Dynamics of Pitch Canker Disease in Bishop Pines (*Pinus muricata*) at Point Reyes National Seashore, CA

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Abstract

Bishop Pine (*Pinus muricata*) is a relict species with a narrow, restricted distribution along the west coast of North America from Northern California to Baja California, Mexico. Pine pitch canker, a disease caused by the fungus *Fusarium circinatum,* was recently discovered in a *P. muricata* forest at Point Reyes National Seashore (PRNS). This has raised concern regarding the spread of *Fusarium circinatum* through native stands of *P. muricata* and other susceptible host tree species beyond coastal California. This study represents the first comprehensive mapping effort to delineate the extent of disease impact in *P. muricata* at PRNS at an early stage of disease development, and additionally examines the spatial distribution of the disease with regard to various environmental parameters. Results are intended to provide a baseline dataset of disease extent to use in conjunction with future data on disease spread to potentially model disease behavior. This will assist natural resource managers with understanding the dynamics of this introduced pathogen in native *P. muricata* forests so that appropriate management strategies can be developed and augmented.

Introduction

Bishop pine (*Pinus muricata)* is believed to have once been widespread throughout western North America in the late Tertiary forest, but now exists as a relict species situated in discontinuous stands along the Pacific Coast ranging from Humboldt County, California to Baja California, Mexico (Barbour and Major 1977; Bakker 1984). As native stands of *P. muricata* exist in a limited distribution, potential threats to the survival of the species warrant serious attention to protect the biological diversity and ultimately the survival of the species. Native stands of *P. muricata* in Point Reyes National Seashore (PRNS) in California have recently been diagnosed with pitch canker disease and provide an opportunity to evaluate the effects of the pathogen in an early stage of disease development.

The fungus *F. circinatum*, the causal pathogen of pitch canker, causes girdling lesions on branches, stems, and exposed roots of trees, which in turn cause the tree to respond by excreting large amounts of pitch at the lesion site (Wood, *et al*., 2003). Causing branch dieback due to obstructed water flow, the excessive pitch at the lesions also attracts engraver beetles, twig beetles, cone beetles, and deathwatch beetles – all of which can attack the tree and cause additional branch dieback (Gordon, *et al*., 2001). Multiple infections in one tree can eventually lead to widespread dieback of the crown, and ultimately tree mortality (Figure 1).

Figure 1: Symptoms of pitch canker disease: bole canker; branch tip dieback; and crown dieback

Although much research has been conducted on pitch canker and its impacts on Monterey pines (*Pinus radiata)* (Wikler *et al*. 2003, Owen and Adams 2001), little has been done to assess the impact of this disease on *P. muricata*. With this project, we hope to address this information gap. Specifically, the research questions asked in this project are:

•*What is the extent of pine pitch canker disease in the P. muricata forest at PRNS?*
A map of disease extent as of summer 2007 was developed to be used as a baseline for future studies potentially modeling the spread of pitch canker disease.

•*What environmental factors could be influencing the spatial extent of the disease and potential future disease spread?*
Descriptive statistics were compiled for disease centers and non-diseased areas of the forest.

Methods

Study Site

Point Reyes National Seashore is situated along the Pacific Coast of California approximately 40 km northwest of San Francisco, CA . This national seashore includes 36,000 hectares of important habitat for many species of flora and fauna. Until 1995, the distribution of *P. muricata* stands within PRNS was generally limited to the northern portion of Inverness Ridge, in the northern half of the park. In October 1995, the Vision Fire served as a seed dispersal agent sending *P. muricata* seeds southwest and down slope, expanding its distribution to include locations at lower elevations and closer to the coast (Holzman and Folger 2005).

Mapping Pitch Canker Disease Centers

Natural color aerial photography (30 cm resolution) from April – May 2007 was acquired from the National Park Service (NPS) and used as the primary data source. Using this imagery and imagery from Google Earth ® taken June 2007, disease center polygons were mapped through heads-up digitizing. Each diseased polygon was categorized based on ocular estimation of crown dieback in the stand:

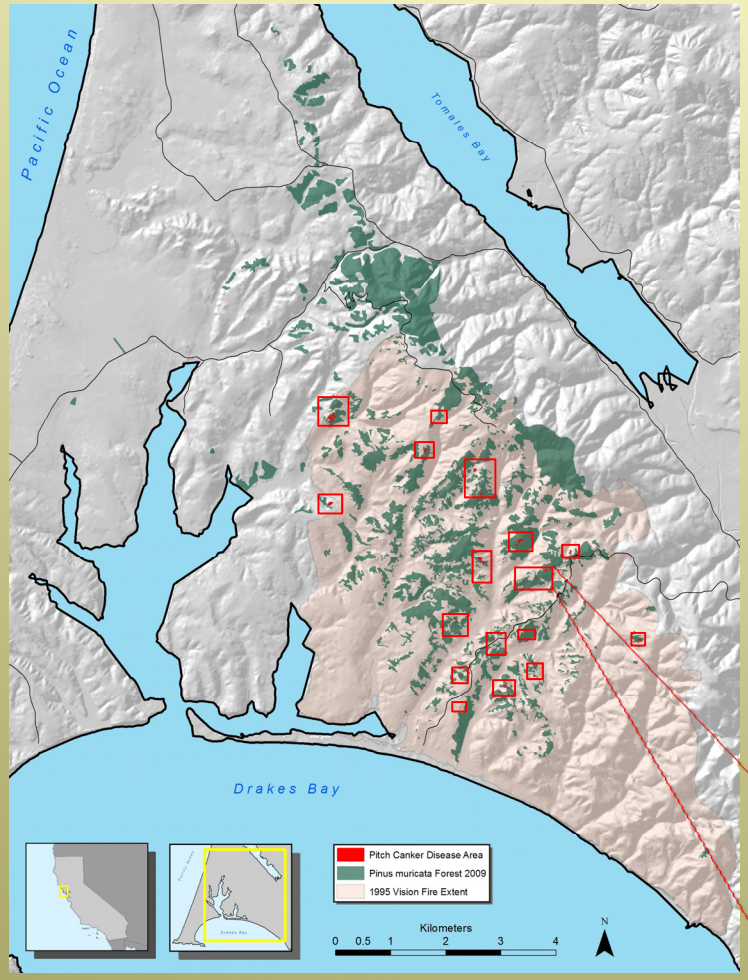
•Category 1: > 50%
•Category 2: 5 – 50%

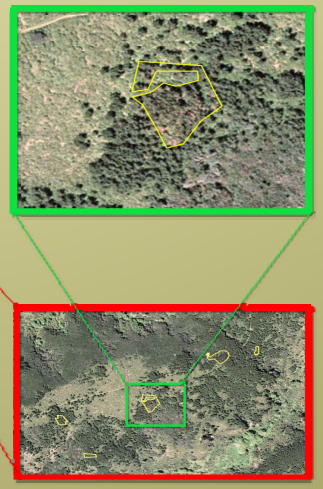
Accuracy assessment of the map was performed by ground-truthing a subset of the delineated polygons.

Data Analysis

To examine potential relationships between disease centers and non-diseased areas in the *P. muricata* forest, environmental attributes of several variables were extracted from GIS layers provided by the NPS.

Variables included in analysis were elevation, slope, aspect, direct solar radiation, indirect solar radiation, duration of direct solar radiation, distance from coast, distance from the Monterey pine plantation in PRNS, pre-fire vegetation community, and soil type.





Preliminary Results

Mapping Pitch Canker Disease Centers

Ground-truthing to perform an accuracy assessment of the disease center polygons was conducted in February 2009 and yielded a 91% (30 / 33) users accuracy. Because the map represents disease extent in 2007, there was no way to perform accuracy assessment on producers accuracy in 2009, as areas that exhibited symptoms in 2009 could have been symptom free in 2007.

Impact of Pitch Canker Disease in 2007

In 2007, the total areal extent of diseased *P. muricata* trees was 4.64 ha, accounting for 0.4% of the total *P. muricata* forest and 0.6% of the *P. muricata* forest that regenerated after the 1995 Vision Fire (Table 1). Field observations in 2008 and 2009 indicate the disease has rapidly spread to well beyond the 2007 extent, furthering the utility of this baseline dataset.

	Area (ha)	% of Total *P. muricata* Forest
Diseased	4.6	0.4%
Non - Diseased (Remanted)	782.5	67.9%
Non - Diseased (Mature)	364.6	31.7%
Non-Diseased (all *P. muricata*)	1,147.1	99.6%

Table 1: Areal extent of pitch canker disease as of 2007.

Environmental Variable Analysis

Due to the dissimilar characteristics of the regenerated and mature forest, the comparative analysis of diseased and non-diseased areas of the *P. muricata* forest was limited to the area within the perimeter of the 1995 Vision Fire. The entire *P. muricata* forest was converted into 10 m x 10 m raster cells for each variable layer. A full census of non-diseased regenerated forest cells (N = 78,257) was used to characterize the non-diseased population. For each disease center, the mean/mode of each variable for every cell was computed (N = 38), and used as a single observation. The results of the comparative analysis are below:

Variable	Minimum	Maximum	Range	Mean	Standard Error	Standard Deviation	Coefficient of Variation
Elevation (m)							
Diseased	57	316	259	131	12	72	55%
Non-Diseased	5	408	403	153	0	89	58%
Slope (degrees)							
Diseased	7	32	25	18	1	6	35%
Non-Diseased	0	52	52	18	0	8	46%
Direct Solar Radiation (kwH/m^2)							
Diseased	599	1126	528	926	25	154	17%
Non-Diseased	347	1163	816	945	0	137	14%
Diffuse Solar Radiation (kwH/m^2)							
Diseased	282	330	48	313	2	10	3%
Non-Diseased	216	342	125	312	0	15	5%
Duration of Direct Solar Radiation (hours)							
Diseased	3108	4190	1081	3815	43	263	7%
Non-Diseased	1707	4366	2659	3790	1	345	9%
Distance from Coast (m)							
Diseased	1429	3748	2319	2659	118	727	27%
Non-Diseased	219	3789	3570	2439	3	717	29%
Distance from Monterey Pine Plantation (m)							
Diseased	1142	7276	6134	4495	211	1303	29%
Non-Diseased	840	10508	9668	4131	5	1357	33%

Table 2: Descriptive statistics for continuous variables.

Variable	Mode	%
Aspect (direction)		
Diseased	East, South (tie)	18%
Non-Diseased	West	17%
Pre-Fire Vegetation Community		
Diseased	Coastal Scrub ; Bishop Pine (tie)	45%
Non-Diseased	Coastal Scrub	57%
Soil Type		
Diseased	Inverness Loam	37%
Non-Diseased	Inverness Loam	47%

Table 3: Descriptive statistics for categorical variables.

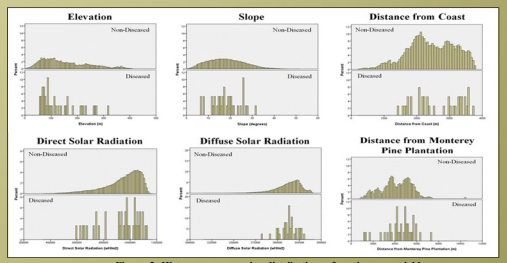


Figure 2: Histograms comparing distributions of continuous variables.

Discussion and Conclusions

The primary contribution of this project was the generation of a baseline dataset of pine pitch canker disease extent within the *P. muricata* forest at PRNS. Preliminary results of the comparative analysis between disease centers and non-diseased areas in the *P. muricata* forest at PRNS indicate that the environmental characteristics of the areas that were impacted by pitch canker disease do not differ considerably from the general environmental characteristics of the entire forest within PRNS. Since this project characterized pitch canker disease extent at its onset (2007), before a state of equilibrium or significant trends were evident, any conclusions drawn from it should be considered preliminary. This dataset will provide researchers with a early-stage snapshot of the disease extent with which to further characterize and understand disease spread.

References

Bakker, E. 1984. *An Island Called California.* Berkeley, CA: University of California Press, 484 pp.
Barbour, M. G., and J. Major. 1977. *Terrestrial Vegetation of California.* New York, NY: John Wiley and Sons, Inc., 708 pp.
Gordon, T. R., A. J. Storer, and D. L. Wood. 2001. The Pitch Canker Epidemic in California. *Plant Disease* 85 (11): 1128-39.
Holzman, B. and K. Folger. 2005. Post-Fire Vegetation Response in the Bishop Pine Forest at Point Reyes National Seashore. Pp. 49-57 in *Vision fire, lessons learned from the October 1995 fire* (S. G. Allen and W. Shook, eds). Point Reyes National Seashore, California, United States Department of the Interior, Washington, D. C.
Owen, D., and D. Adams. 2001. Impact of Pitch Canker on Ornamental Monterey Pines in Santa Cruz County, California, U.S., 1987-2000. *Journal of Arboriculture* 27 (6): 298-305.
Wikler, K., A. J. Storer, W. Newman, T. R. Gordon, and D. L. Wood. 2003. The dynamics of an introduced pathogen in a native Monterey pine (*Pinus radiata)* forest. *Forest Ecology and Management* 179: 209-23.
Wood, D. L., T. W. Koerber, R. F. Scharpf, and A. J. Storer. 2003. *Pests of the Native California Conifers.* Berkeley, CA: University of California Press.