Monitoring insect and disease in whitebark pine (*Pinus albicaulis*) in the Greater Yellowstone Ecosystem

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Introduction

Insect and disease outbreaks in forest ecosystems can be linked to local weather and regional climate patterns. Warm temperatures and the loss of extreme cold days reduce winter overkill of insects, speed up life cycles, and lead to range expansions (Logan et al. 2003). When favorable conditions exist, mountain pine beetle (*Dendroctonus ponderosae*) populations can quickly increase to epidemic proportions.

The dispersal and germination of white pine blister rust (*Cronartium ribicola*) is also linked to weather and climate. Dispersal of the fungus is influenced by wind, temperature and humidity (Van Arsdel et al. 2006). White pine blister rust germination and infection of pine occur when nighttime temperatures stay cool (below 68 degrees F), free moisture is available on the needle surface, and relative humidity is high for at least two consecutive days (Koteen 1999). The low natural resistance of five-needle pines, including whitebark pine (*Pinus albicaulis*) along with favorable climatic conditions has enabled white pine blister rust to spread to higher elevations and more recently to a greater number of pine species (Ashton 2010).

The combined effects of insect and disease on whitebark pine in the Greater Yellowstone Ecosystem (GYE) have research scientists, plant ecologists and wildlife biologists working together to address the status and trends of this important tree species. Working through the Greater Yellowstone Coordinating Committee, the Greater Yellowstone Network and the USGS Interagency Grizzly Bear Study Team have completed an unprecedented level of monitoring to document and report on levels of blister rust infection and the proportion of trees dying during the current outbreak of mountain pine beetle. This report summarizes monitoring data collected from 2004 through 2007, the sampling period when transects were first established, and from 2007 through 2010 the sampling period when transects were resurveyed for trend.

Purpose and Background

The purpose of our long-term monitoring program is to determine the status and trends of whitebark pine forests throughout the GYE. To date, the principle focus of the Interagency Whitebark Pine Monitoring protocol (GYWPMWG 2007) has been the presence and severity of white pine blister rust and mortality of whitebark pine > 1.4 m tall.

Our target population is all whitebark pine (regardless of habitat type) in the GYE on federal lands (six National Forests and two National Parks, Fig. 1). The sample frame includes forest stands ≥ 2.5 ha within and outside the U.S. Fish and Wildlife Service Grizzly Bear Recovery Zone (RZ) that have a component of whitebark pine in the species composition. Forest stands that burned in the 1988 wildfires or later were excluded from

the sample frame as these stands were considered too young to have whitebark pine trees >1.4 m tall.

We selected our sampling units using a 2-staged, probability based sampling design that allows for statistical inference to the entire GYE. Our primary sampling units are randomly selected forest stands and our secondary sampling units are 10 by 50 m randomly selected transects from each stand. At least one whitebark pine tree >1.4 m tall was required for a permanent transect to be established.

Between 2004 through 2007, we established 176 permanent transects and permanently marked 4,772 individual live trees >1.4 m tall so that we can follow the incidence of white pine blister rust and survivorship of individual trees over time. Within each 5 by 10 m wide transect, we measured diameter breast height (DBH) of all permanently tagged live whitebark pine trees. We also measured the DBH of standing dead and recently dead whitebark pine trees >1.4 m within the transect but did not permanently tag these trees.

Each live whitebark pine tree >1.4 m tall was surveyed for white pine blister rust cankers based on aecia (the active, fruiting body of the canker), the definitive symptom of white pine blister rust (Tomback et al. 2005). We also surveyed for auxiliary signs of infection including rodent chewing, branch flagging, swelling, roughened bark and oozing sap (Hoff 1992). If three of the five auxiliary signs occurred in the same area on a tree, that location was noted as having white pine blister rust infection. The numbers of branch and trunk cankers were recorded for each of the tree sections. For analysis purposes, we considered an individual whitebark pine tree infected with white pine blister rust if one canker (aecia or three auxiliary signs) on either the tree bole or branch was observed.

We also surveyed trees for evidence of mountain pine beetle infestation. We considered an individual whitebark pine tree infested with beetles if we observed pitch tubes and/or frass on live trees or the presence of J-shaped beetle galleries beneath the bark of dead trees.

Since 2008, we resurveyed transects based on a 4 year rotating panel for white pine blister rust and a 2 year rotating panel for mountain pine beetle. Each year we resurveyed two panels of 40-45 transects each to capture rapid changes in tree mortality and evidence of attack during an active mountain pine beetle outbreak. During resurveys, each permanently tagged tree was evaluated for its status as live (green needles present), recently dead (having non-green needles present) or dead (needles are absent). Live trees with a fading crown were noted in the tree comment field. The most recent assessment of tree status took place in 2009 and 2010 when all transects were resurveyed for mortality and evidence of mountain pine beetle infestation.

The proportion of trees infected with white pine blister rust was calculated using a design-based ratio estimator that accounts for the total number of mapped stands within the sample frame and stratified by within and outside the RZ (GYWPMWG 2007). We used data from repeat surveys to document rates of tree mortality. Tree mortality, expressed as a percent, was calculated by dividing the total number of tagged dead and

recently dead trees observed between 2007 and 2009 by the total number of live trees tagged between 2004 and 2007 and multiplied by 100. We used data from repeat surveys to document changes in the size class distribution of live whitebark pine trees in the monitoring sample.

Results

What is the proportion of trees > 1.4 m tall with white pine blister rust in the GYE?

Using our design-based ratio estimator, we estimated the proportion of whitebark pine trees infected with white pine blister rust was 0.20 (± 0.037 se) at the end of 2007 (GYWPMWG 2008). Our monitoring indicated that white pine blister rust was widespread and highly variable in intensity and severity across the GYE (Fig. 2).

What is the increase of standing dead trees > 1.4 m tall within our permanent monitoring transects?

Using data from repeat surveys, the percentage of dead standing trees increased from 16% to 29% by the end of 2010 (Table 1). We derived the baseline value of 16% from the sum of all recently dead and dead trees > 1.4 m tall encountered during initial transect establishment. A recently dead tree has persistent non-green needles whereas a dead tree has no remaining needles. We did not reassess status of untagged dead trees and assumed they were still standing as dead whitebark pine can stand for years, even decades.

What is the mortality in whitebark pine trees > 1.4 m tall within our permanent monitoring transects?

Mortality at the end of 2010 among whitebark pine trees > 1.4 m tall that were tagged during transect establishment was 16.4% (Table 2).

How has the recent mountain pine beetle epidemic changed the size class distribution of living whitebark pine trees in the monitoring sample?

We grouped the DBH of live whitebark pine trees by size class and plotted this frequency to compare the number of trees in each size class during the initial survey in 2004 through 2007 with that of most recent survey results from 2009 through 2010 (see fig. 3). The decrease in live trees was especially evident in trees > 10 cm DBH that are most susceptible to mountain pine beetle attack. The increase in the number of trees ≤ 2.5 cm represents the number trees recruited into our sample as they reached 1.4 m in height (see table 2).

Conclusion

Weather and climate will continue to play a role in insect and disease outbreaks in forest ecosystems in the GYE. Gibson et al. (2008) anticipate beetle populations to remain high as long as weather conditions are conducive to beetle survival and/or until most mature host trees have been killed. In our monitoring transects, a large number of live whitebark pine trees >10 cm DBH are still present in 2010 (Fig. 3). Trees larger than 10 cm DBH

are most susceptible to mountain pine beetle attack (Furniss and Carolin 1977). Some whitebark pine surviving the current mountain pine beetle outbreak will continue to be stressed by white pine blister rust. Unlike mountain pine beetle, white pine blister rust infects all size classes. Seedlings and saplings are especially susceptible and are often killed within 1 to 3 years of infection (Schoettle and Sniezko 2007). Although not reported here, we are developing protocols to monitor trees < 1.4 m tall to track changes white pine blister rust infection and survival within this size class.

Our whitebark pine monitoring program provides valuable information to help guide management strategies, restoration planning and application of scarce funding and other resources (Schwandt 2006; GYWPWG 2007). Moreover, the collaborative, interagency approach of monitoring and management of whitebark pine in the GYE is an effective strategy to help this important high elevation species persist across the landscape.

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Figure and table captions

Figure 1. Location of whitebark pine survey transects (n=176) in the Greater Yellowstone Ecosystem in Idaho, Montana, and Wyoming, USA. A panel is a subset of the total sample size that is visited within a given year.

Figure 2. Proportion of whitebark pine trees (> 1.4 m tall) infected with white pine blister rust infected (red) and not infected with white pine blister rust (light green) at each transect within the Greater Yellowstone Ecosystem. Due to map scale the pie charts are distributed for readability and may not be placed on the actual survey location.

Figure 3. Change in size class distribution of whitebark pine trees > 1.4 m tall between our initial survey in 2004 through 2007 and our most recent survey in 2009 through 2010. Data from the Greater Yellowstone Ecosystem.

Table 1. Summary data from the Greater Yellowstone Ecosystem showing the increase of standing dead trees over time. Dead and recently dead trees encountered during initial transect establishment between 2004 through 2007 are untagged.

Table 2. Mortality and recruitment statistics for whitebark pine trees > 1.4 m tall within permanent monitoring transects in the Greater Yellowstone Ecosystem. New recruits that have grown >1.4 m tall since transect establishment were tagged and added to the database during resurveys.