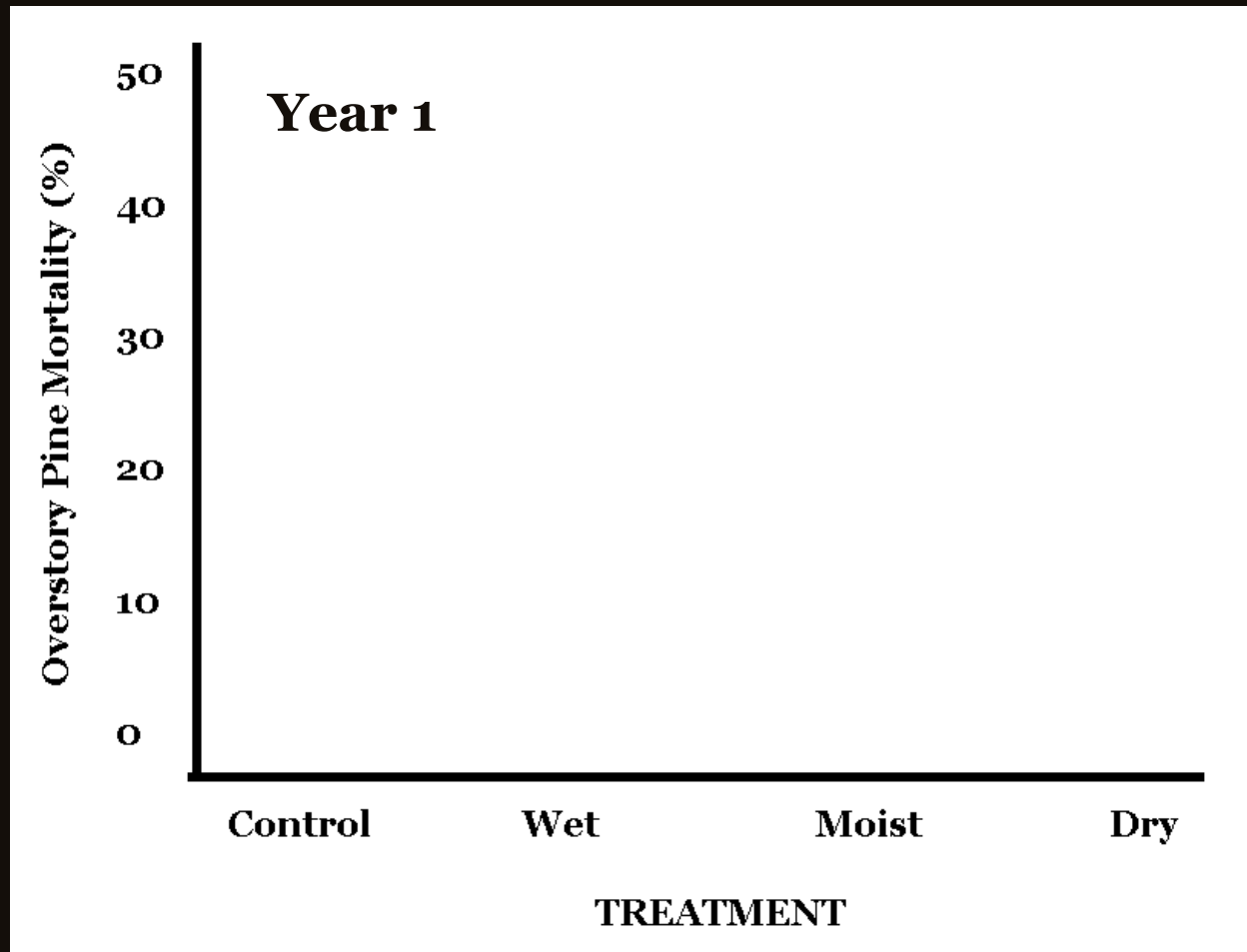


Eglin Air Force Base, Florida

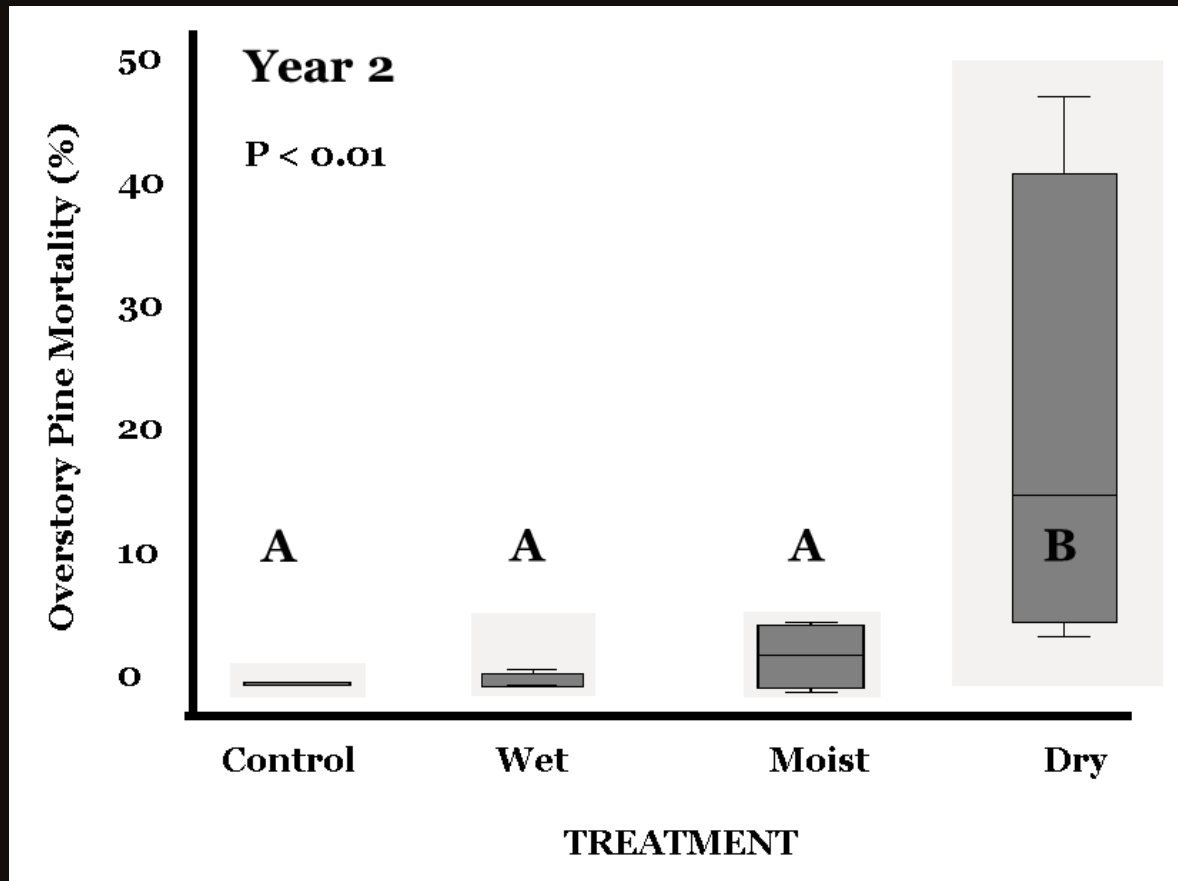
- 4 treatments × 4 reps (>25 ac)
 - No burn
 - Wet duff (115% mc)
 - Moist duff (85% mc)
 - Dry duff (55% mc)
- Injury surveyed within 3 wks
- Mortality surveyed every 6 mo



Post-fire Pine Mortality

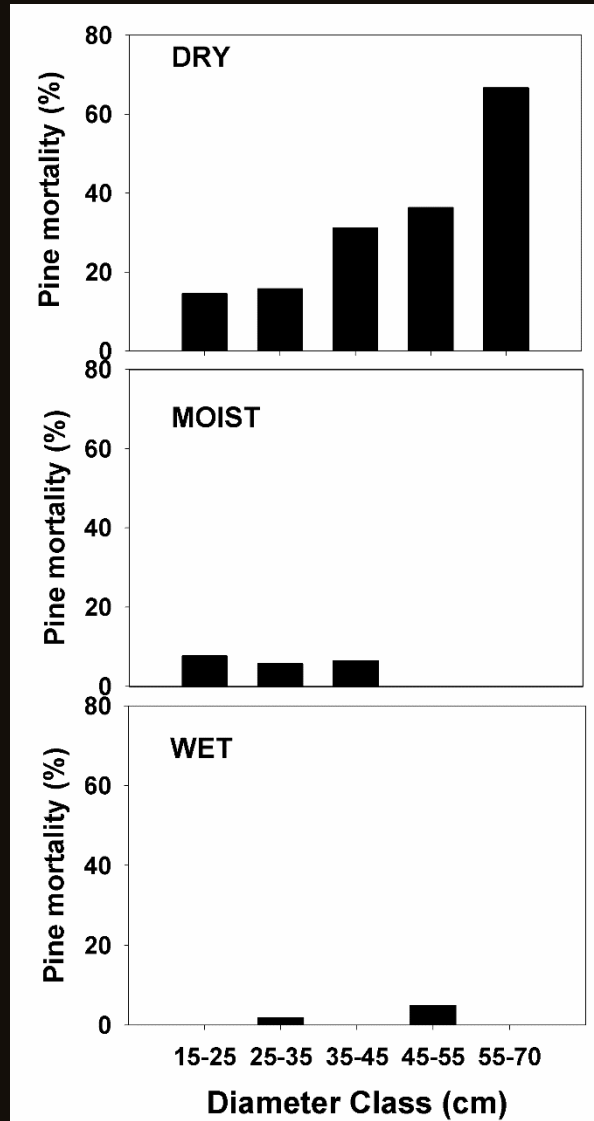


Delayed Post-fire Mortality



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

Patterns of Large Tree Mortality?



$DBH_{\text{dead}} > DBH_{\text{surviving}}$ $P = 0.002$

trees < 16" dbh: 19% mortality

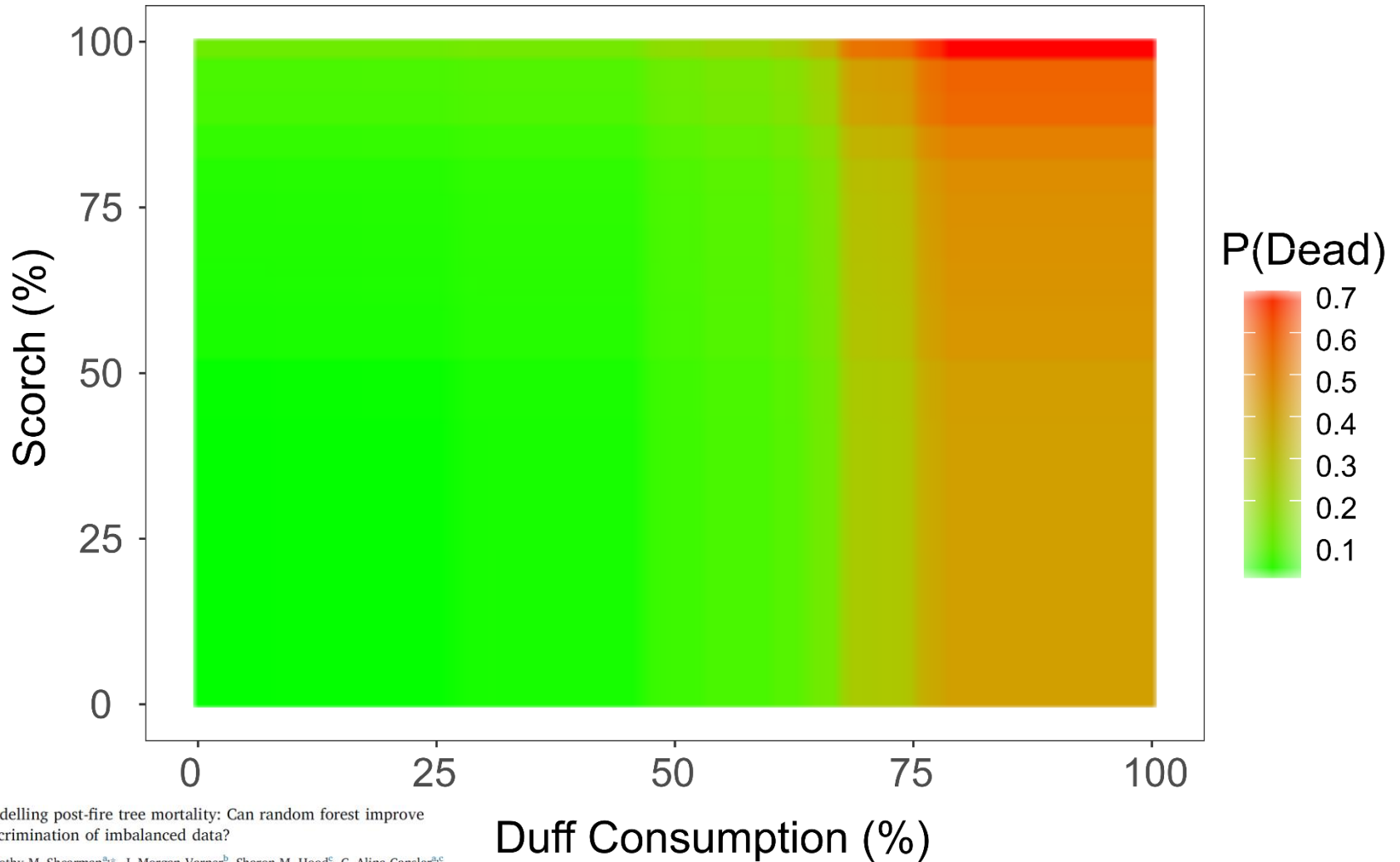
trees > 16" dbh: **53% mortality**

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

J. Morgan Varner III, J. Kevin Hiern, 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?

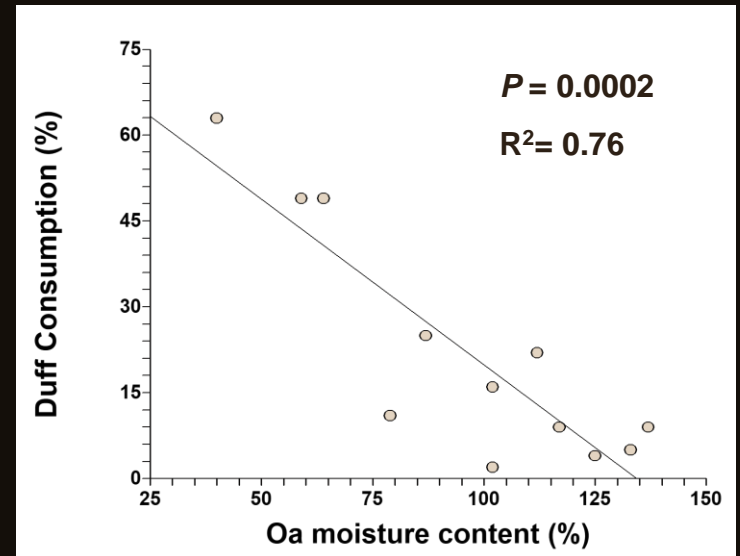


Modelling post-fire tree mortality: Can random forest improve discrimination of imbalanced data?

Timothy M. Shearman^{a,*}, J. Morgan Varner^b, Sharon M. Hood^c, C. Alina Cansler^{a,b,c}, J. Kevin Hiers^b

What drives duff consumption?

- **Primarily lower duff (Oa horizon)**
- **Other factors...**
- **Moisture is patchy...**



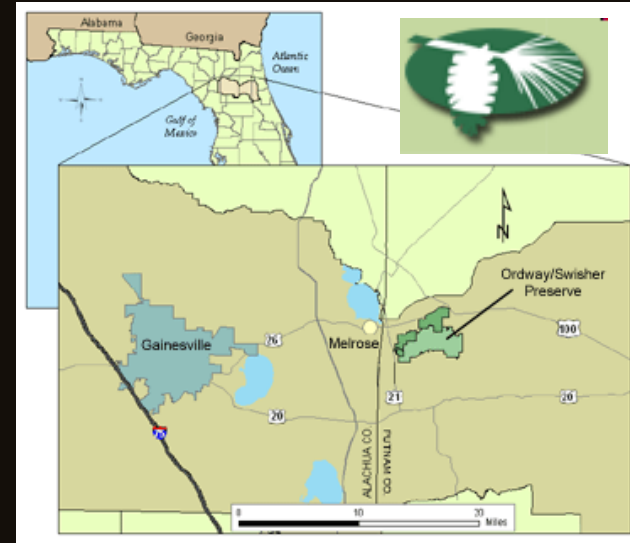
Varner et al. 2007 *Can. J. For. Res.*

What are the mechanisms of large pine mortality?

Individual Tree Experiments

Ordway Biological Station, FL

- Long-unburned (37 y)
- *Pinus palustris*-*Aristida*-*Quercus*
- Deep forest floor



- 4 treatments × 20 trees
 - “injury” treatments
 - ROOT
 - STEM
 - ROOT + STEM
 - CONTROL (×2)



Patterns of heating during fires



Contents lists available at ScienceDirect

Forest Ecology and Management

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

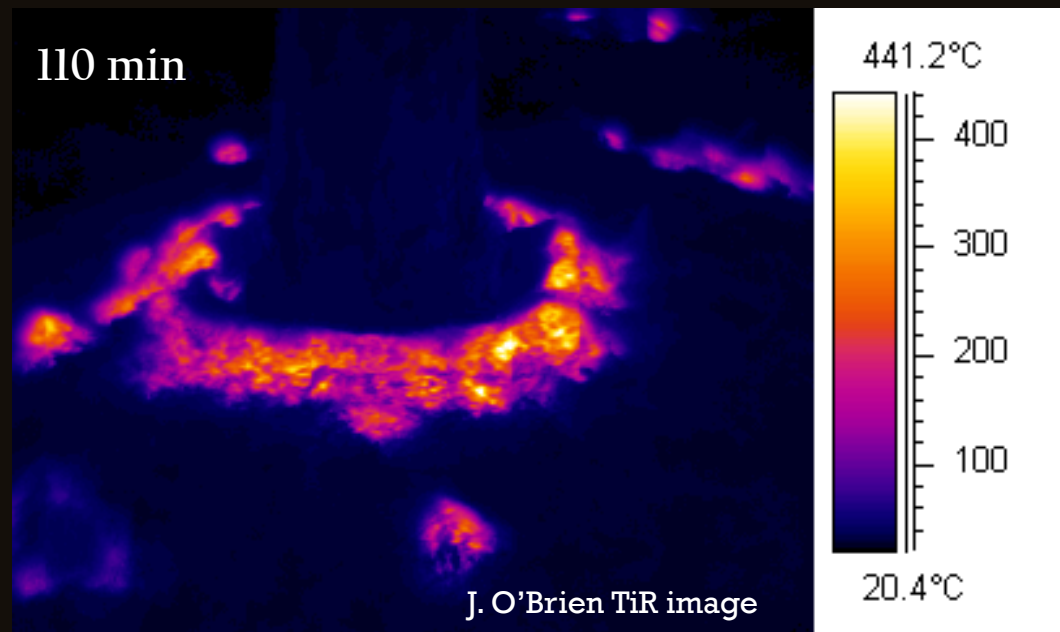
Post-fire tree stress and growth following smoldering duff fires

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,c}

25% of burns recorded lethal temperatures (>140 °F) at 8" depths

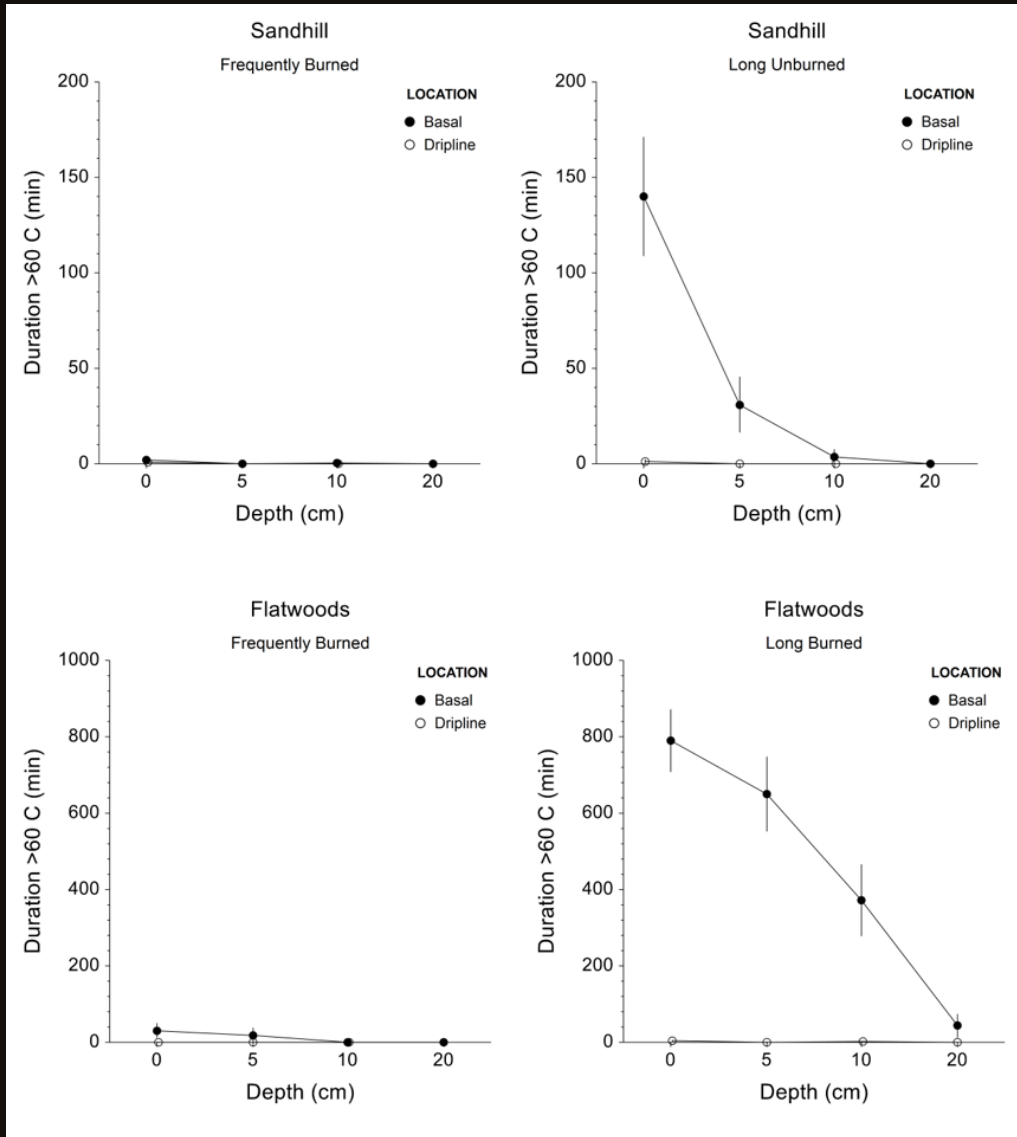
Durations of lethal heating (i.e. temperatures >60 °C) to basal bark, duff, and mineral soil during individual tree burns at the Ordway-Swisher Biological Station in northern Florida, USA.

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



Patterns of heating during fires

...What about flatwoods?



Sandhills:

~25 minutes of lethal heating at 2 inches, 2 minutes at 4"

Flatwoods:

**~12 HOURS of lethal heating at 2"
~6 HOURS at 4"**

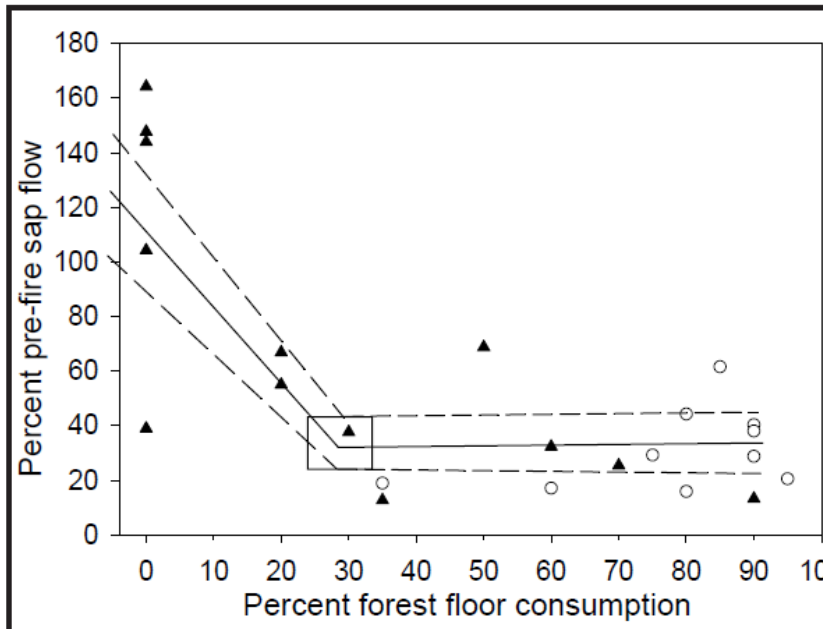
Kreye et al. 2020. Forest Science.

Other evidence of duff fire-induced stress

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

Joseph J. O'Brien^{1*}, J. Kevin Hiers², R.J. Mitchell³, J. Morgan Varner III⁴, and Kathryn Mordecai¹

O'Brien et al. 2010 Fire Ecology



Pines are sensitive to duff consumption

- Root starch
- Sap flow
- Latewood growth
- Mortality

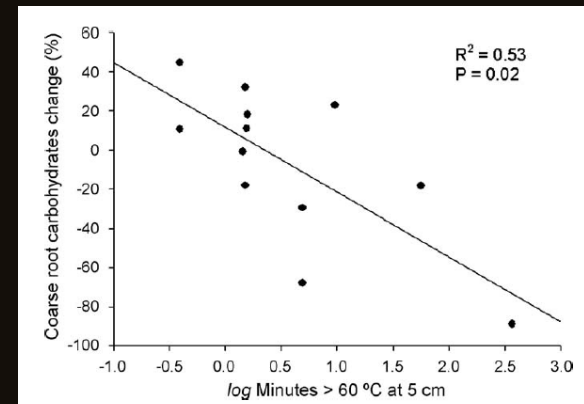
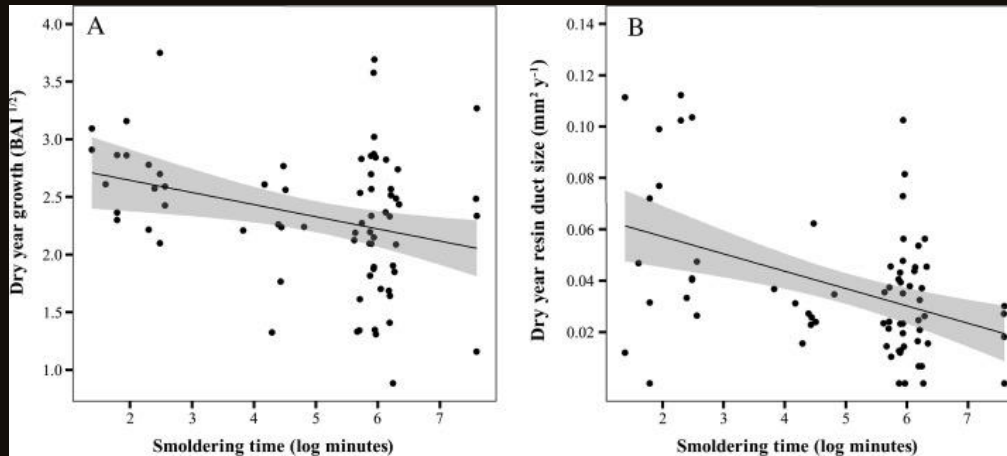


Fig. 3. Relationship between the change (2003–2004) in coarse root non-structural carbohydrates (sugar + starch) in mature *Pinus palustris* and duration of lethal heating (temperatures >60 °C) at 5 cm below the surface of the mineral soil in experimental fires in northern Florida, USA.

Varner et al. 2009 For. Ecol. & Mgmt

Consequences for long-term growth & stress

Slack et al. 2016 For. Ecol. & Mgmt

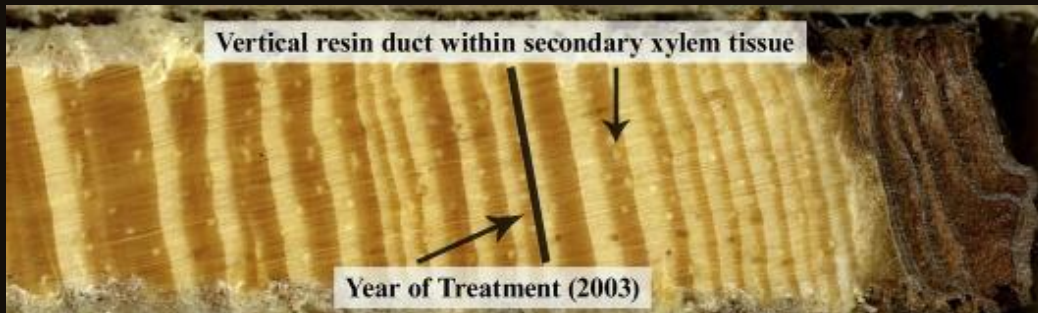


Pines remain weakened after duff consumption

– Slower growth in droughts

• As much as **10 yrs** later

– Defense weakened



Duff ignition is complicated...



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J. M. Varner², 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.*



ARTICLE

Spatial and temporal variability of forest floor duff characteristics in long-unburned *Pinus palustris* forests

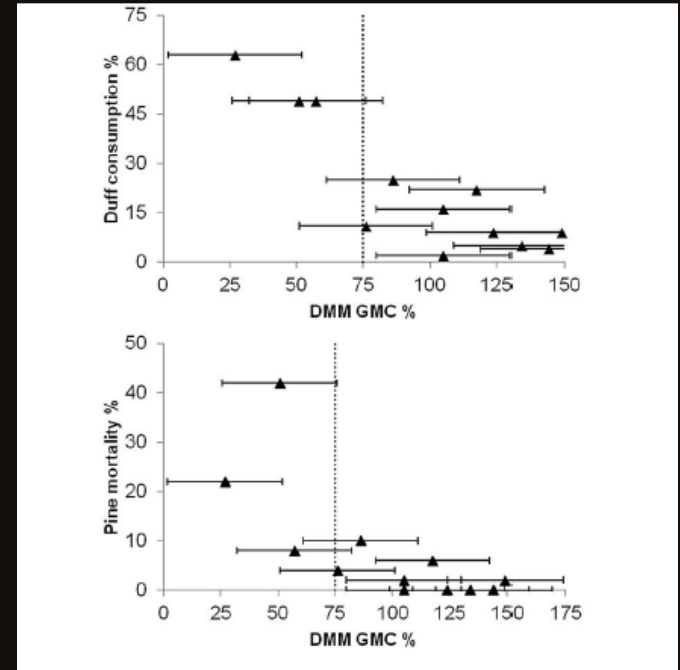
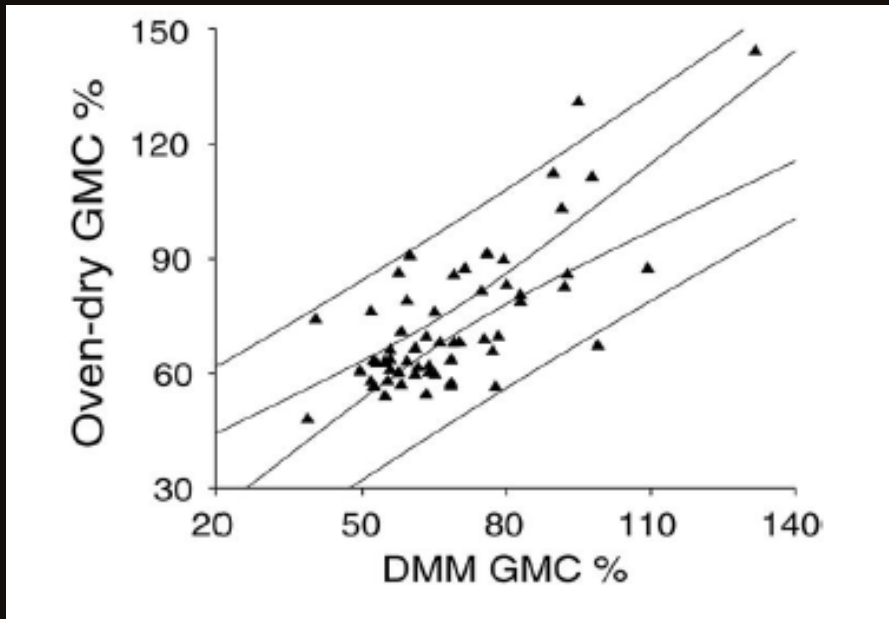
Jesse K. Kreye, J. Morgan Varner, and Christopher J. Dugaw



Utility of an Instantaneous Moisture Meter for Duff Moisture Prediction in Long-Unburned Longleaf Pine Forests

Eamon A. Engber, J. Morgan Varner, Christopher J. Dugaw, Lenya N. Quinn-Davidson, and J. Kevin Hiers

Burn unit vs. Tree approaches



Utility of an Instantaneous Moisture Meter for Duff Moisture Prediction in Long-Unburned Longleaf Pine Forests

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Silver bullets are elusive.

Conclusions

- **Advent of forest floor is a major threat**
- **Duff-fire caused mortality a serious issue**
 - **Pine stress & mortality**
- **Duff consumption is key**
 - **Linked to moisture**
 - **Long-duration heating**
- **Much to learn...**



