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Project Name: The life cycle of dead trees: Implications for forest management in the Sierra Nevada.

Background and justification

> …standing dead trees may result from a number of agencies, such as fire, bark beetles, tree diseases, flooding and drought. Once produced, they become of concern to foresters…
>
> Keen 1929

Standing dead trees (aka snags) are vital but ephemeral elements of the forest. They represent the transition from living trees where entropy is actively delayed by the input of energy to downed wood where the direct contact with soil microbes speeds decay (Franklin et al. 1987). While they remain standing, these trees provide essential habitat for wildlife; they store a significant amount of carbon; and they present potential hazards (Hilger et al. 2012). Thus as Keen (1929) noted, snags are a concern to foresters and to the practice of forestry.

At the heart of the long-standing conflict is the fact that snags provide benefits to wildlife. For example, Raphael and White (1984) documented 18 different species of cavity nesting birds using snags in just one Sierra Nevada forest. At the same time, snags pose fire and safety risks (Knapp 2015). These very real threats justified the earlier requirement (1947-1976) in the California Forest Practice Rules to remove nearly all large snags during timber harvest operations (Raphael and White 1978). Today the Forest Practice Rules clearly recognize the value of snags. For example, in the Appendix Technical Rule Addendum # 2, snags are a "significant factor" in the biological habitat condition of a timber harvest plan [C.4, p.45]. Snags are also acknowledged as an important part of the vegetation structure along water courses that deserve protection [916.4, 936.4, 956.4 Watercourse and Lake Protection (b).g.6]. Thus the Forest Practice Rules stipulate the retention of snags, with a few exceptions, in logging areas [14 CCR § 919.1 (939.1, 959.1)].

A more recent consideration for forest practice in California is the impact management has on the carbon balance. Specifically timber harvests need to consider the capacity of the forest to sequester carbon dioxide [Article 4, 4551 (b) (1)]. Given the recent increases in tree mortality (van Mantgem and Stephenson 2007, Young et al. 2017), snags will play an increasingly important role in the carbon dynamics of California forests – a role that is poorly quantified at present. Moreover, reducing wildfire hazard [915,935,955] and limiting carbon emissions from wildfires [4598 (a)] are objectives in the Forest Practice Rules. Yet we lack basic information on the flammability of snags. Thus snags represent a nexus in forest management. They provide essential wildlife habitat but their impacts on fire risk and carbon storage are largely undocumented.

Critical questions and relevance to forest practice

This proposal addresses critical monitoring questions identified in the Effectiveness Monitoring Committee's (EMC) strategic plan. Snags are a major component of the EMC theme: "Wildlife Habitat: Structures" and the EMC theme "Wildfire Hazard." The Forest Practice Rules [C4a, p. 45] specifically recommend that given the importance of snags as den and wildlife trees, "(t)he degree of snag recruitment over time should be considered." Yet the dynamics of snags are complex (Cousins et al 2015). During the time a dead tree remains standing, a typical sequence of changes occurs leading to an overall reduction in tree size. Tree volume declines through loss of leaves, twigs, and branches, which fall to join the downed wood on the forest floor. Concurrent with these dimensional reductions are changes to the tree's physical and chemical properties caused by weathering, decomposition, and insect activity. This complexity makes meeting retention requirements such as 14 CCR § 1038(k)(5) that stipulates retaining one large snag (greater than 16" DBH and 20' in height) difficult. For this and other regulations that either require snag retention or that count snags for stocking compliance, key questions are: What level of snag retention during operations is sufficient, given how long they will last? Should active snag recruitment (i.e. girdling) be an option for snag management or mitigation? What is the impact of snag retention and recruitment on carbon cycling and fire hazard?

As a consequence of the decay process, the value of snags as resource for wildlife evolves with time since death (Raphael and White 1984). In the early stages, snags are an important source of food for wood boring insects, which in turn, are the primary food source for woodpeckers. With the decomposition of wood, wildlife use evolves further. As cavities form, they provide critical den and nest sites. At the same time, the carbon stored in the snag decreases along with mechanical stability (Cousins et al. 2015). Just as foresters do with live trees, they can plan for a sustainable presence of snags if they have adequate demographic information.

However, we have limited information on the longevity of snags. The fall rates vary by species and tree size. For Sierran mixed conifer forests, annual fall rates range from 7% yr^{-1} to 14% yr^{-1} (Battles et al. 2015). There is even less information on the rate of decay. We know the steps but we do not know how long it takes for a recently dead tree to become a suitable wildlife habitat tree.

Another consequence of the degradation and decay process is that the flammability of wood changes as logs and snags decay (Albini and Reinhardt 1995, Albini and Reinhardt 1997, Monsanto and Agee 2008, Zhao et al. 2014) but there is little quantitative information on how standing snag flammability patterns vary by time since death and by species in California. A consistent finding is that less energy is required to ignite decayed wood than sound wood and once ignited more of the rotten material is consumed under the same ambient conditions. Moreover, the majority of the early work on wood flammability and log consumption was focused on downed and dead woody debris (Albini and Reinhardt 1995, Albini and Reinhardt 1997, Monsanto and Agee 2008). Downed and dead woody log flammability patterns may differ from more solitary snags as we know that downed woody logs burn more readily when in contact with smaller diameter woody branches, litter and duff such as in a campfire than when separated from other material as a single solitary log (Albini and Reinhardt 1995, Albini and Reinhardt 1997). In this context, a reasonable assumption would be that decayed standing snags would be less likely to ignite than downed logs due to standing as a single isolated stem. However, it is common for wildland firefighters to drop all decayed snags as they are assumed to readily ignite and serve as a source of embers that can enhance the spread of wildfires. A better understanding of snag ignition and consumption dynamics could provide a better understanding of the tradeoffs for leaving snags for wildlife habitat while simultaneously managing to reduce wildfire potential across the landscape.

Finally as snags fall, they add to the downed wood in the forest. The decay rate of the downed wood then determines the longevity of this additional surface fuel. Usually this downed wood is in steady state with losses (decay) and matching additions (snag fall). However in stands in the Sierra Nevada with drought-related mortality, there is the potential for large pulses and sustained additions in downed wood that in turn increase the fire hazard. A key gap in our knowledge is that we do not have good measures of decay rates of downed wood in Sierran conifer forests that can guide management and policy decisions relating to snag retention and recruitment.

Objectives and scope

The goal of this project is to quantify the life cycle of standing dead trees in order to inform forest management and policy development. We will rely on a rare resource -- a long-term snag inventory and monitoring study at Blodgett Forest Research Station. In 1983, all the snags (≥ 5" diameter at breast height, DBH) in a 59 ac stand (Compartment 160) were evaluated and tagged. The evaluation included several measures of decay (e.g., wood strength, presence of bark) as well as a detailed assessment of habitat elements (e.g., woodpecker holes, cavities). The inventory has been repeated at irregular intervals: 1989, 1994/95, 2005, and 2012. There are currently 1,163 snags being tracked and the study has recorded 680 tree falls. This study has proven valuable for estimating fall rates and for quantifying wildlife habitat value. However to obtain precise rates of change, we need to monitor individual snag more regularly and more frequently. Also to complete the snag life cycle, decay rates of downed wood must be added. To our knowledge, there is exactly one empirical estimate of log decay in the Sierra Nevada (white fir in Sequoia National Park, Harmon et al. 1987). Finally, we have the opportunity to obtain vital baseline information on the flammability of snags across a range of species common to California. As part of a previous study on snag decay rates (Cousins et al. 2015), we have archived almost 100 wood samples collected from five species spanning all stages of decay. There are no known studies of snag flammability by species or decay state that we are aware of in California.

Compartment 160 at Blodgett Forest is a mature mixed conifer forest under single-tree selection management. Stand basal area in 2013 averaged 169 ft^2/ac. White fir and Douglas-fir are the dominant species (> 20% relative dominance) but incense-cedar (18%), ponderosa pine (16%), sugar pine (12%), and black oak (9%) are common. For the entire stand, there are approximately 9,900 live trees (≥ 5" DBH) with 3,200 of these trees ≥ 20" DBH. Given prevailing mortality rates, about 100 new snags are recruited each year.

Our proposal has four major objectives:

1. Extend the record in Compartment 160 to 2018 by repeating the snag inventory and evaluation.

We last measured the snags in 2012. During this inventory, we developed a survey protocol that made the search for snags throughout the compartment more efficient. With these data, we can update and refine our existing estimates of snag fall rate.

2. Establish a new monitoring protocol that tracks cohorts of new snags on an annual basis to quantify development of cavities and other important habitat elements.

We will tag and locate all newly recruited snags with the aim of estimating two key rates: the rate of decay and the rate of development of wildlife habitat elements. During the course of this three-year study, we will survey the stand for new snags each year as well as assess earlier cohorts. An important goal would be to evaluate the best methods for conducting such a snag demography study. Annual visits may not be necessary but exactly how frequently snags need to be checked to obtain management-relevant information is uncertain. Given the challenge posed by the abundance of snags due to drought and beetle kill, we need to better understand snag dynamics and thus require robust and tested methodologies.

3. **Measure the flammability of snags.**

We plan to use the 100 samples from the earlier Cousins et al. 2015 study to evaluate snag flammability by species and decay status. Minimum sample size is approximately 12 cm by 5 cm by 3 cm. Samples will be burned in the combustion chamber at the USDA Forest Service Laboratory in Riverside, California. The environmental (ambient) conditions such as heat source, heat duration (time sample is subjected to heat source), moisture content, and chamber temperature will be held constant across species and samples to ensure that we are testing the effects of species and decay status on snag wood ignitability and consumption potential. As part of the wood decay study (see below), we will opportunistically collect larger wood samples from felled snags at Blodgett Forest.

4. Establish a long-term study of downed wood decay rates.

We plan to install a long-term log decay study in Compartment 160. From timber operations at Blodgett, we will experimentally create sets of five logs for each of the major canopy species. The logs will be roughly 3 ft in length and members in each set will have similar diameters. These logs will be tagged and the sets will be placed together in the compartment. At established time intervals, one log from each set will be collected for determination of wood density and carbon content. The sample intervals will be 2, 5, 8, 12, and 20 years. The timing is designed to capture the exponential nature of wood decay: more frequent intervals early when the rate of change is steep and longer intervals later when the pace of change slows. We will install five replicates with each replicate containing sets of five logs for the six major species (white fir, Douglas-fir, incense-cedar, ponderosa pine, sugar pine, and black oak).

Principal Investigator and Collaborators

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Anticipated Timeline

We propose a three-year study with the majority of the effort focused on the first year (2018). In Year 1, we will complete the snag inventory, establish the first cohort of new snags, and install the dead wood decay experiment. We will also complete the initial round of wood flammability measures and collect any additional wood samples. In Year 2, we would revisit the Year 1 snag cohort and establish a Year 2 cohort. Wood flammability tests will be completed. In the third year of the study, we would add an additional year to the snag cohort study and make the first decay measurements (two years since start). The main cost of the log decay study is in the set-up. Future years can be completed a modest cost (30 samples). Also by the end of the project, we will have established 3 cohorts of snags that is estimated to total 300 trees. We will check these snags annually as part of the regular Blodgett inventory.

Funding

We estimate that the direct cost of this project is $90,000. This estimate includes costs of field operations, summer salary for the PI, travel for field crew and senior collaborators, and lab analyses. Substantial logistical support will be provided by Blodgett Forest. Moreover this project leverages the long-term snag record in Compartment 160 and the existing archive of dead wood samples. If invited to submit a final proposal, UC Berkeley's sponsored projects will assist with detailed budget development and administration. The current negotiated indirect cost rate at UC Berkeley for projects sponsored by the state is 25%.

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