Reciprocal Interactions Between Bark Beetles and Wildfire in Subalpine Forests of the Greater Yellowstone Ecosystem

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RECIPROCAL INTERACTIONS BETWEEN BARK BEETLES AND WILDFIRE IN SUBALPINE FORESTS OF THE GREATER YELLOWSTONE ECOSYSTEM

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✦ INTRODUCTION

Wildfire and bark beetle epidemics are two ecologically important natural disturbances in the Intermountain West, yet we know very little about how these two phenomena interact. It is widely believed that beetle-killed trees increase the risk of severe fires; and trees that are weakened, but not killed by fire, are thought to be more susceptible to beetle invasion. However, few studies have rigorously tested these hypotheses. The GYE is currently experiencing an outbreak of unprecedented intensity and complexity, involving several species of bark beetles, including the mountain pine beetle. The outbreak is affecting multiple species of coniferous trees in and near recently burned areas, providing a timely opportunity to investigate these interactions at multiple scales.

In addition to the basic ecological questions posed above, forest managers throughout the western US are grappling with how to deal with the most extensive bark beetle outbreaks ever recorded for the region. Following various kinds of natural disturbance, salvage harvest may be conducted to extract economically valuable timber and/or to reduce perceived risk of subsequent disturbance. However, the consequences of such post-disturbance management on stand structure and function in the context of the current bark beetle outbreaks are largely unknown. There has been some recent attention to salvage harvest in the literature, but empirical studies are relatively scarce. Therefore, as part of this study, we are quantifying the effects of post-beetle salvage logging on fuels, regeneration, and nitrogen cycling in lodgepole pine forests on the Bridger-Teton National Forest.

By means of seven closely related projects (described below), we conducted field work in 2007 in Yellowstone and Grand Teton National Parks, as well as on the Bridger-Teton and Shoshone National Forests, to answer four fundamental questions:

1. *What are the current patterns of beetle outbreaks in the Greater Yellowstone Ecosystem, and what factors explain these patterns?* [Projects #1 and #2]

2. *What are the consequences of bark beetle outbreaks and post-beetle salvage harvest on nitrogen dynamics?* [Project #3]

3. How do mountain pine beetle outbreaks influence the risk and severity of wildfire? [Projects #4 and #5]

4. Does fire injury in lodgepole pine affect colonization rates, reproductive success, and potential for population increase of mountain pine beetle? [Projects #6 and #7]

Project #1: Remote Detection of Bark Beetle Damage

The objective of this research is to map the magnitude, spatial patterns and temporal trend of several concurrent beetle outbreaks including mountain pine beetle, spruce beetle and Douglas-fir beetle. A visit to the area was made in 2007 for the purpose of gaining on-the-ground familiarity with the topography and vegetation patterns, but most of the analysis was conducted in the remote sensing laboratory at the University of Wisconsin – Madison. A 9-year (1999-2007) time series of Landsat imagery was employed to estimate the probability that each pixel was disturbed on yearly basis. The probability map for each year was developed from the difference image of Moisture Stress Index (MSI: Landsat band 5/band 4) between a disturbance year and the base date (1999) using the normalized distribution of spectral data for the larger study area.

We have detected the initial year of attack as the time at which MSI showed increases that were sustained in subsequent years (Figure 1).

The MSI difference values (disturbance year minus base year) were then related to field measurements of beetle damage collected during the summers on 2006 and 2007. These values were related to the MSI index difference for 2007 (expressed as a P-value of the statistical distribution from subtracting 19999 MSI from 2007 MSI). This analysis showed a very strong linear relationship between the MSI difference and percent mortality (Figure 2). This suggests that we can also map a continuous measure of beetle damage.

The relationship between MSI and field measures then facilitated mapping total percent damage for the entire study area (Figure 3).

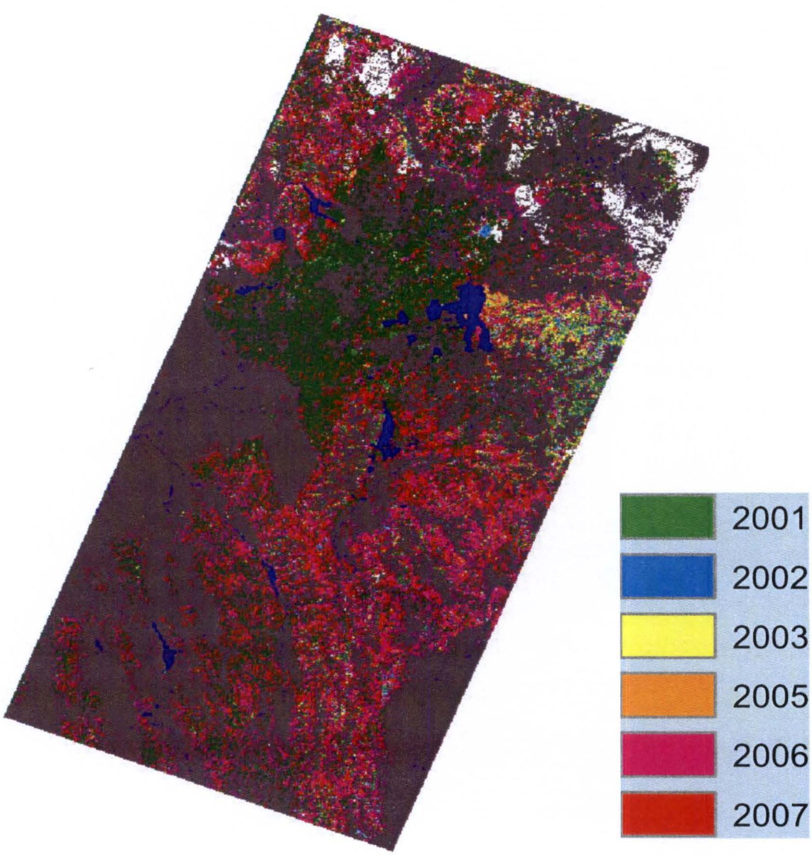

Figure 1. Temporal pattern of initial attack date. Dark green areas are unattacked forests (show no increases in Moisture Stress Index, MSI). Note that some areas marked as attacked in 2006 and 2007 (magenta and red) are mapped as such because they exhibited increases in MSI. If those increases are not sustained in images from subsequent years, then those areas may switch to being mapped as not attacked -- see also Figure 3 (preliminary results – please do not distribute).

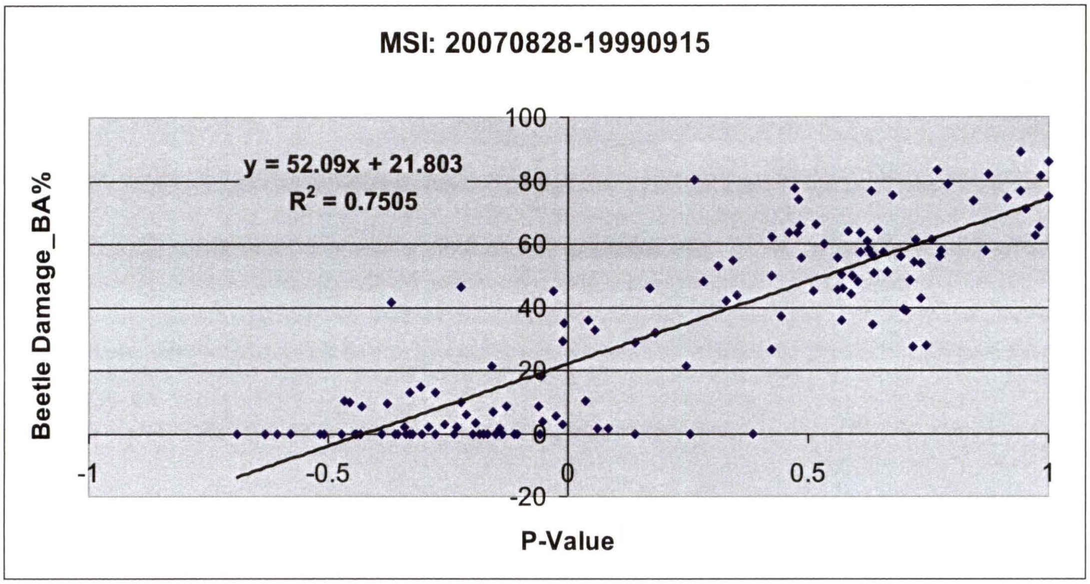

Figure 2. Mapped probability of disturbance showed a linear regression relationship with field data (%mortality), R^2 is 0.75 *(preliminary results – please do not distribute)*.

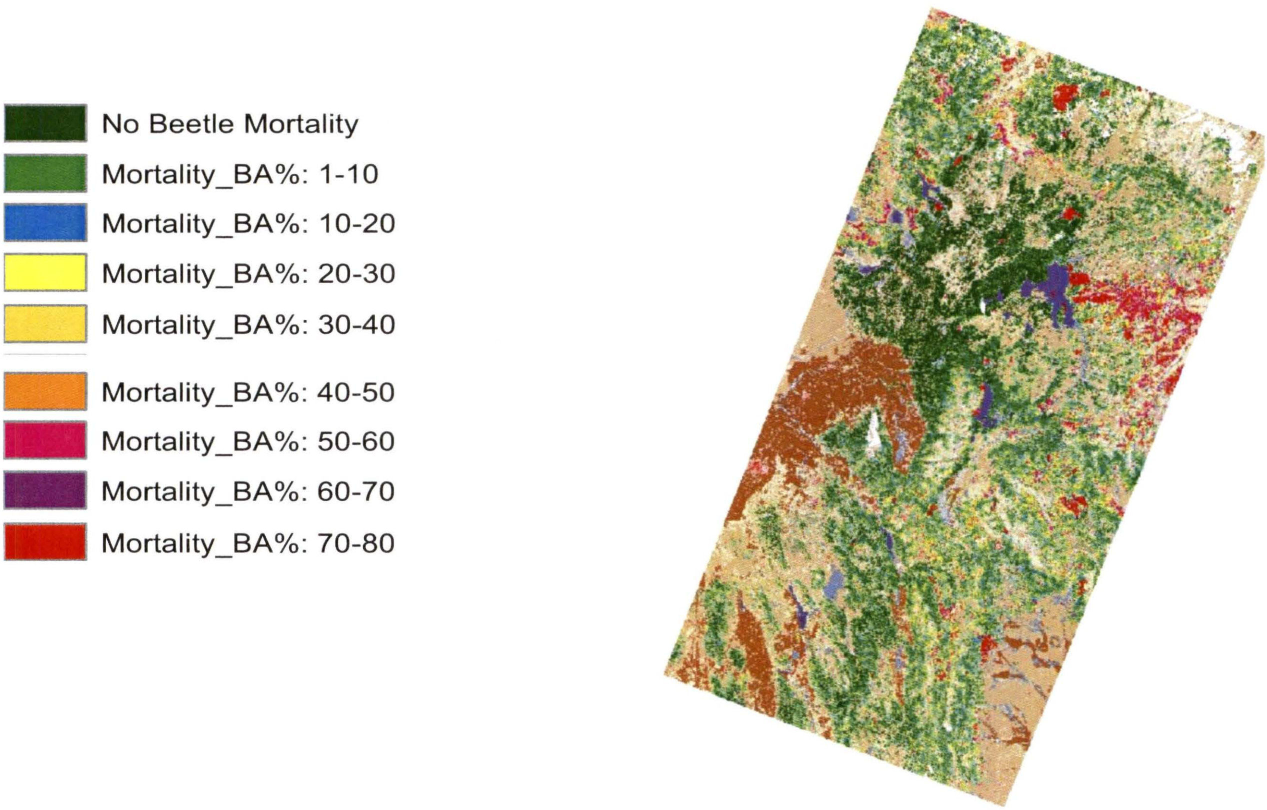

Figure 3. Spatial pattern of forest mortality for 2007. Note the extensive area of forests with low mortality that were mapped as first attacked in 2006 or 2007 in the Figure 1. True attack and mortality will be assessed with future images *(preliminary results – please do not distribute)*.

Several aspects of the research are ongoing as we work to write up our results. First, the maps simply identify forest disturbance, regardless of cause. We will use YNP fire perimeter data and the USGS dNBR (normalized burn ratio, equivalent to a burn severity index) data to mask out damage from fire and other sources. Second, the maps do not distinguish between pest species. We will employ the best existing forest type map to identify host species and label the likely pest species. Lastly, we will use the disturbance index of Healey et al (2005) (to identify logged areas. We expect that the percent mortality maps will remain accurate, although there may be some confusion between partially logged areas and beetle killed forests.

Project #2: Explaining broad-scale infestation patterns of three bark beetle species

The objective of this project is to determine what factors explain bark beetle infestation patterns being mapped at broad scales (project #1). Field data were collected in 2006 (working out of the AMK Ranch) on spatial patterns of four insect-host tree pairings: mountain pine beetle in whitebark pine, mountain pine beetle in lodgepole pine, Douglas-fir beetle in Douglas-fir, and spruce beetle in Engelmann spruce. One week of additional sampling was conducted in 2007 to supplement the previous year's effort. Data analysis is still underway, and results are not yet available.

In summer 2006 we sampled 64 stands (16 of each lodgepole pine, whitebark pine, Douglas-fir, and Engelmann spruce) that were either severely damaged or undamaged by the beetles. During summer 2007, we sampled 56 additional stands (14 stands of each species) to complement the previous year's effort. In each stand, we determined 1) forest attributes (composition, % mortality, serotiny for lodgepole pine); 2) stand structure (density, diameter, and age); 3) presence and damage by bark beetles; 4) soil characteristics; and 5) site conditions (elevation, slope, aspect, site index, surficial deposits, etc.). Sampling was done in two National Parks and two National Forests.

Project #3: Effects of bark beetle outbreaks and of post-beetle salvage logging on fuel dynamics and nutrient cycling

In 2007 we sampled 20 lodgepole stands that were heavily attacked by mountain pine beetle 2-4 years ago and measured stand structure, tree regeneration, and the quantity and distribution of surface and canopy fuels. We took soil samples to determine available N and installed buried resin cores to determine annual fluxes of N. Half (n = 10) of these plots are scheduled to be salvage logged in summer 2008, after which we will return to re-sample all of the stands. Data analysis is still underway, and results are not yet available.

Project # 4: Time-Since-Beetle chronosequence

The objective of this project is to characterize long-term (0 to 30 years after outbreak) effects of mountain pine beetle outbreaks on forest structure and regeneration; surface and canopy fuels; and nitrogen dynamics. Field sampling was initiated in 2006 (working out of the AMK Ranch), and six weeks of additional sampling were conducted in 2007. Data analysis is still underway, and results are not yet available.

Project #5: landscape patterns and the risk of high-severity fire

We sampled lodgepole pine stands that were attacked by mountain pine beetle at different times in the past (2, 4, 25, and 35 years ago), as well as undamaged stands (5 replicates per class; n = 25). In each stand we measured stand structure, regeneration, and the quantity and distribution of surface and canopy fuels. We will apply these field data to a suite of fire behavior models (e.g., Behave and Nexus) to evaluate how changes in the fuel complex will likely influence fire behavior under a range of weather conditions. Data analysis is still underway, and results are not yet available.

Project #6: Host preference of MPB

The objective of this project is to compare mountain pine beetle "performance" (success of attack, growth of larvae, and overall reproductive success) on its two major tree hosts in the Greater Yellowstone Ecosystem: lodgepole pine and whitebark pine. This project was initiated in 2006 (working out of the AMK

Ranch), and addition sampling was conducted during two weeks in 2007. Data analysis is still underway, and results are not yet available.

Project #7: Fire-injured lodgepole pine as a potential reservoir for mountain pine beetle

The objective of this project is to determine if fire injury in lodgepole pine affects colonization rates, reproductive success, and potential for population increase of mountain beetle. Field sampling was initiated in 2006 (working out of the AMK Ranch), and ten weeks of additional sampling were conducted in 2007. We deployed pheromone traps near 4 areas that burned in 2006 (two on the Bridger-Teton NF, one in Yellowstone NP, and one in Grand Teton NP) to document beetle population densities. At each site, we installed transects perpendicular to the fire edge, from the burned area to the unburned forest, and quantified fire injury and presence of bark beetles on individual trees. Data analysis is still underway, and results are not yet available.

✦ LITERATURE CITED

Healey, S.P., Cohen, W.B., Yang, Z.Q., & Krankina, O.N. 2005. Comparison of Tasseled Cap-based Landsat data structures for use in forest disturbance detection. Remote Sensing of Environment, 97, 301-310.