Complex Interactions Lead to Douglas-Fir Mortality in the Klamath Mountains

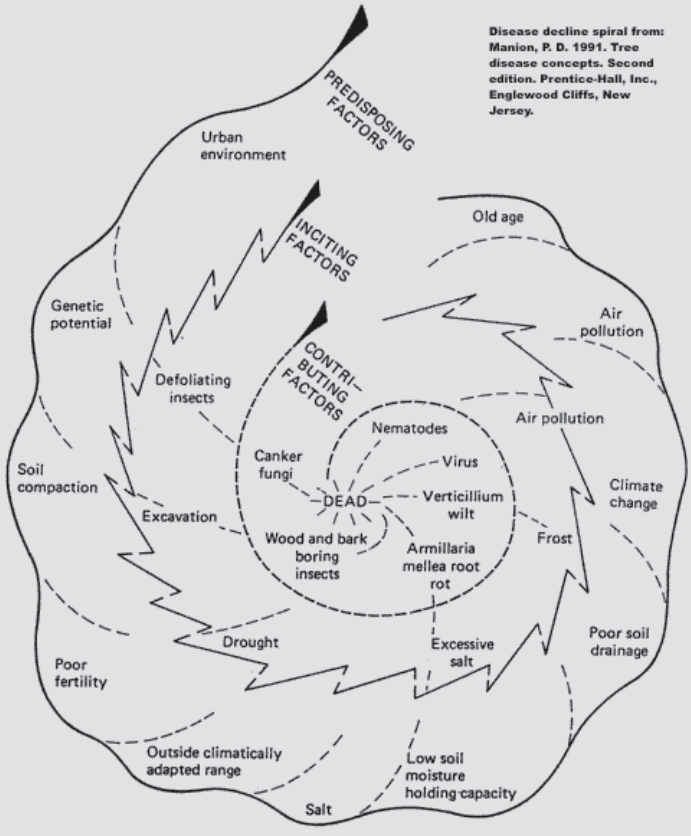
In this interview, we dig into the work of Max Bennett, David Shaw and Laura Lowrey, who recently analyzed landscape scale Douglas-fir mortality in the Klamath Mountain ecoregion. Their published paper can be found in the ***Journal of Forestry****. Interview conducted by Kayla Seaforth, BEF.*

Kayla: Let's start by talking about what you found regarding the major die off of Douglas-fir in the Klamath Mountains.

Max Bennett: This study looked at the Southwest Oregon portion of the Klamath mountains ecoregion. The main finding was confirmation of a decline spiral with Douglas-fir. This is primarily true in trees that are growing on sites that were already pretty marginal; hot and dry sites that likely didn't have as much Douglas-fir historically due to more frequent fire. As a result of fire exclusion, Douglas-fir has become more dense. Then, a hot drought came along. We used the framework of Mannion's decline disease spiral, which suggests there are predisposing, inciting and contributing factors that lead to tree decline over time. It's pretty common sense, this idea that it's usually not just one thing that kills a tree. It's a complex interaction of biotic and abiotic factors. So, the combination of Klamath Douglas-fir existing on marginal sites, with conditions caused in part by fire exclusion and hotter drought in the past few years led to trees becoming extremely stressed and probably physiologically compromised. In that state, they're very vulnerable to various diseases, insects and opportunistic pests, like flatheaded fir borer (FFB). It's a multiyear process where trees go down a spiral from stress to decline to death.

David Shaw: We also found a connection with elevation, where this is primarily occurring at low to moderate elevations. It's also heavily skewed toward drier sites that receive under 40 inches of precipitation a year.

Laura Lowrey: This is occurring on a landscape level. It's pretty widespread across the Klamath ecoregion of Oregon and Western Cascadia. One of the other



Disease decline spiral from: Manion, P. D. 1991. Tree disease concepts. Second edition. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Douglas-fir mortality overstory. Photo Credit: Chris Adlam, OSU

outcomes of the paper was to develop a hazard or risk rating for managers to use to prioritize management, perhaps on a landscape level, giving them a tool that they could use to focus work in areas experiencing Douglas-fir decline.

MB: There's a pretty clear relationship between the likelihood and the severity of Douglas-fir mortality and precipitation. Under 25 inches mean annual precipitation is pretty much too dry for coastal Douglas-fir. A lot of areas in Southwest Oregon fall into the 25-35 inch range, which is the highest risk zone for mortality. As you get to 35 to 45, there's still some risk, but as mean annual precipitation increases, mortality likelihood decreases. The other metric that we've been using is called climatic water deficit, which is the difference between potential evapotranspiration and actual evapotranspiration at a site. It's a really good measure of drought stress as experienced by plants. We're finding really good correlations with high deficit areas and tree mortality.

KS: I'm curious if you came to any conclusions that you think are applicable to folks outside of the Klamath region, especially in terms of thinking about how to manage decline in general, and how to prioritize management in areas that might be vulnerable going forward?

LL: We hope that the climate water deficit piece will be useful to other land managers outside of Southwest Oregon, and they can start to see if similar correlations exist in their regions. The prevalence of flatheaded fir borer is something that came up as a part of the decline spiral that we are learning about in real time. We'd really like to dig in more on that side of things and see if there are any management recommendations we can develop around the fir borer, since it has had such an impact on Douglas-fir in the Klamath and attack dynamics seem to be different when populations are high.

DS: I think we can anticipate seeing this in the Willamette Valley at a much greater extent than we have historically. We're already seeing some Douglas-fir decline in the Willamette Valley, but not to the extent that they're seeing it in the southwest. We've been in an exceptional drought until very recently, and if that continues we may see this phenomenon moving on more of a continental scale. We're seeing this kind of thing happen with other species in other areas, all associated with hotter, longer drought, and increased vapor pressure deficit (VPD). I think this complex interaction of biotic and abiotic factors is an emerging theme all around the globe right now. There are many papers talking about how hotter drought is causing increased mortality in many different parts of the world. But it's not just hotter drought, it's the interaction of what some people might call secondary disturbance agents. It's all of these multiple factors interacting. I think the decline spiral concept from Mannion does provide a nice context for predisposing factors, inciting factors and contributing factors. We would consider the flatheaded fir borer a contributing factor and the drought being the inciting factor and then the low elevation and marginal sites being a predisposing factor, all of which taken together are associated with mortality rather than any one of those alone.

MB: I think land managers can anticipate that there are going to be these trailing edge forest problems in many places. For example, the margins of the Willamette Valley are hot, dry sites that may become less hospitable to their current suite of species sooner. Similarly, the western red cedar decline in the Pacific Northwest is also manifesting in the same way. Trees on the edge of development in areas that tend to experience greater extremes are the ones in decline. Bigleaf maple in Washington, red alder in the valley bottom of the Willamette, juniper in Utah, we're seeing it in a number of species in a number of different places.

DS: Environmental aspects like hotter drought and increased VPD are really important, but the legacy of fire suppression can't be understated. It changed the density of the forest, and increased the conifer presence amongst the oak in some of these transitional areas. Having abundant conifers in the

Thinned Douglas-fir stand in high risk zone with little mortality.

Fuels buildup in snag patch.

oak zone actually stresses the system more, and increases susceptibility to drought, exacerbating the problem even further.

LL: This study and others like it provide tools for land managers to get ahead of what's to come in some of these trailing edge areas. It allows some degree of proactivity. It may help prioritize our work and provide some parameters around what is possible on the landscape. We hope the risk assessment tools will allow managers to find the stands at various mortality risk levels and develop management strategies accordingly. Often when insect outbreaks hit, or extreme drought sets in, it's too late to do anything about it. Hopefully, with more information we can start prioritizing actions that build additional resilience into these forests so they may have a better chance of dealing with potentially hotter or drier conditions.

MB: Land managers and agencies have a role to play in helping people understand that these forests are going to undergo a potentially rapid transition, and it's not a comfortable topic for a lot of people. In Oregon, we have a lot of Douglas-fir dominated forests, and some of them are pretty hammered. We didn't get ahead of the current situation, and now the trees are dying, and many of them are dead. There isn't always great social acceptance for a lot of management interventions, especially those that involve cutting down trees. But by letting the forests persist in their unnaturally dense states, we may have set them up for this die off.

KS: Could you paint a picture of what this shift implies for management, and what folks can be doing now to get ahead of this issue? What might this area look like in 50 years?

DS: One of the things that we're realizing is that the density of Douglas-fir is probably too great, and that we may want to lean on some more drought tolerant native species. A lot of people want to manage conifers because of their value, but we're suggesting things like madrone, oak, incense cedar, maybe, or pine might be better suited than Douglas-fir. That doesn't mean these sites will have no Douglas-fir, but it will likely be a smaller component of the forest than it has been.

MB: I couldn't agree more. I think that we're going to have to help these sites transition into a species composition that's more drought and heat tolerant. The other side of it is that some folks think we shouldn't have any Douglas-fir at all at lower elevations and it becomes a black and white thing. I think it requires nuanced management, but certainly the trend will be a shift to fewer Douglas-fir on the landscape.

Further Reading

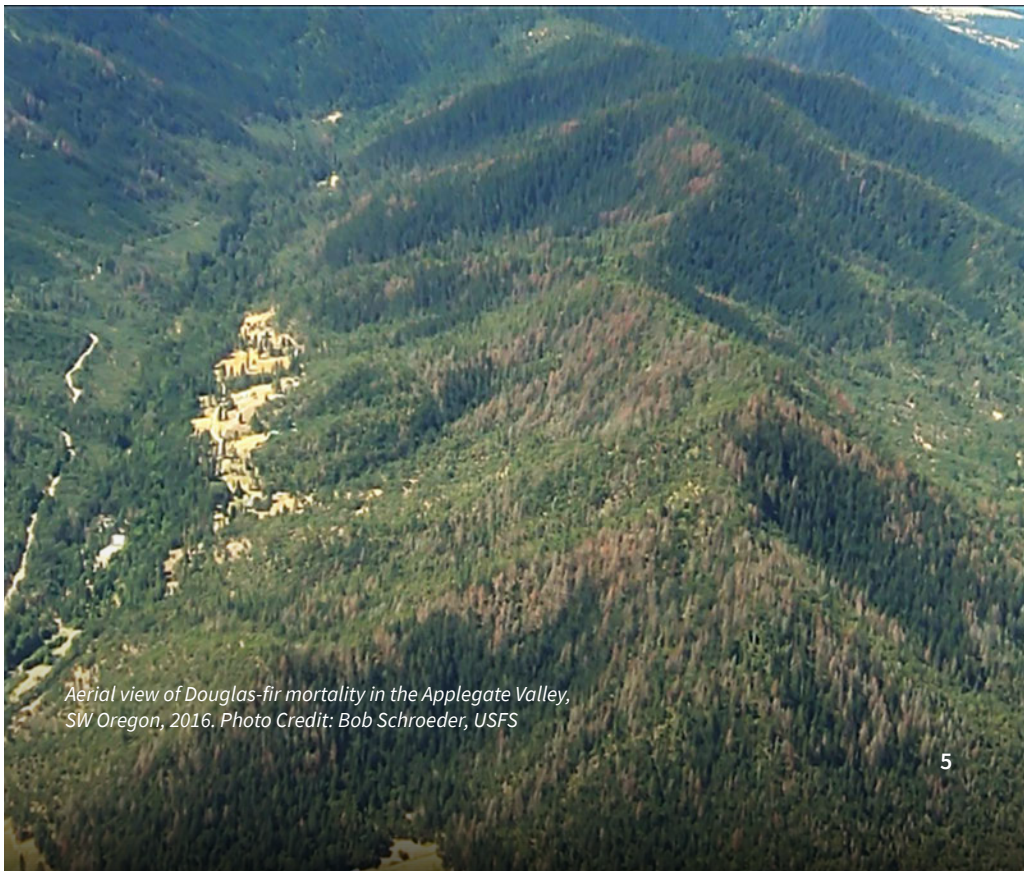
Interested in learning more about the shift of species composition to more heat tolerant plant communities? This phenomenon, referred to as thermophilization, is explored in the recently published paper "**Climate change, tree demography and thermophilization in western US Forests.**"

LL: The water deficit is an indicator of where we might have more problems with Douglas-fir dying. The amount of water that can be stored in the soil limits how many trees a site can support, and that factor will be an even greater stress point as things get hotter and drier. We'll have fewer trees, which gets at the basic but very powerful point that we can't necessarily stop what's happening; the composition of these sites is changing. The hard part is imagining what that will look like.

KS: Are there any differences between coastal and interior Douglas-fir that play into the die-off we are seeing?

DS: The US Forest Service's 2022 aerial surveys showed 450,000 acres of Douglas-fir mortality across Oregon, with 378,000 acres associated with flatheaded fir borer and other secondary agents. Even though it was concentrated in the southwest, they're also seeing isolated mortality elsewhere. We do think that Douglas-fir is being influenced on the east side. If this drought persists, we're nervous that we may see elevated mortality of Douglas-fir on the east side, similar to what has occurred in the Klamath.

LL: Bark beetles and Douglas-fir beetles (DFB) have been important mortality agents in interior Douglas-fir historically. One of the factors that can determine who the mortality agents are is how



Aerial view of Douglas-fir mortality in the Applegate Valley, SW Oregon, 2016. Photo Credit: Bob Schroeder, USFS

much large, stressed Douglas-fir is on the landscape near insect populations following drought. For example, forests in the high and dry Intermountain West also push the boundaries of where Douglas-fir can grow and forests tend to be less diverse than in the coastal region. DFB hang out in these drought and water stressed forests, perhaps in root disease pockets, and outbreak when a pulse of habitat is created via fire-scorched and/or defoliated trees. This makes them prone to large landscape-scale bark beetle outbreaks, but DFB progeny need to have good phloem to eat under the bark. FFB larvae severely damage the phloem of the trees they have attacked and we are thinking that DFB can't compete well in those trees, or parts of the tree where FFB larvae are living. DFBs do attack quickly using pheromones, maybe faster than FFB at the landscape level in the short term. It will be interesting to see how dynamics of insect competition play out in low diversity forests versus the more diverse westside forests, and what will change as they dry out. We are still learning a lot about the current distribution of FFB.

MB: I'm thinking of the western red cedar work, and one thing I gleaned from that discussion was the interior western red cedar occuring on fairly dry sites were not as affected by the decline that's been seen on on the west side of the Cascades. I do wonder if there are some parallels between inner mountain Douglas-fir in the sense of genetic differences and how that might play into this.

When we say drought, we're often talking about a precipitation deficit. But, it's much more of an elevated heat issue than it is just drought. If you look at the elevated mortality in southwestern Oregon in the last seven or eight years, and then you look at drought patterns, what really stands out is the consistently higher summer temperatures versus the precipitation deficit, which is there, but by the historical standards, it's nothing extraordinary. It's up and down, but what really jumps out is the heat.

LL: With hot drought, we need to learn more about cavitation processes, embolisms and how those events can influence which insects are interested in affected trees. For example, will different levels and types of decline make trees more or less attractive to bark beetles versus wood boring insects versus other agents of insect and disease? There's still some work to do looking into mechanisms of cavitation as cues for FFB.

It's very important for us to work with our tree and plant physiologists to understand what's happening with Douglas-fir during hot droughts, and how they are coping with the strain. When do they shut down seasonally? Is it timed with hotter periods in the summer? During the 2021 heat dome, for example, we saw damage to the foliage in northern Oregon, but we didn't see that same damage to foliage in southwest Oregon. However, a lot of us that work out here are of the opinion that the damage may have been far greater to the trees in the southwest because of potential starvation and hydraulic failure caused by that event. The tipping point was reached after they had experienced chronic drought stress for several years, then the heat dome was the event that pushed them over the edge. So really understanding the physiological processes happening within trees, and how extreme events and climate may be affecting those processes is going to be important for understanding which trees will be threatened in the future.

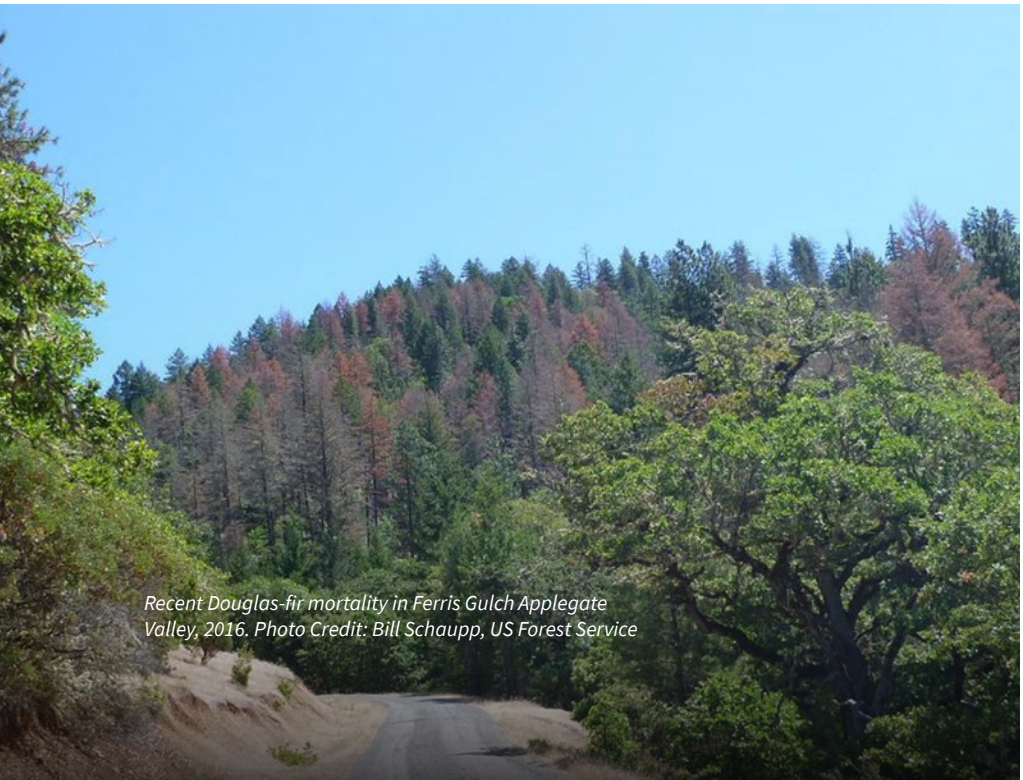
KS: How does the life cycle of these mortality agents line up with seasonal patterns and processes?

LL: We are observing flatheaded fir borer attacks throughout the year, which is more frequent than we previously thought. In the last two years we've seen new attacks in January and February, which surprised us. We still have a lot of work to do to fully understand the timing of the attacks, but it appears they may be active longer throughout the year, which could lead to more year-round mortality.

DS: The season for wood borer activity has increased, and therefore they're able to attack trees during more months of the year. That makes a lot of sense, really, especially for something like the flatheaded fir borer that doesn't necessarily follow a synchronous pattern.

KS: What kind of framework may be helpful for folks to really understand the decline cycle?

MB: One framework piece that I think is important is thinking about site and microsite level differences. In more hot, dry, moisture limited landscapes, a small change in the aspect, or slope, or soil depth, or some sort of physiographic feature can make a big difference in terms of the atmospheric demand and the soil moisture availability, and therefore, the vigor of the tree. I think people have to become more attuned to the finer scale differences. Especially with climate



Recent Douglas-fir mortality in Ferris Gulch Applegate Valley, 2016. Photo Credit: Bill Schaupp, US Forest Service

change in these dry landscapes, subtle differences can be the difference between survival and mortality.

LL: That's very true. When I was working in Idaho the landscape was so dramatic; a slight change in aspect was the difference between trees and scrub-shrub or grassland. Because that environment tends to host less diversity than westside forests, it was more apparent. On the west side, we're not used to thinking that microsites can be so important to conifer survival, but we may need to shift that thinking soon.

DS: One other thing I'd like to remind folks of is that it wasn't one of the big mortality agents that we normally think about that ultimately caused this event. We normally think Douglas-fir beetles are the big killer of Douglas-fir, in this kind of situation. But in this case, we found no Douglas-fir beetle in our sample trees. In many of the declines that we may see in the future, we may not see the expected big mortality agent that everybody is familiar with. We may start seeing native insects and pathogens playing a lot bigger role in mortality than they have historically. Some forest health protection people are calling it "the rise of the secondaries." Basically, the insects and diseases we know are potentially pathogenic, but haven't been big players on the landscape. When site conditions shift, they become the biggest player on the landscape. I think we need to expect more of that in the future.

KS: Is there anything else you'd like to share?

DS: I think the concept of vapor pressure deficit (VPD) is really central to this conversation and important to understand. VPD is the difference between the amount of water in the air and the amount of water the air can hold. As temperature gets hotter, the air can hold more water. So if there was 2 inches of precipitation during the summer, and if the vapor pressure deficit increases, the plants experience a drier summer. The vapor pressure deficit in the study was off the charts in some of these areas: 20%, 30%, 40% greater than the baseline. We think the higher temperature is not only affecting the trees themselves, but the increased vapor pressure deficit that comes with that, we think is really putting the squeeze on the trees. The study found that higher VPD was associated with greater landscape scale mortality. All of the climate change models are calling for higher VPD even if precipitation doesn't change.

It's important to recognize that in our response to this, it's not going to be a one size fits all management approach. It's nuanced, and associated with site specific factors, stand structures, stand history and all of that. It doesn't lend itself to easy solutions that can be easily described, it has to be more nuanced and informed by the site, and the timing of the outbreak.

Bios

Max Bennett has served as an Extension Forester for Oregon State University since 1999. Max covers Jackson and Josephine counties working with small woodland owners, natural resource professionals and collaborative groups to improve forest stewardship. In his work, Max utilizes the latest research and innovations from Oregon State University and other institutions to provide science-based education and expertise. His areas of interest include climate adaptive silviculture, forest health, and living with wildfire.

David Shaw is a Professor in the Department of Forest Engineering, Resources, and Management at Oregon State University, a Forest Health Specialist with Forestry and Natural Resources Extension, and Director of the Swiss Needle Cast Cooperative (a research cooperative focused on needle disease of Douglas-fir).

Laura Lowrey is a Forest Entomologist with the USDA Forest Service, Pacific Northwest Region, Forest Health Protection currently based out of the Rogue River-Siskiyou National Forest covering all federal lands in SW Oregon. She worked in vulnerable Douglas-fir Rocky Mountain forests of the Intermountain Region for 15 years, and has been working in Southwest Oregon since 2020.