



# Duff and Fuel Moisture

## Science and Tools for a Common Problem

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Hello my name is David Godwin and I'm the coordinator for the Southern Fire Exchange with the University of Florida. Today I'm going to briefly introduce our program and then I'll talk about some science and tools related to issues associated with duff fires.



As you know, natural resource managers put themselves at risk every time they burn. Conditions are changing: fuels, weather, climate, populations and plant and animal species. Because fire is always risky and careers are on the line every time they strike a match, managers need and increasingly demand the latest science, tools and models to make sure that each burn is as effective, successful and as safe as possible. No burn can be wasted.

Research funding programs are increasingly looking for scientists that are including tech transfer deliverables. Scientists are increasingly recognizing that to stay relevant and competitive, they need to understand the needs of natural resource managers on the ground.

The role of the Southern Fire Exchange is to serve as a boundary spanning organization to bridge the gap between the diverse fire science and fire management communities in the South so that both groups achieve greater outcomes.

Very much like Cooperative Extension, we're funded to be unbiased brokers of fire science.



We're funded entirely by grants from the Joint Fire Science Program.

Around 2009, JFSP started the development of what would become the 15 regional members of the Fire Science Exchange Network. the Network now covers the entire U.S. including Alaska, Hawaii and the Northeast Atlantic Region.



# Program Structure



Alan Long, Ph.D., SFRC Prof. Emeritus (Current PI and Admin. Dir.)

Rae Crandall, Ph.D., SFRC Asst. Prof. (Upcoming PI)



Kevin Robertson, Ph.D., Dir. Fire Ecology Program (Co-PI)



Joe Roise, Ph.D., Prof. Forestry and Env. Resource (Co-PI)



**Southern  
Research  
Station**

Joe O'Brien, Ph.D., Research Ecologist and Fire Team Leader (Co-PI)

SFE started in 2009 with a regional needs assessment project and an initial funding grant in 2010. I came on board in 2013. We were just refunded for 2019-2020.





# Essential Regional Partnerships



So how do we leverage our resources to serve the managers and researchers of the South? In FY16 alone we worked with over 50 partner organizations on science delivery projects.

Prescribed Fire Councils have been absolutely key partners in helping us to connect science with managers.

## SFE Science Delivery Programing



So how do we work to connect scientists and managers on those four topic areas? Through a science delivery strategy that provides a range of programs that span a spectrum of user engagement and effort:

From user accessed materials (such as fact sheets and newsletters) - to direct delivery content (such as webinars) - to more personal interactions such as workshops and field tours.

The goal is to provide a range of information exchange opportunities that require a range of user investment and engagement.

### Since FY15:

- 51 workshops/field tours/training events
- >2,000 participants
- Locations including: FL, GA, AL, TX, LA, SC
- Topics Including:
  - Longleaf Mgt.
  - Ground Cover Rest.
  - Duff Fire Science
  - Fire Models



Our fire science workshops and field tours are effective for bringing scientists and managers together for exchange.

Since FY15 we've hosted or been involved with 51 workshops, fieldtours or training events that have had over 2,000 participants.

In just two of our workshops last year participants indicated that as a whole they were responsible for the management of more than 2 million acres in Florida.

Our Duff Fire Science workshop last year brought leading scientists and experienced managers to talk about the latest understanding and tools for reducing duff-fire induced pine mortality. We spent time indoors with expert presentations and outdoors at a field site with a heavy duff load. The workshop was a huge success and we had managers come back and tell us that it absolutely changed how they use prescribed fire.





Our bimonthly FireLines newsletter summarizes research on topics relevant to the SE and includes the news, tools, resources and events for the fire management and research communities.

It goes out to our email list of almost 3,000 subscribers.

We have over 40 fact sheets that synthesize and translate peer-reviewed publications into two to three page documents that allow potential management implications to be easily identified. They're scientist reviewed and collaboratively produced to ensure accuracy.

One fact sheet synthesized the results of 50 years of research focused on answering the question: How long does prescribed fire reduce wildfire risk? One day after our fact sheet was released, it was highlighted in the Georgia Department of Natural Resources newsletter as a resource for those trying to do public outreach during the West Mims Fire.





Webinars are an efficient and effective way to use technology to connect scientists and managers. Our webinar participants are overwhelmingly in the management community and most of our presenters are researchers sharing their work.

Last year we hosted 14 webinars that reached 1,859 viewers. Post-webinar surveys showed that 90% of participants were satisfied with the webinar content and 92% indicated that webinars increased understanding of fire science topics, and 85% responded that webinars provided information that could be applied to their fire management activities

We've be lucky to work with regional and national level expert speakers including Steve Pyne, Reid Noss, Joe O'Brien, Scott Goodrick and many others.

Our webinars have covered topics from WindNinja, to Fire Adapted Communities, to Ground Nesting Birds, to Prescribed Fire, to advanced weather topics and more.



Our webinars have served as cutting-edge training resources for wildland fire programs and courses by providing access to relevant and timely research findings before they make it into standard fire training courses. They've been used as training and discussion tools for Everglades National Park, the Florida Forest Service, the Georgia Interagency Burn Teams and others.



## Duff and Fuel Moisture

Science and Tools for a  
Common Problem

Now I'm going to transition and talk about duff and fuel moisture.



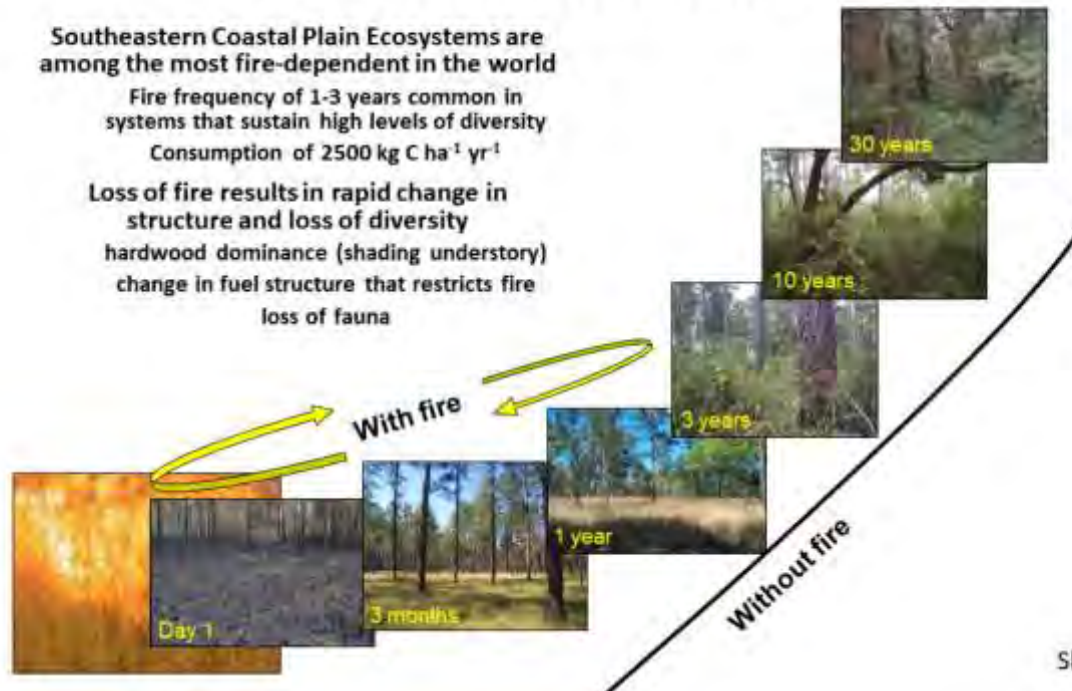
# Fire as a Maintainer

Southeastern Coastal Plain Ecosystems are among the most fire-dependent in the world

Fire frequency of 1-3 years common in systems that sustain high levels of diversity

Consumption of  $2500 \text{ kg C ha}^{-1} \text{ yr}^{-1}$

Loss of fire results in rapid change in structure and loss of diversity  
hardwood dominance (shading understory)  
change in fuel structure that restricts fire  
loss of fauna



Slide: Kevin Hiers

Fire plays a critical role in maintaining forest structure and composition in our frequent fire ecosystems of the South.

You know that in the fire-free interval forest vegetation continues to grow.

# Problems Arise Without Fire



Photo: J.M. Varner

In the absence of fire, forest fuels continue to accumulate leading to the formation of DUFF – No not that kind of duff...

Duff tends to build up particularly near the bases of mature trees.

# Duff Composition



What is duff? The composition varies with the location, but closest to the tree you'll find more sloughed bark than you would further away. Leaves/Needles and other material, including roots. From the Oe horizon down you'll find roots.



# Long Duration Heating

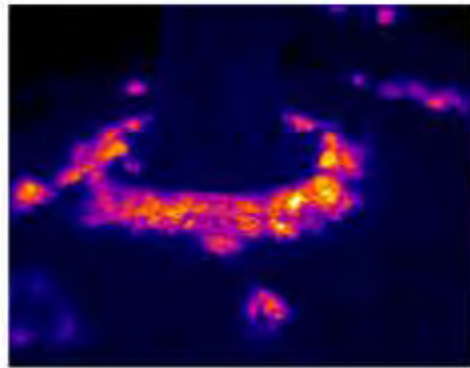


Photo by J. O'Brien.

**110 min**

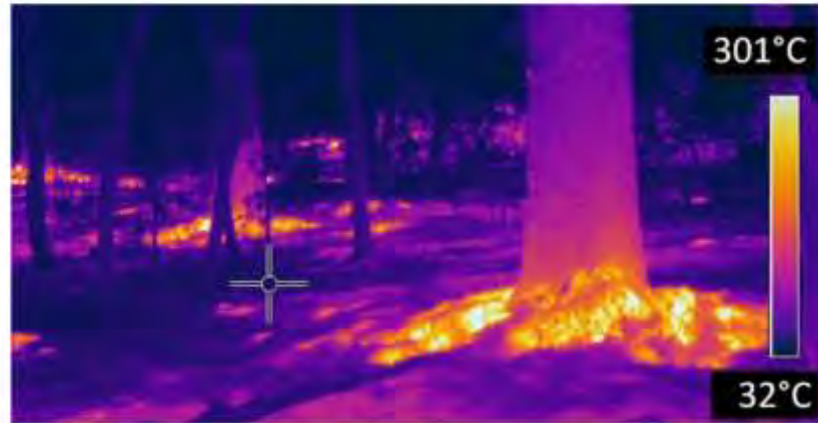


Photo by J. Kreye, Eglin AFB

Duff is an issue because it causes long duration heating that impacts the roots that mature pines tend to put up into the duff material.

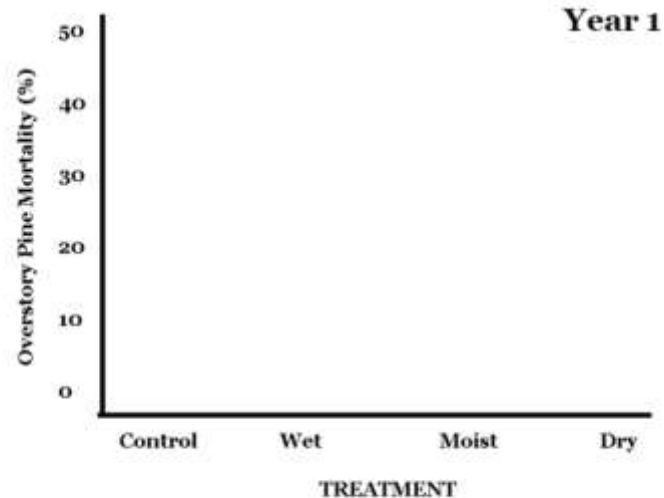


This long duration heating often leads to overstory mortality. Unfortunately, duff fires have killed many mature and much loved pines across the Southeast.

# Delayed Duff Mortality

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

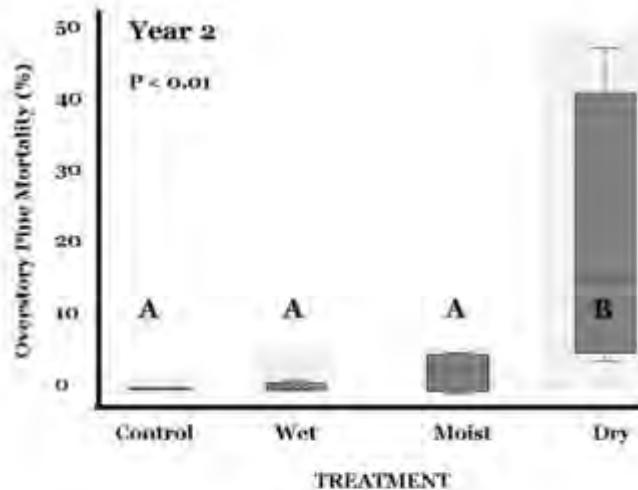


Varner et al. 2007. *Canadian Journal of Forest Research* 37: 1349-1358.

What's interesting about duff mortality are the impacts and the timing. In this study by Morgan Varner at Eglin Air Force Base they looked at four duff moisture regimes and surveyed pine mortality every six months following the fire. Within a year of the burn – they had NO mortality.



# Delayed Duff Mortality

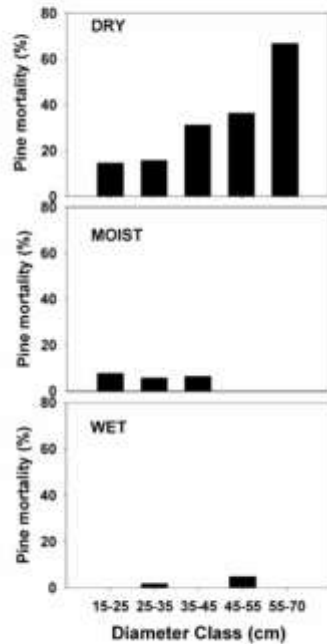


- Mortality delayed 18-24 months
- Mortality peaked in dry burns
- Mortality in unburned not different from moist & wet

Varner et al, 2007, *Canadian Journal of Forest Research* 37: 1349-1358.

But.....by year two....things looked differently and mortality in the dry duff treatment spiked and ranged from 0 – 42 %. Research and anecdotal evidence point towards this 12-18 month delayed mortality window – suggesting that trees might be dead and not even know it yet following a duff fire.

# Duff Kills Big Trees



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

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

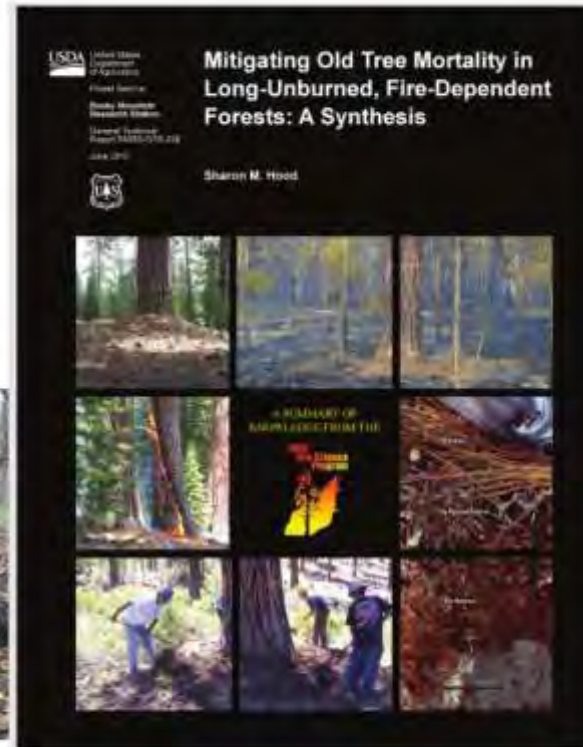
Varner et al. 2007. *Canadian Journal of Forest Research* 37: 1349-1358.

What's also interesting about duff fire induced mortality is that it tends impact the larger trees the most. If you see the diameter class distribution here from the Eglin study, you can see the mortality was concentrated in the larger trees. Unfortunately in so many cases these trees are the very reason that a tract might be conserved.

# Not Simply a Coastal Plain Issue



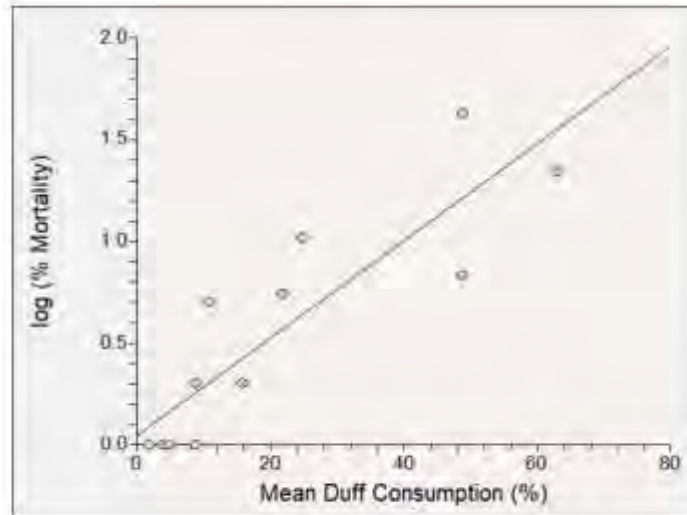
Rough Ridge Fire 2016, sampled 1-yr later Photos: Kevin Hiers



Unfortunately duff induced mortality isn't simply a coastal plain issue. Duff induced mortality appears to be at work in parts of the Appalachians following the 2016 wildfire season. These are photos showing duff consumption and pine mortality following a wildfire in the Cohutta Wilderness Area in NW Georgia. In 2010 JFSP published a synthesis that address the issue as it relates to fire dependent forests across the country.

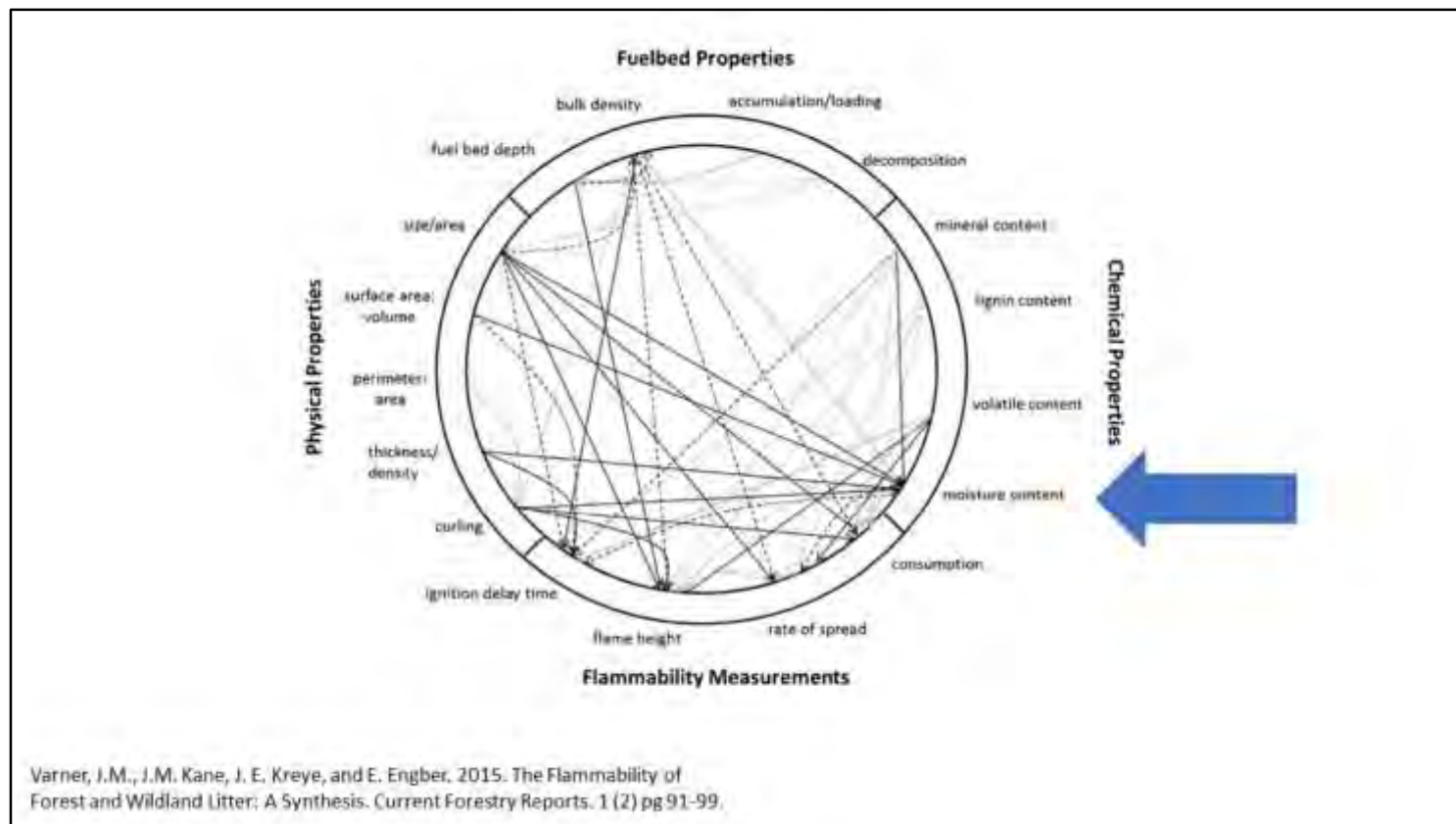


# Duff Consumption Matters



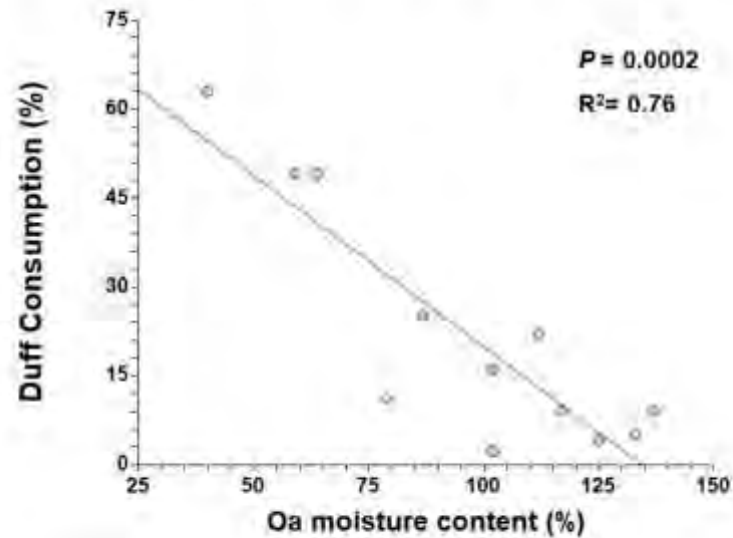
Varner et al. 2007. *Canadian Journal of Forest Research* 37: 1349-1358.

Research by Morgan Varner has shown that as Duff Consumption goes up pine mortality goes up. So what can be done to manage duff consumption?4.54



Well there are a range of properties associated with forest floor fuels and fuelbeds that can impact their flammability. This graphic from a recent synthesis illustrates many of the properties. But in the case of duff we're going to focus on moisture content.

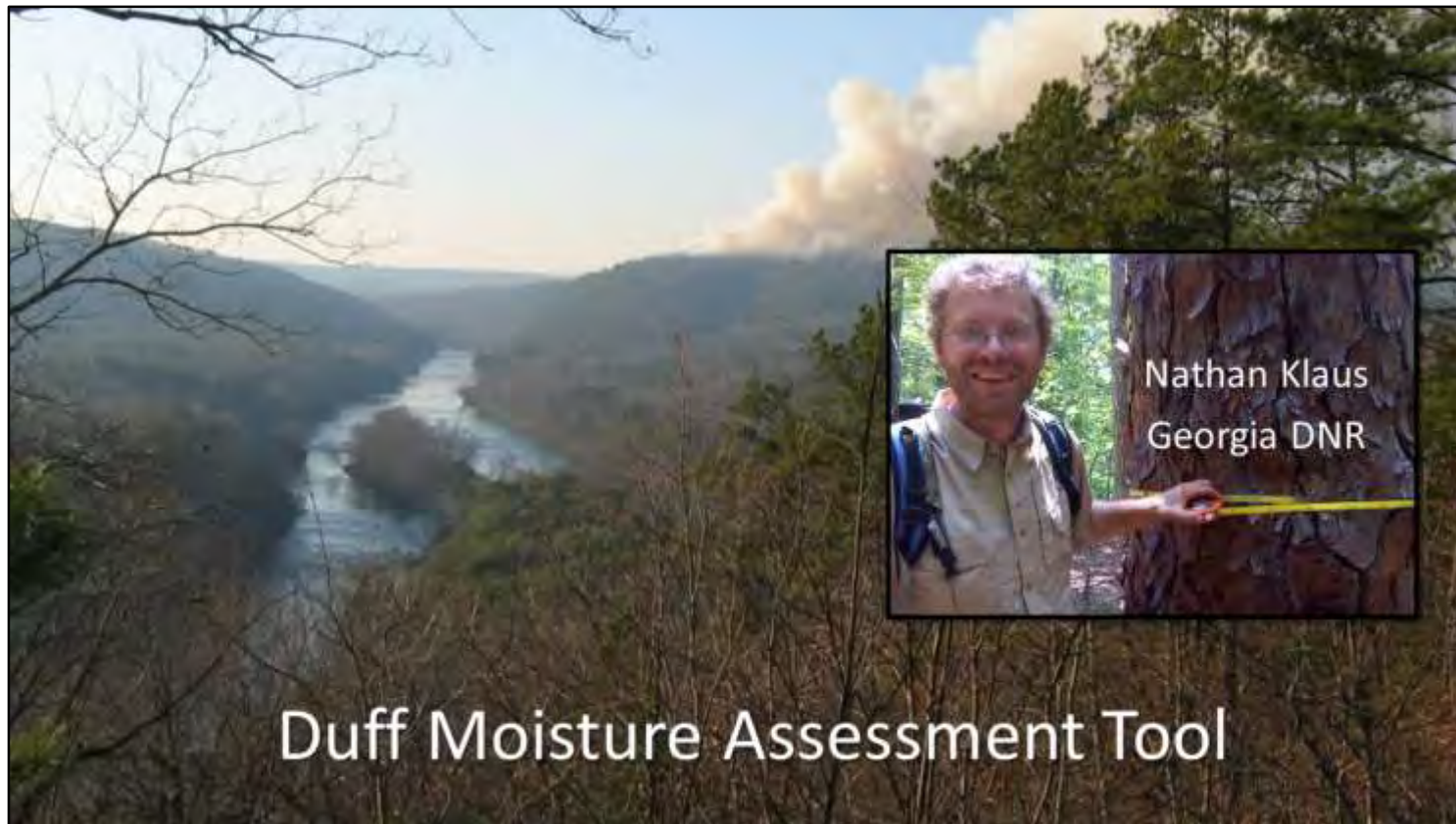
# Duff Moisture Matters



Varner et al. 2007. *Canadian Journal of Forest Research* 37: 1349-1358

Which goes back to Varner's 2007 study that found that as Oa horizon (duff) moisture content went up, duff consumption went down. And you'll remember that duff consumption was associated with pine mortality.





My friend Nathan Klaus with the GA DNR put together these slides for our workshop last October about a tool that his team has been using for the past several years to assess that question about duff moisture.

# Sprewell Bluff WMA Restoration

- Sprewell Bluff WMA near Thomaston, GA and the Flint River
- Scattered old growth montane longleaf pine duff trees (some > 400 years old)
- Dry rocky soil, steep ground, lots of hardwoods



They work primarily on restoring a mountain longleaf site in middle GA called Sprewell Bluff.

## Sprewell Bluff WMA Restoration



When the state of GA started managing the site the duff loads were deep.



## Sprewell Bluff WMA Restoration



## Sprewell Bluff WMA Restoration



But with such old trees on the site, quite a bit was at risk.

# Challenges with Duff Management

- Average duff depth was 9" (23 cm) many trees much deeper
- Standard prescription was to burn <24 hrs of 1" or more of rain
- Most burns in Feb-Mar
- Many years with only 4-5 burn days



Under their initial operations – their prescribed was to burn on days with 1" of rain or more within 24 hrs. Unfortunately this conservative approach left them with only 4-5 burn days per year.



# Challenges with Duff Management

- Duff can still burn after 1-2" of rain during drought years
- Questions remained: What if they had three rain events each separated by 4 days, none over 1", total accumulation 1.75", should they burn or not?
- Checking duff meant feeling it with our hands, hard to teach this to techs or landowners



More challenges: Duff can still burn after 1-2" of rain during drought years

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Checking duff meant feeling it with our hands, hard to teach this to techs or landowners

## New Tool: Delmhorst BD-2100 Moisture Meter

- Designed to sample moisture in sawn lumber
- Gives a true and consistent value
  - Quick to train people to use
  - % scale, 0-100
  - No more guesswork
- Gives values instantly
- Very rugged, holds up to use in fire



## How to use the BD-2100 Moisture Meter

- Set meter to % scale
- Pull away straw/litter
- Gently insert probes, get reading
- Remove top layer of duff and repeat, take 4-5 measurements through entire column of duff
- Measure 2-3 spots per tree, different sides of tree
- Measure 10-20 trees, various aspects and slope positions



## BD-2100 Measurement Tips

- Take lots of readings. If in doubt sample 20 trees total, sampling three areas in your unit is reasonable, ~ 20 minutes.
- Take readings from multiple parts of your unit. Try to pick the most likely places for duff fires: high ridges, steep slopes, windward side of ridge, leeward side of trees during rain





## BD-2100 Measurement Tips

- Compressing duff around probes squeezes moisture out, resulting in inflated readings
- Make sure you are using percent scale
- Make sure there isn't a dry layer of duff below the top layer, sample duff all the way to mineral soil



## Duff Moisture Thresholds for BD-2100

- **Above 80% duff will not burn**
- **85%+ you are golden**
- **Below 73% duff will burn**
- **Mid 70s is risky, maybe can get away with it but not on 1<sup>st</sup> entry, likely will have some trees burn**



KEY: Try it. Experiment with it and use it to make your OWN duff moisture thresholds.

## BD-2100 Benefits

- Lower mortality rates of most valuable trees. We are losing 1-3% of trees total over a ten year period of reintroducing fire.
- Anyone can get info on duff moisture to burn boss, allows burn boss to focus on other things the morning of the burn



## BD-2100 Benefits

- Greatly expanded # of days to burn duff, we found our duff burn days went up 3X!
- Wider prescriptions – most rain events that bring 1+” of rain are from a cold front.
- Burning right after this rain/cold front meant high wind and low RH. We now know how long we can wait before it is too dry and burn under calmer conditions. We also can assess whether we can burn during wet periods of smaller rain events that don't have extreme weather





## Where can I get one?

- Google “Delmhorst BD-2100 WCS”
- About \$400 online. It’s not cheap but what is a 200 year-old tree worth?
- Other moisture meters?
  - We have only evaluated one other, extremely cheap (\$10) meter used to measure soil moisture in potted plants. It was worthless
  - Likely other high-end meters would work but we have not evaluated them



Questions? [Nathan.Klaus@dnr.state.ga.us](mailto:Nathan.Klaus@dnr.state.ga.us)

## Sometimes things still go wrong.



Photos: Shan Cammack and Bryn Pipes

Even when using care, tools and techniques, there may be situations where duff mounds ignite. In this case what do you do? Well my friends Shan Cammack and Bryn Pipes with the Georgia DNR put these slides together to talk about their duff fire management technique.

# Why not just drown it?

- Smoldering duff is insidious and doesn't always produce smoke or surface evidence
- Time intensive
  - Requires a lot of water
  - Where is your water source?
  - Regular checkups even after treatment
- Wear and tear on equipment



Slides: Shan Cammack and Bryn Pipes

Given the depth of some duff loads and fires – water may not be an option.

There is a better way

# DUFF BUSTERS!

- No water
- Resource and time efficient
- Identifies duff spots, even the “hidden” ones
- Minimal impact (Good M.I.S.T. practice)
- Actually kind of fun!



Slides: Shan Cammack and Bryn Pipes



So instead they use backpack blowers to “blow out” duff fires.



# What you need

- Full PPE (Safety first!)
- Leaf blower
- Boots with fire-resistant soles (Vibram)
- Breathing mask (Whiff or paper)
  - If not available, blow from the upwind side!



Slides: Shan Cammack and Bryn Pipes

They use back pack blowers + masks

## Step by Step

- Blow around base of tree
  - Look for any glowing embers or flare ups
- Kick out hot spots
  - Must separate heat from unburned duff
  - Sometimes the leaf blower does all the work for you!
- Blow the area again to get heat away from duff and check for residual spots
- Repeat as necessary

Slides: Shan Cammack and Bryn Pipes



To blow the ash and hot spots away from the remaining duff.

# Fight duff smarter!

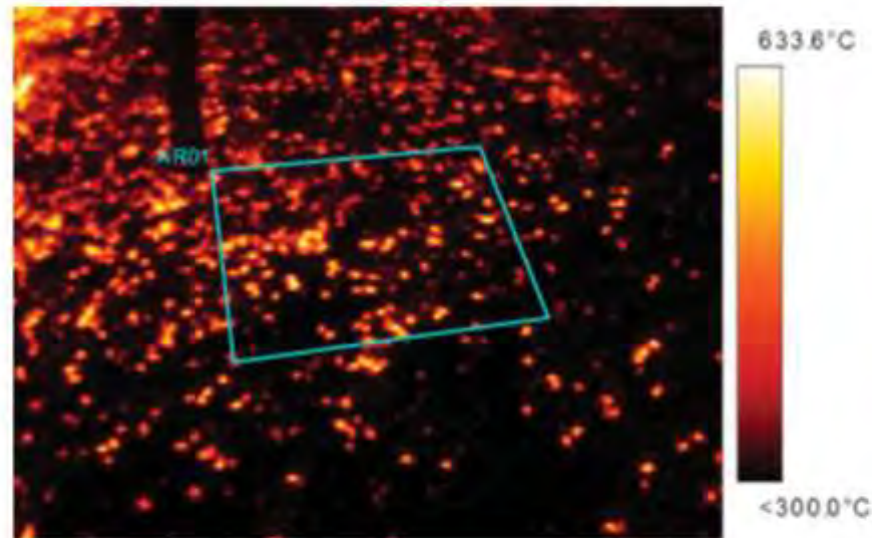
- Extinguishing duff is never ideal, but it is inevitable.
- Increase productivity from your crew
- Expand your burn window to prevent making a bad situation worse



Slides: Shan Cammack and Bryn Pipes

They've found this technique to be effective for sites across GA.

## Pine Cones: A Wildcard?

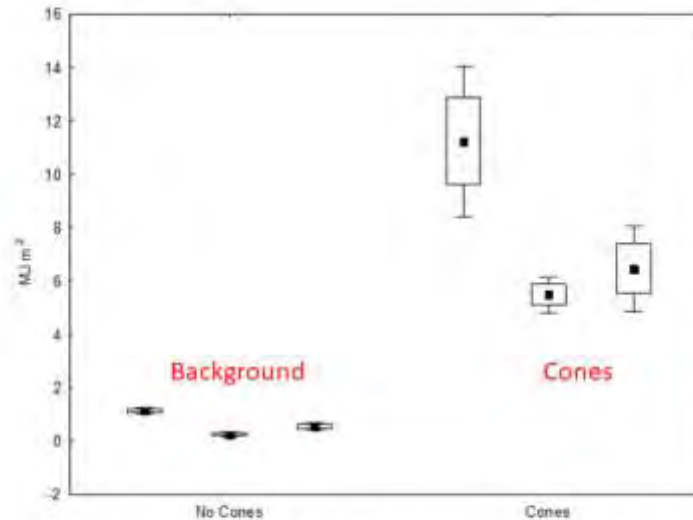
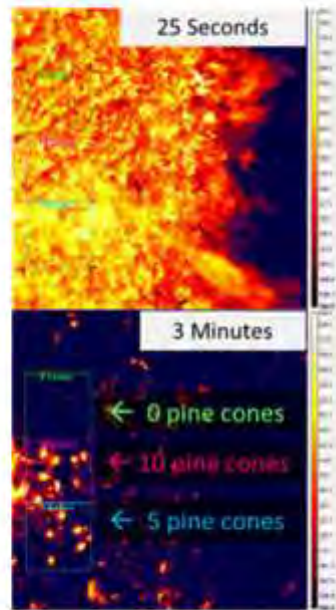


O'Brien et al. 2016. Canopy-derived fuels drive patterns of in-fire energy release and understory plant mortality in a longleaf pine (*Pinus palustris*) sandhill in northwest Florida, USA, *Canadian Journal of Remote Sensing*, 42(5): 489-500.

Here's something interesting about some research by Joe O'Brien, Jesse Kreye, Morgan Varner and others. They have started to look into the role of pine cones in longleaf pine ecosystems as important contributors to fire behavior and effects. In this oblique thermal image from the Jones Center in SW Georgia, you can see a variety of glowing hotspots. Yep those are pine cones scattered about on the forest floor.



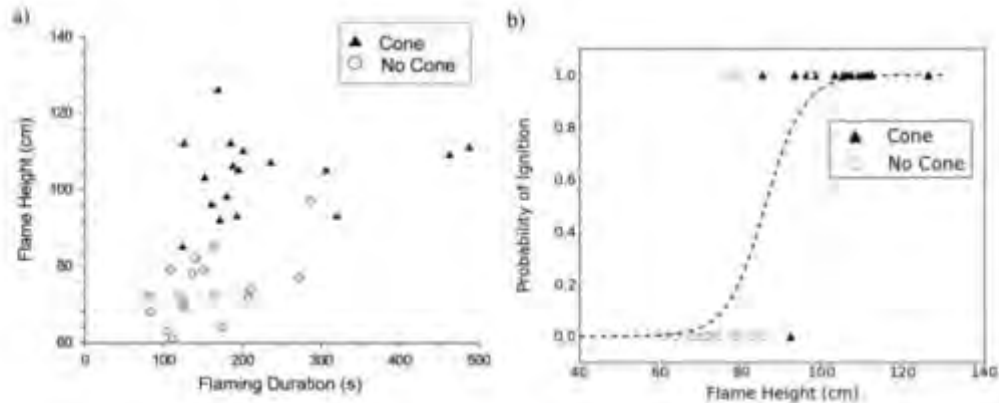
## Pine Cones: A Wildcard?



O'Brien et al. 2016, Canopy-derived fuels drive patterns of in-fire energy release and understory plant mortality in a longleaf pine (*Pinus palustris*) sandhill in northwest Florida, USA. *Canadian Journal of Remote Sensing*, 42(5): 489-500.

Joe O'Brien and his collaborators found that pine cones were important drivers of energy release during fires in longleaf pine systems. In the image on the left you can see screen captures from their thermal camera suspended over a prescribed fire. At 25 seconds the impact of cones is not as obvious, but at 3 minutes you can see that they're important contributors towards long-duration heating. On the right you can see that their energy release estimates show cones result in significantly more energy release than the background understory fuels in this system.

# Pine Cones: A Wildcard?



*Figure 3. The effects of pine cones on flame height and probability of ignition of forest floor samples (from Kreye et al. 2013)*

Kreye, J.R., Varner, J.M., Dugave, C.J., Cabi, E., Szecsei, J., Engber E.A., 2013. Pine cones facilitate ignition of forest floor duff. *Canadian Journal of Forest Research*. 43:512-516. <https://doi.org/10.1139/cjfr-2013-0019>

Further work on pine cones by Jesse Kreye and others showed that cones had significant impacts on flaming height and flaming duration.

## Pine Cones: A Wildcard?

“The ignition of longleaf pine forest floor duff in this study was primarily a result of the presence of pine cones.”

“Sixteen of the 17 burn trials that included a cone vector resulted in duff ignition, whereas only 3 of 18 burn trials without a cone resulted in duff ignition.”

Kreye, J.K., Venter, J.M., Engawa, C.L., Cao, L., Sorensen, J., Engster E.A., 2013. Pine cones facilitate ignition of forest floor duff. *Canadian Journal of Forest Research* 43:512-516. <https://doi.org/10.1139/cjfr-2013-0019>

Further more, Kreye and collaborators were able to show that cones played an important role in getting duff to ignite – in fact – their study showed that cones were the primary vectors that would cause duff to ignite even when moisture contents were high enough that the duff was not otherwise igniting.

# Recommendations

- **You are in it for the long haul (but the haul is not as long as we once thought)**
- **Mortality can cause management problems for years—don't break the eggs to make the omelet!**
- **Restore fuels before forest structure**
- **Burn on the margins of combustion**
  - After rain, night (if you can), in front of rain
- **Dedicate mop up resources for 2-3 days afterwards**
  - Focus on “vector” fuels
- **When safe conditions are present prioritize duff units!**
- **Use conservative prescription for 3+ burns**
- **Monitor depth reduction with duff pins**

-Adopted from Kevin Hiers and Morgan Varner.

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## Further Information

- Ferguson et al. 2002. *International Journal of Wildland Fire* 11: 267 – 279.
- Varner et al. 2005. *Restoration Ecology* 13:536-544.
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- Varner et al. 2009. *Forest Ecology and Management* 258:2457-2474.
- O'Brien et al. 2009. *Fire Ecology* 6(2):1-12.
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- Kreye et al. 2013. *Canadian Journal of Forest Research*. 43:512-516.
- O'Brien et al. 2016. *Canadian Journal of Remote Sensing*. 42(5): 489-500.

## Slide, Image and Content Credit

- Morgan Varner, Ph.D.
- Kevin Hiers
- Joe O'Brien, Ph.D.
- Jesse Kreye, Ph.D.
- Nathan Klaus
- Shan Cammack
- Bryn Pipes





# SOUTHERN Fire Exchange



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Thank you!