DIFFERING EFFECTS OF MORTALITY AGENTS ON SNAG PERSISTENCE IN SOUTHWESTERN PONDEROSA PINE FOREST

CARTHAGE COLLEGE

NORTHERN ARIZONA UNIVERSITY

Dr. Joy Nystrom Mast[1] and Dr. Carol Chambers[2]

[1] Department of Geospatial Science, Carthage College, Kenosha, Wisconsin

[2] School of Forestry, Northern Arizona University, Flagstaff, Arizona

Objectives

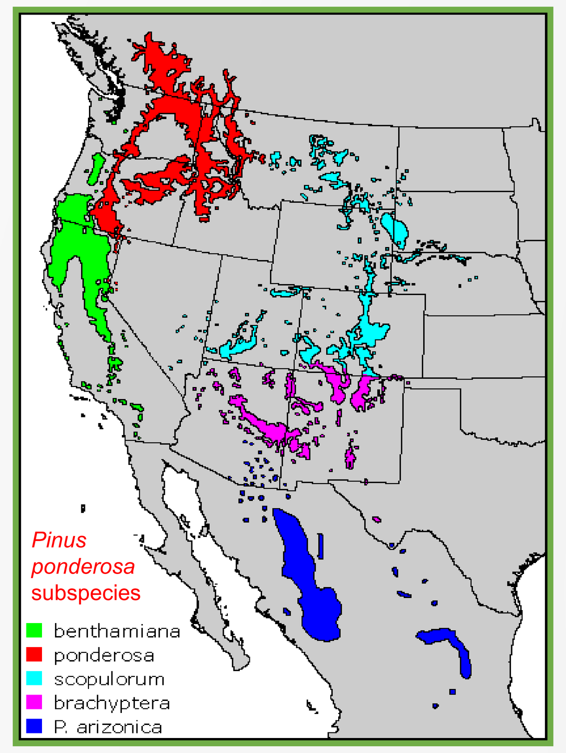
We compared two key mortality agents, high-intensity crown fires and an outbreak of bark beetles, in southwestern ponderosa pine (*Pinus ponderosa* subsp. *brachyptera*). Our objectives were to conduct a longevity analysis to predict the persistence of standing dead trees (snags) from large mortality events and determine characteristics of snags that remained standing.

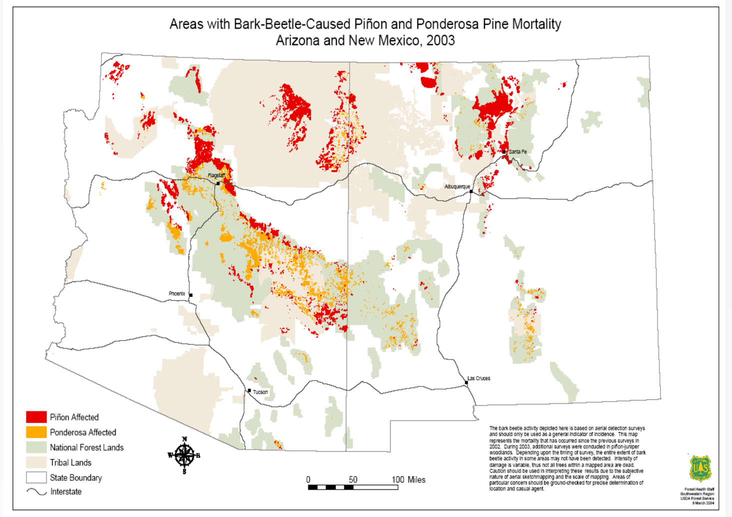
Methods

We documented ponderosa pine snag dynamics in northern Arizona with repeat sampling of 14 variables in 18 one-ha permanent plots across two national forests. Specifically, we followed two high-intensity wildfires that occurred in 1996 and 2000 and 4 bark beetle outbreaks from 2002-2005.

Results

After field sampling >2500 snags for 1 to 13 years post-mortality, we estimated a 7.6 (± 0.1) year period for a snag to remain standing. Mortality agent was the strongest predictor of how long a snag stood, with the hazard of falling for beetle-killed snags 2.5 greater than for fire-killed snags. **Beetle-killed snags with intact tops, higher degree lean and smaller diameter were most likely to fall.** Inversely, the snags more likely to stand longer were fire-killed, with broken tops, straighter (lower degree lean), and larger diameter.





Discussion

Our long-term study provided a useful model to forest managers seeking to select longer-standing snags for wildlife immediately following a high-intensity fire or beetle outbreak. Given the likelihood of drought and the elevated densities of ponderosa pine in the Southwest, these mortality agents likely will recur. When combined with increased drought-related tree stress due to climate change and the similarity of southwestern snag dynamics to the western United States, snag demography reported in our research indicates future conditions across a broader geographic region.

Baseline Results (Time 0)

Summary descriptive statistics for southwestern ponderosa pine snags (n = 2526) at six sites in northern Arizona at initial sampling (Time 0)

Variable	Mean	SE	Median	Minimum	Maximum
Dbh (cm)	27.8	11.5	25.0	10.0	104.5
Height (m)	12.4	4.1	12.4	2.0	30.2
Bark (%)	95.2	10.5	100	0	100
Limbs (#)	1.1	4.5	0	0	80.0
Lean (º)	5.4	16.6	0	0	90.0
Basal area (m^2/ha)	93.4	63.6	80.0	0	320.0
Slope (%)	6.3	2.7	6.0	0	19.0
Aspect: Northness	0.2	0.8	0.6	-1.0	1.0
Aspect: Eastness	-0.1	0.6	-0.1	-1.0	1.0
Decay class (1-5)	2.0	0.9	2.0	1.0	5.0

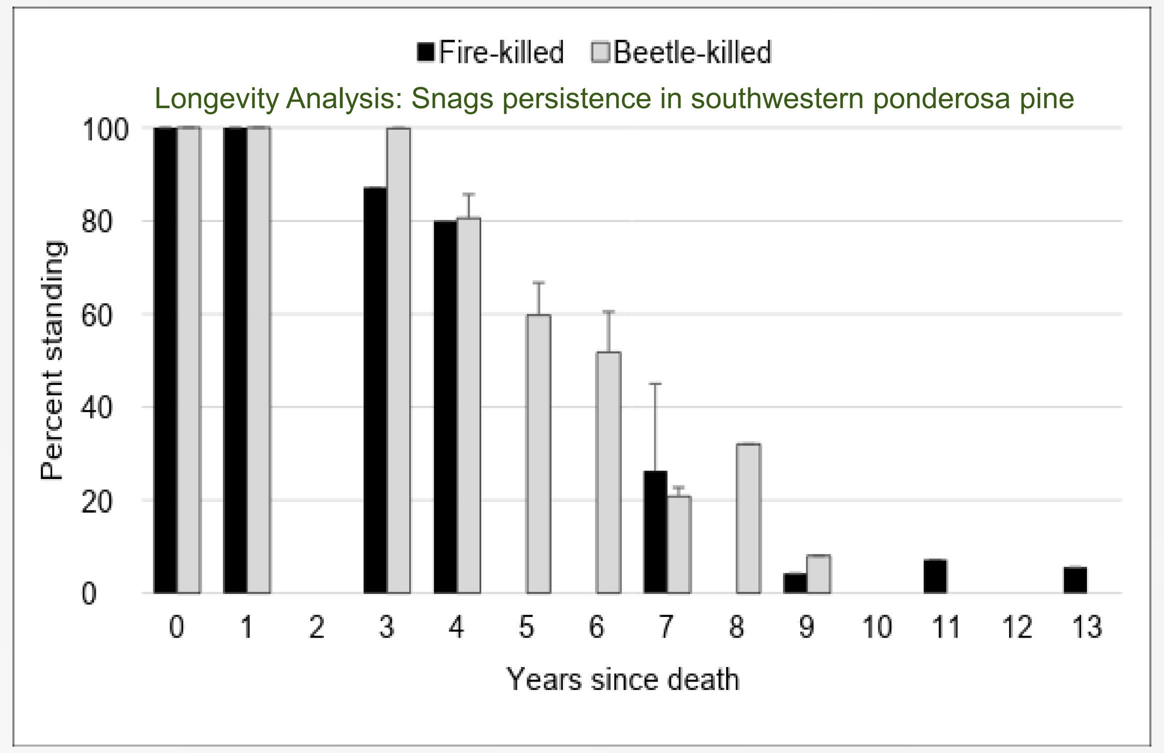
Means (SE) for standing southwestern ponderosa pine snags for variables at initial sampling (Time 0) arranged by number of years post mortality event

Forest	P	TH	NC	H	KL	SC
Mortality agent	Fire	Beetle	Beetle	Fire	Beetle	Beetle
Sampling year post mortality	1	3	3	4	5	5
Age tree prior to death (yrs)	70 (1)	133 (10)	66 (1)	72 (1)	80 (6)	74 (6)
Dbh (cm)	27.4 (0.2)	37.4 (2.5)	20.4 (0.4)	28.9 (0.4)	34.7 (1.6)	33.3 (1.6)
Height (m)	13.6 (0.1)	11.9 (0.7)	12.4 (0.2)	11.6 (0.2)	12.2 (0.5)	9.8 (0.4)
Bark (%)	98.4 (0.1)	93.4 (1.3)	96.8 (0.5)	91.2 (0.5)	92.9 (1.8)	90.8 (1.7)
Limbs (#)	0.2 (0.0)	10.9 (1.5)	0.2 (0.1)	1 (0.2)	2.5 (0.5)	3.4 (0.5)
Lean (º)	0.9 (0.0)	4.5 (0.6)	6.9 (0.4)	1.4 (0.2)	4 (0.5)	2.8 (0.5)
Basal area (m^2/ha)	29.6 (0.5)	13.3 (1.1)	50.3 (0.7)	28.7 (0.5)	17.6 (0.8)	10.4 (0.8)
Slope (%)	5.4 (0.0)	6.7 (0.2)	8.4 (0.1)	5.8 (0.1)	7.8 (0.3)	6.4 (0.4)

Summary descriptive statistics for snags of categorical variables at initial sampling (Time 0) arranged by number of years post mortality event

Forest		P	TH	NC	H	KL	SC
Mortality agent		Fire	Beetle	Beetle	Fire	Beetle	Beetle
Sampling post mortality (yrs)		1	3	3	4	5	5
% in Decay class							
	1	21	20	26	27	5	1
	2	79	73	62	48	92	84
	3	0	6	4	12	1	3
	4	0	1	6	10	1	6
	5	0	0	3	3	0	6
% in Top condition							
	Broken	1	3	15	28	24	20
	Intact	99	97	85	72	76	80

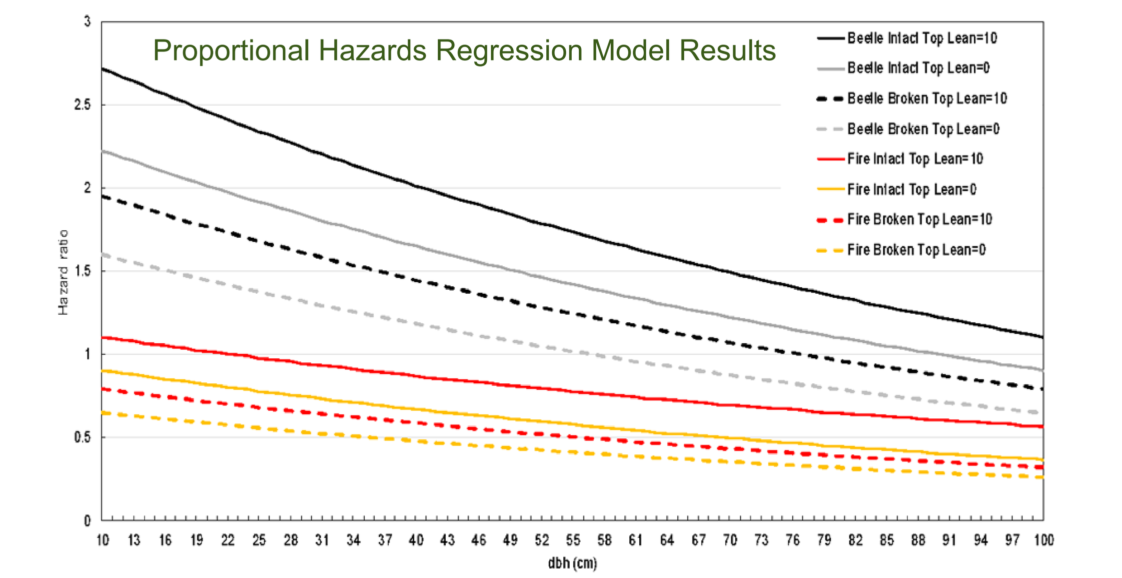
Longevity Analysis



Longevity Results: Analysis of Maximum Likelihood Estimates for all southwestern ponderosa pine snags (n = 2398) at six sites in northern Arizona

Parameter		Parameter Estimate	SE	Pr > Chi Sq.	Hazard Ratio	95% Wald Conf. Limit	
Mortality Agent	**Beetle**	0.902	0.358	0.012	2.465	1.222	4.971
Top Time 0	**Broken**	-0.325	0.077	<0.001	0.722	0.621	0.8421
Dbh Time 0		-0.015	0.003	<0.001	0.985	0.980	0.990
Lean Time 0		0.015	0.002	<0.001	1.015	1.012	1.019

Falling hazard for southwestern ponderosa pine snags by diameter at breast height (dbh), mortality agent (fire or beetle-killed), top condition (intact or broken), and lean (0º or 10º lean) for all snags (n = 2398)



Proportional Hazards Regression Model

Percentage of standing southwestern ponderosa pine snags by year last resampled since mortality event

Forest	NC	TH	KL	SC	P	H
Mortality agent	Beetle	Beetle	Beetle	Beetle	Fire	Fire
Sampling post mortality (yrs)	3, 4, 6	3, 4, 5, 7	5, 6, 8	5, 6, 7, 9	1, 3, 7, 9	4, 7, 11, 13
% Snags standing at last sample	58	28	32	8	4	6

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