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A Conceptual and Mechanistic Approach to Understanding Interactions Among Multiple Disturbance Agents: Compound Effects of Fire on Resource Availabilty to Bark Beetles

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A CONCEPTUAL AND MECHANISTIC APPROACH TO UNDERSTANDING INTERACTIONS AMONG MULTIPLE DISTURBANCE AGENTS: COMPOUND EFFECTS OF FIRE ON RESOURCE AVAILABILITY TO BARK BEETLES

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✦ OVERALL PROJECT OBJECTIVES

The objective of our project has been to determine the effects of fire on bark beetle populations in the Greater Yellowstone Ecosystem. Our general hypothesis has been that fire damaged trees provide refugia for mountain pine beetles (*D. ponderosae*) that allow populations to persist during non-outbreak periods. Our work combines field testing of bark beetle populations within a range of forests from burned to unburned, as well as spatial analyses (remote sensing) to determine whether the forest more proximal to fires have greater incidences of beetle mass attack. New efforts have focused on determining whether lodgepole pine (*P. contorta*) and whitebark pine (*P. albicaulis*) have differing chemical defensive capacities to beetle attack.

✦ RESULTS

During the summer of 2010, we completed sampling lodgepole pines that had experienced varying degrees of wildfire injury for attack and development by the mountain pine beetle, in the Greater Yellowstone Ecosystem. Eight sites that experienced wildfire and eight unburned sites, including half each in areas where mountain pine beetles were in the outbreak versus non-outbreak stages, were examined. We examined 2056 trees one year after fire for fire injury and bark beetle attack. We quantified beetle reproductive success in a random sample of 106 trees, and measured gallery areas of mountain pine beetle and competing subcortical herbivores in 79 additional trees. We used pheromone-baited funnel traps to sample stand-level populations of various subcortical herbivore and predator species.

Wildfire predisposed trees to *D. ponderosae* attack, but in a nonlinear fashion: moderately injured trees were most preferred. This relationship at the tree level was influenced by stand-level beetle population size: both healthy and fire-injured trees of all classes were attacked where populations were high, but no healthy trees, and only low- and moderately injured trees were killed where populations were low. The number of adult brood produced per female was likewise curvilinear, being highest in moderately injured trees. There was high intraspecific competition arising from the large number of beetles needed to overcome defenses in healthy trees, and high interspecific competition and low substrate quality in more injured trees. The major competitors were *Ips*, Cerambycidae, and *Pityogenes* species. We developed a conceptual model of how these disturbances and inherent feedbacks interact to affect beetle population dynamics at the tree and stand levels.

We conducted chemical analyses of lodgepole pines of various fire injury classes, in terms of resistance parameters against mountain pine beetle and its associated ophiostomatoid fungus *Grossmania clavigera*. Fire injury reduced the total monoterpene concentration of induced but not constitutive phloem tissue. It also affected the relative composition of various monoterpenes in both induction and constitutive phloem. These results agree with field patterns showing higher incidence of attack on fire-injured trees.

We also compared the constitutive and induced monoterpene chemistry in the phloem of lodgepole pines vs. whitebark pines, in mixed stands. We are extending these studies in 2011.

During the summer of 2010, we continued our research to map the spatial extent and intensity of bark beetle infestation (both new activity and older infestations) and the proximity of damage to fires. We partnered with the USGS and NPS to acquire SPOT 10m and 5m satellite imagery over most of the Greater Yellowstone Ecosystem (GYE, Table 1). These images are currently being processed for two sets of analyses: (1) mapping of bark beetle damage with respect to fire locations and (2) mapping of forest vertical structure associated with long-term disturbance history and forest regeneration. The remote sensing efforts were linked to field data collected in 2010 and new data collection for 2011.

Field data collection completed in 2010 included plot-based samples of mortality, red trees, newly infested trees and unattacked trees. Because accessibility to large numbers of plots in remote areas was not feasible, we additionally developed a new method in which we used infrared and visible camera with telephoto lenses to take pictures of distant slopes. Using GPS locations, bearings and camera tilt, we precisely located the photos using Google Earth to place the actual camera shot locations on SPOT images. From 47 sets of photos, we co-located 97 positions (hereby called “photo plots”) in the imagery in which we tallied green, yellow (recently attacked), red (attacked) and gray (dead) trees (Figures 1, 2). Figure 3 illustrates the geo-location of a landscape photo using Google Earth, while Figure 4 illustrates the interpretation of the photos for green, yellow, red and gray trees. Plot locations are determined in Google Earth. 2011 activities continue this work, as well as sampling of plots on the ground at the same locations as the photo interpretations.

✦ TRAINING

Graduate student Erinn Powell has gained expertise in chemical analysis, particularly gas liquid chromatography, and also in methods of fungal culturing, identification, and inoculation.

The undergraduates have gained expertise in performing field work, conducting assays of tree defense physiology, chemical ecology, insect identification, and insect sampling. Undergraduate student Wes Fox developed the method for co-locating photos with satellite imagery using GPS and bearing data within Google Earth.

✦.OUTREACH

Our work was highlighted in an article in University of Wisconsin College of Agricultural and Life Sciences Grow magazine.

✦ HUMAN RESOURCES

This project has contributed to the graduate training of one graduate student (below). It has also contributed to the training of several undergraduate students.

Powell, EN. 2010. Interactions among disturbance agents in conifer forests: Does fire injury increase susceptibility of lodgepole pine to mountain pine beetles and influence their population dynamics? MS, Entomology, and Forest & Wildlife Ecology, University of Wisconsin-Madison.

✦ CONTRIBUTIONS BEYOND SCIENCES

This research is assisting the capability of natural resources managers to contend with interactions between disturbance agents. Specifically, there is intense socioeconomic interest in interactions between fire and insects, especially in western forest ecosystems. This work is assisting managers in evaluating whether wildfires increase the likelihood of subsequent bark beetle outbreaks.

Table 1. List of SPOT multispectral (MS, 10m pixels) and panchromatic (Pan, 5m pixels) collected over the GYE in 2010.

File ID	MS 10m file	Date	Pan 5m file
60	554725810080118244491J1_1GST	8/1/2010	
61	55472581009111836341J1_1GST	9/11/2010	
62	55472591008011824581J0_1GST	8/1/2010	55472601008011825041A0_1GST
62	55472601009111836501J0_1GST	9/11/2010	55472591009111836401A0_1GST
68	55492581008161836262J0_1GST	8/16/2010	55492581008161836242A0_1GST
69	55492591008161836342J0_1GST	8/16/2010	55492591008161836322A0_1GST
78	55502601009121817311J0_1GST	9/12/2010	55502601009121817281A0_1GST
80	55502621008171817421J0_1GST	8/17/2010	55502621008171817401A0_1GST
88	55522601009071813371J0_1GST	9/7/2010	55522601009071813341A0_1GST
91	55522611009071813451J0_1GST	9/7/2010	55522611009071813431A0_1GST
93	55522621009071813531J0_1GST	9/7/2010	55522621009071813511A0_1GST
200	55502591009121817221J0_1GST	9/12/2010	55502591009121817201A0_1GST
201	55502611008171817341J0_1GST	8/17/2010	55502611008171817321A0_1GST
202	55502631008171817501J0_1GST	8/17/2010	55502631008171817481A0_1GST
203	55502601008171817261J0_1GST	8/17/2010	55502601008171817231A0_1GST
204	55472591009111836421J0_1GST	9/11/2010	55472591009111836401A0_1GST
205	55522631009071814021J0_1GST	9/7/2010	55522631009071813591A0_1GST
206	55472601008271825151J0_1GST	8/27/2010	55472601008271825121A0_1GST
206	55472601009271829081J0_1GST	9/27/2010	55472601009271829061A0_1GST
207	55492601008161836432J0_1GST	8/16/2010	55492601008161836402A0_1GST
210	55522591009071813291J0_1GST	9/7/2010	55522591009071813261A0_1GST
211	55492581008161836262J0_1GST	8/16/2010	55492581008161836242A0_1GST
212	55522611009071813451J0_1GST	9/7/2010	55522611009071813431A0_1GST
316			55492601008161836402A1_1GST

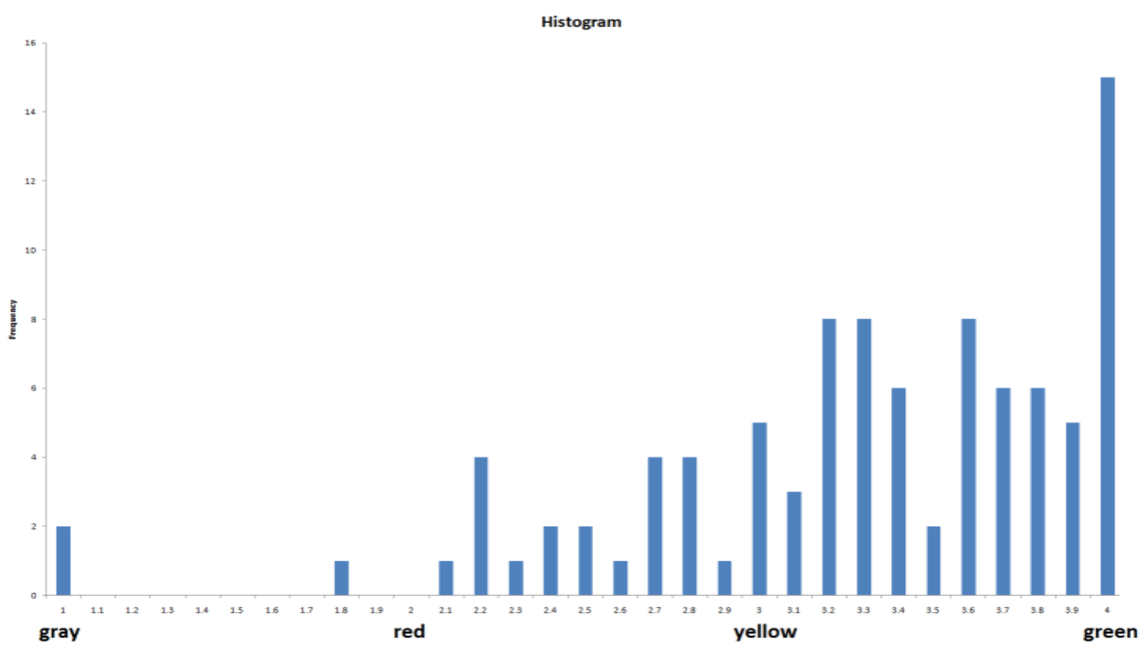

Figure 1. Histogram of the range of mortality in the “photo plots.”

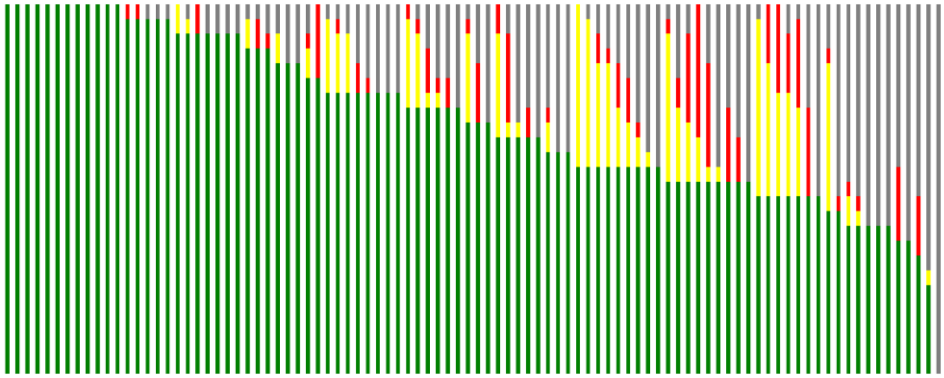

Figure 2. Bar graph showing tree color composition among the sampled "photo plots."

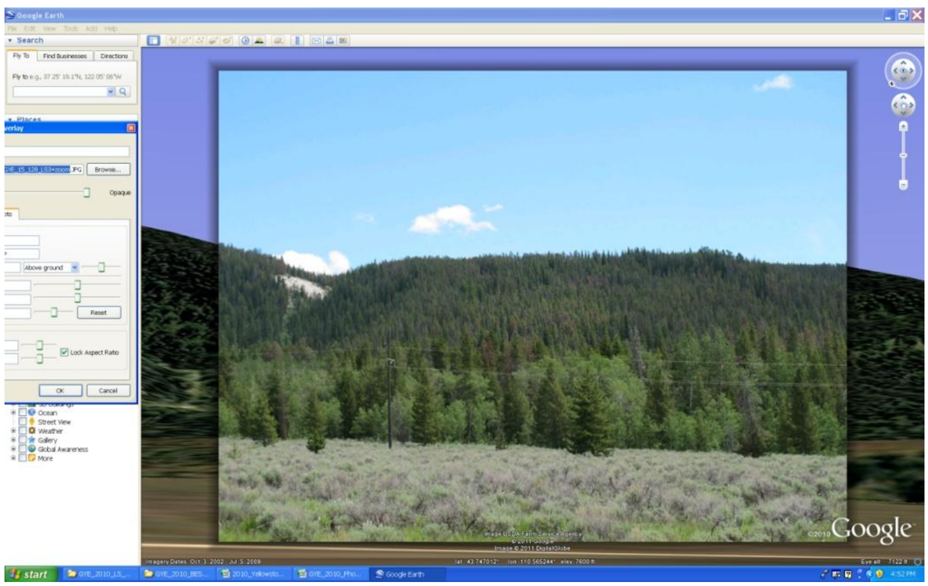

Figure 3. Landscape photo with inset placed in Google Earth.

Figure 4. Inset photo with tree count/classification marks. Orange marks are spot centers. Blue numbers delineate counts for each GPS/bearing pair.