2006 Annual Report

Monitoring Whitebark Pine in the Greater Yellowstone Ecosystem

Greater Yellowstone Whitebark Pine Monitoring Working Group

Whitebark pine (WbP) occurs in the subalpine zone of western North America, including the Pacific Northwest and Rocky Mountains, where it is adapted to a harsh environment of poor soils, steep slopes, high winds and extreme cold temperatures. While its inaccessibility and sometimes crooked growth form lead to low commercial value, it is a highly valuable species ecologically and is often referred to as a "keystone" species in the subalpine ecosystem (Tomback et al. 2001). Its best known role in these ecosystems is as a high-energy food source for a variety of wildlife species, including red squirrels, Clark's nutcracker and the threatened grizzly bear.

Photo courtesy B.R. McClelland

Background of the Program

Forest monitoring has shown a rapid and precipitous decline of WbP in varying degrees throughout its range due to non-native white pine blister rust (Kendall and Keane 2001) and native mountain pine beetle (Gibson 2006). Given the ecological importance of WbP in the Greater Yellowstone Ecosystem (GYE) and that 98% of WbP occurs on public lands, the conservation of this species depends heavily on the collaboration of all public land management units in the GYE. Established in 1998, the Greater Yellowstone Whitebark Pine Committee, comprised of resource managers from eight federal land management units, has been working together to ensure the viability and function of WbP throughout the region. As a result of this effort, an additional working group was formed for the purpose of integrating the common interests, goals and resources into one unified monitoring program for the Greater Yellowstone area. The Greater Yellowstone Whitebark Pine Monitoring Working Group consists of representatives from the U.S. Forest Service (USFS), National Park Service (NPS), U.S. Geological Survey (USGS), and Montana State University (MSU). This report is a summary of the data collected from the third field season of this long-term monitoring project.

A Unified Effort

Although other efforts within the GYE have contributed greatly to our initial understanding of the status of whitebark pine, differences in study designs and field methods make it difficult to make reliable comparisons across the region and among other monitoring efforts. In order to effectively detect how rates of blister rust infection, survival and regeneration of whitebark are changing over time in the GYE, a repeatable, long-term sampling design provides the most advantageous approach. The Greater Yellowstone Whitebark Pine Monitoring Working Group has been developing a protocol for monitoring whitebark pine in a consistent manner throughout the entire ecosystem. This program will facilitate a more effective effort to understand the status and trends of whitebark on a comprehensive, regional scale. The working group method was designed with the intent of detecting long-term health shifts in the GYE whitebark population, which in turn, will provide critical information on the likelihood of this species' ability to persist as functional part of the ecosystem.

Photo courtesy Lisa Landenburger

NPS Photo, Rosalie LaRue

Objectives

Our objectives are intended to monitor the health of whitebark pine relative to levels of white pine blister rust and to a lesser extent mountain pine beetle. The approach we are taking is a combination of assessing the status and trends of whitebark pine with respect to these potentially injurious agents as well as to assess the demographic rates that would enable us to determine the probability of whitebark pines persisting in the Greater Yellowstone Ecosystem.

Objective 1 *- To estimate the proportion of live whitebark pine trees (>1.4 m high) infected with white pine blister rust, and to estimate the rate at which infection of trees is changing over time.*

Objective 2 *-Within infected transects, to determine the relative severity of infection of white pine blister rust in whitebark pine trees > 1.4 m high.*

Objective 3 *- To estimate survival of individual whitebark pine trees > 1.4 m high, explicitly taking into account the effect of infection with, and severity of, white pine blister rust, infestation by mountain pine beetle and fire.*

Objective 4 *- Currently in the planning stages, this objective is aimed at assessing recruitment into the cone producing population. We anticipate a pilot effort to begin in 2007.*

Objective 5 *- This objective is aimed at assessing the effect of forest succession and is being planned for future implementation.*

Study Area

Our study area is in the Greater Yellowstone Ecosystem and includes 6 National Forests and 2 National Parks (the John D. Rockefeller Memorial Parkway is included with Grand Teton National Park) (Figure 1). The habitat types from which our sample was selected correspond to aggregation of "High Elevation Whitebark Pine Dominated Sites" described by Mattson et al. (2004). However, it should be noted that this name is a bit confusing because "high elevation" in the context of this report, refers to the entire ecosystem, not just to whitebark. Thus, it does not imply that the whitebark sites are limited to higher elevation sites within the whitebark pine cover types. Rather, it includes whitebark pine cover types ranging from relatively pure whitebark pine stands that occur at higher elevations, to mixed-species stands that occur at lower elevations within the range of whitebark.

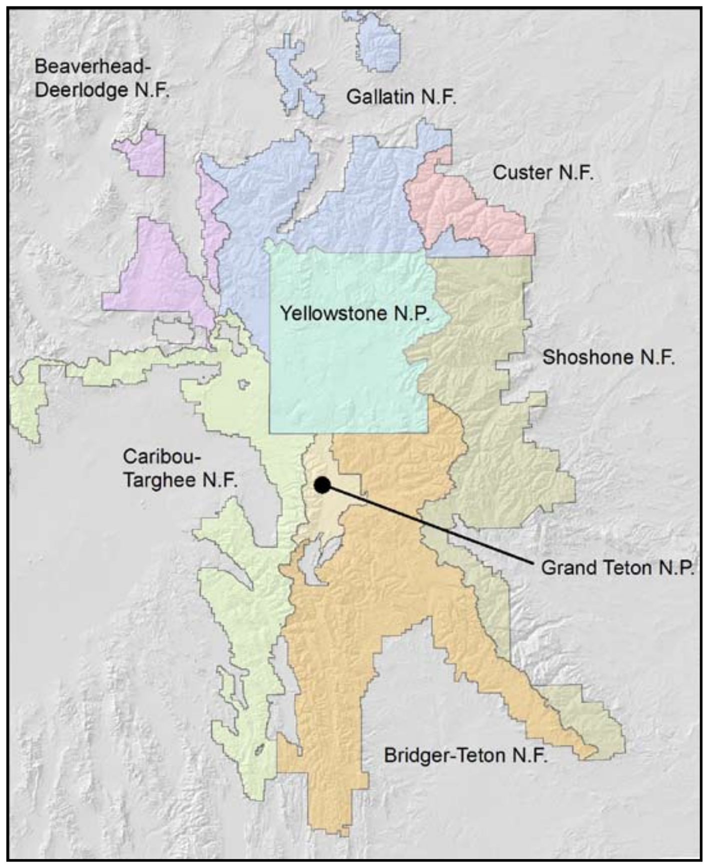

Figure 1. Study area showing national forest and national park units.

Methods

Details of our sampling design and field methodology can be found in Greater Yellowstone Whitebark Pine Monitoring Working Group (2005, 2006). However, our basic approach is a 2-stage cluster design with stands (polygons) of

whitebark pine being the primary units and 10x50 m transects being the secondary units. During 2004 all WbP stands sampled were within the Grizzly Bear Primary Conservation Area (PCA) due to the limitations in the mapped distribution of WbP across the study area. Our sample during 2005 extended outside of the PCA to the boundaries of what is considered the GYE (Figure 2). For 2006, our sampling encompassed the entire region. Separation of the areas within and outside the PCA enabled us to account for map limitations during 2004 and to analyze survey results separately. Transects and individual trees within each transect were permanently marked in order to estimate changes in infection and survival rates over an extended period. Transects will be revisited approximately every 5 years to determine changes in blister rust and individual tree survival since the previous visit.

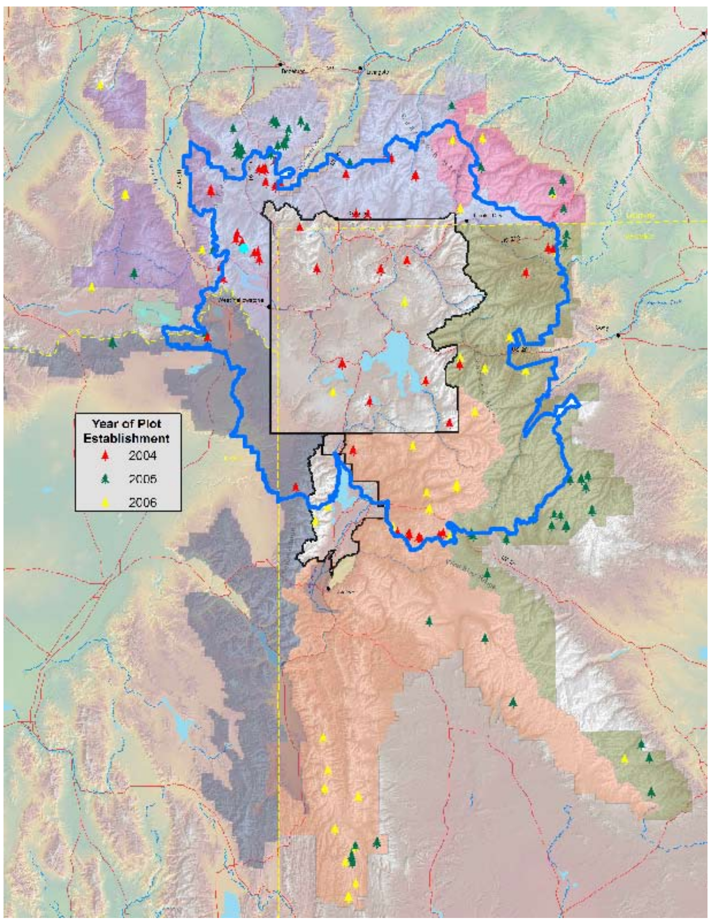

Figure 2. Distribution of samples (transects) in 2004, 2005, and 2006. The Grizzly bear PCA is shown in blue.

White Pine Blister Rust

For each live tree, the presence or absence of indicators of blister rust were recorded. For the purpose of analyses presented here, a tree was considered infected if either aecia or cankers were present. For a canker to be conclusively identified as resulting from blister rust, at least three of five ancillary indicators needed to be present. Ancillary indicators of blister rust included flagging, rodent chewing, oozing sap, roughened bark, and swelling.

Mountain Pine Beetle

The presence or absence of mountain pine beetle was noted in all WbP; however, we did not attempt to assign a cause of death for dead WbP trees. Mountain pine beetle presence was identified in the following ways: 1) small, popcorn-shaped resin masses called pitch tubes; and 2) the characteristic J-shaped galleries under the bark.

Evaluating Observer Differences

Previous monitoring efforts for WbP have largely ignored observer variability in identifying white pine blister rust infection. To assess this effect, we conducted independent surveys by different observers on 6 transects in 2004, 18 transects in 2005 and 9 in 2006. The first observer marked the individual trees which were subsequently visited by each of the other observers.

Preliminary Results

White Pine Blister Rust

A total of 167 transects have been surveyed within 136 stands of WbP in the Greater Yellowstone Ecosystem between 2004 and 2006 (Table 1). Of these, 67 transects in 59 stands were surveyed within the grizzly bear PCA and 100 transects within 77 stands were sampled outside the PCA. The proportion of infected trees on a given transect ranged from 0 to 1.0. The number of live trees per transect for each year ranged from 1 to 219 for a total of 1,012 live trees examined during 2004, 2,732 during 2005 and 805 in 2006. Although a formal spatial analysis has not yet been conducted, our preliminary data indicate that infection rates are highly variable across the region (Figure 3).

Table 1. Summary statistics for Greater Yellowstone Ecosystem 2004-2006.			
Location	Within PCA	Outside PCA	Total for GYE
Number Stands	59	77	136
Number of Transects	67	100	167
Number of Trees Sampled	1330	3233	4563
Proportion of Transects Infected	0.70	0.87	0.80
Estimated Proportion of Trees Infected.	0.14 ± (0.04 se)	0.30 ± (0.05 se)	0.26 ± (0.04 se)

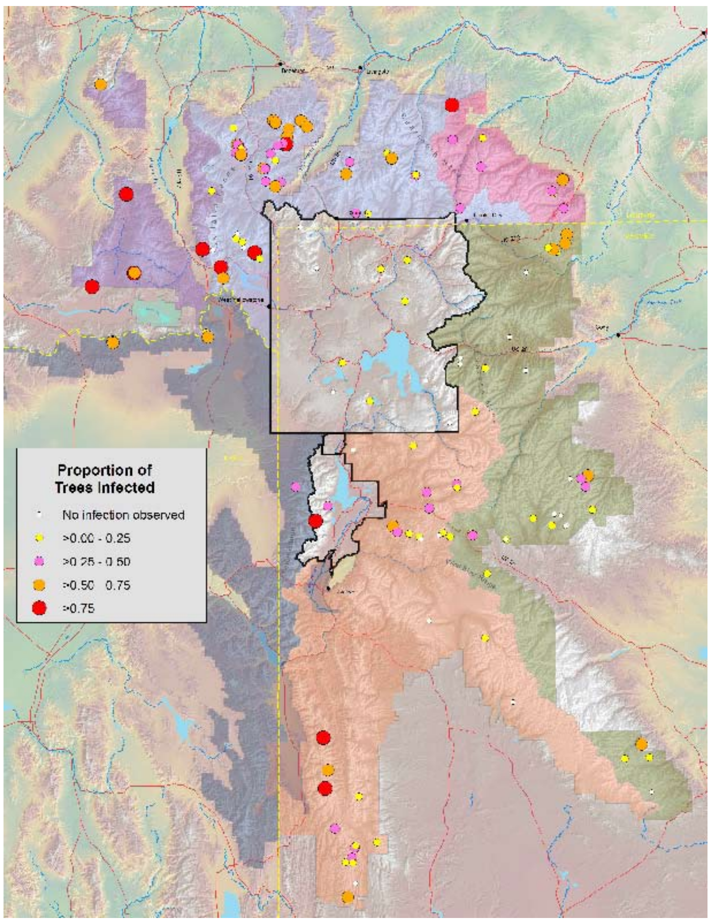

Figure 3. The proportion class of infected trees within each transect of the Greater Yellowstone Ecosystem in 2004-2006.

Within vs Between Stand Variability

One of the concerns we had regarding sampling design was how to balance our effort between estimating within-stand variability versus between-stand variability. To address this issue, we estimated the proportion of trees infected, and the corresponding variance for 23 stands that had two transects per stand. The resulting estimate of proportion of trees infected was 0.28, not dissimilar to our other estimates. However, the interesting result is that the standard error ignoring within-stand variation was 0.08649 compared to 0.08657 when accounting for within-stand variation. We concluded from this exercise that within-stand variation was not contributing significantly to our estimates. We still believe that it is worthwhile and will continue to estimate both components, but obtaining replicate samples within stands need not be a primary emphasis.

Severity of White Pine Blister Rust on Infected Trees

The total number of cankers observed on infected live trees for the three years (2004-2006) combined was 3,252, of which 2,692(83%) were located on branches and 560 (17%) were located on a main bole. The total number of cankers per infected tree ranged from 1 to 39. Bole cankers that are located on the lower portion of the bole (middle to bottom third) are generally considered lethal to trees. Cankers that are found in the upper third of the bole are not necessarily lethal but can have a negative impact on cone production. Such cankers were less numerous than branch cankers and ranged from 0 to 7 per infected tree; whereas branch cankers ranged from 0 – 39 per infected tree.

In most cases, the number of cankers per tree was low with approximately 59% of the infected trees having <= 2 cankers. Further, most (83%) of the cankers observed were on branches rather than the bole.

Mountain Pine Beetle

Of the 45 stands visited in 2004, 10 (22%) had evidence of mountain pine beetle attacks in live or recently dead (i.e., with intact needles) trees. Of the 1,062 live or recently dead trees we sampled in these stands, 30 (3%) had evidence of mountain pine beetle attacks. In 2005, 12 out of 55 (22%) stands had evidence of mountain pine beetle attacks and of the 2,827 live or recently dead trees, 26 (1%) had evidence of mountain pine beetle attacks. For 2006, 15 (41%) of the 36 stands surveyed had evidence of mountain pine beetle attacks with 55 (6%) of the 805 live or recently dead trees exhibiting signs of mountain pine beetle attack.

Observer Differences

Some of the factors that may influence observer variability are observer positioning, observation effort, stand density and physical structure, observer experience, lighting, and equipment (e.g., binoculars). Thirty three transects between 2004 -2006 were surveyed by multiple observers. Each observer recorded blister rust infections independently for each

tree on the same transect. Our data suggests that observer variability may be quite important. This result has broad implications for all monitoring efforts of whitebark pine where observer differences are not considered. For monitoring efforts to be reliable, true differences in infection rates over time should not be confounded with differences among observers in their ability to detect infections.

In order to study this phenomenon, an independent analysis on observer variability for data collected in 2004 and 2005 was conducted (Huang 2006). Three statistical procedures were used to examine observer variability including Cohen's Kappa coefficient, McNemar's test and Cochran's test.

Although the overall proportions (Kappa coefficient) of agreement for the presence/absence of infection/aecia seem relatively high (between 82% and 92%), this was not the case when separate observer records of agreement for presence and for absence were studied independently (McNemar's and Cochran's tests). For the most part, observer agreement remained high (between 88% and 96%) when comparing the absence of infection or aecia. However, when comparing observer agreement for the presence of infection or aecia, agreement among observers was substantially lower (between 44% and 83%). Thus, it would be misleading to base observer variability for overall proportions of agreement on the Kappa coefficient alone.

A fourth procedure was conducted to look for the possibility of a "learning curve" effect for inexperienced observers. To study this, the proportions of multiple observer agreements were generated and graphed across time (beginning of the season to the end). The agreement on infection and on aecia in 2004 was "fairly good" and more variable among observers in 2005. Nonetheless, there was an increasing trend in the agreement over time which may indicate the presence of a learning effect variable (Figure 4). At the transect level,

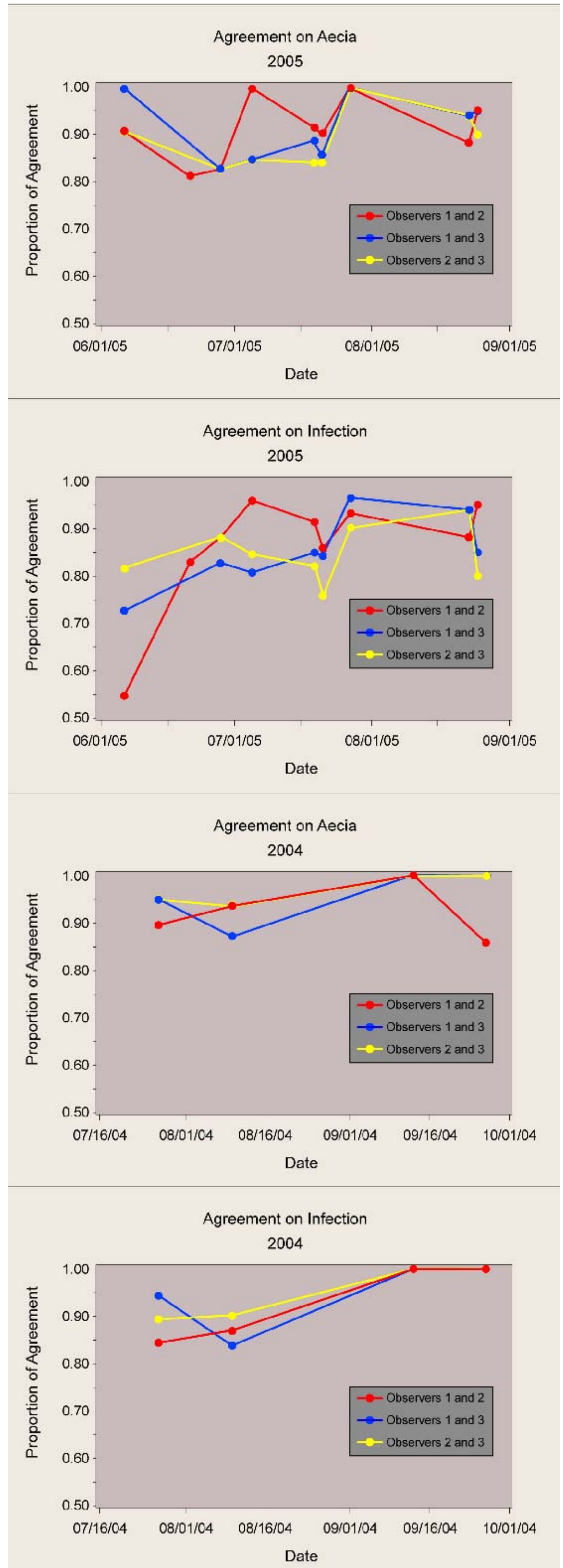

Figure 4. Observer agreement on the proportion of trees infected and the presence of aecia between different observer pairs during 2004 and 2005 (after Huang 2006).

consistency among observers in estimating the proportions of trees infected or aecia present on each transect was, in general, only moderate.

Accounting for Access

One concern that reviewers of this project have raised is the selection of transects that might be difficult or time consuming to access. Some feel that we have decreased our sample size "potential" by using a random selection prototcol resulting in a percentage of extremely remote stands. It has been argued that if we had implemented a stratified approached based on distance to roads, we would have been able to sample more stands. We fully understand this concern and we had considerable debate and discussion on this topic during the development of our sampling approach. However, two circumstances of our sampling diminish this concern. First, our desired inference was for the entire population of whitebark pine within the GYE. Thus a stratified sample would still have required a minimum sample in remote areas if our inference was to remain as the total study area. Given the remote nature of our study area, the majority of stands require some sort of hiking effort. As it turns out, a random sample is distributed such that relatively few extremely remote sites are included, merely by chance and by the distribution of roads throughout the ecosystem. In the 3 years of plot establishment, very few (3%) of the transects selected were extremely remote (e.g., > 10 miles one way) and most (78%) were ≤ 5 miles one way (Figure 5). Having to select a stratified sample, with a minimum number in remote locations, could even result in having more remote sites than our existing sample.

The second consideration was that our total sample was not limited to a set number of seasons, such that we were prepared to spend as many seasons as necessary to attain the desired sample. With this in mind, we met our target sample size in 3 seasons without jeopardizing statistical validity. In addition, hiking distance to a given plot was often not the

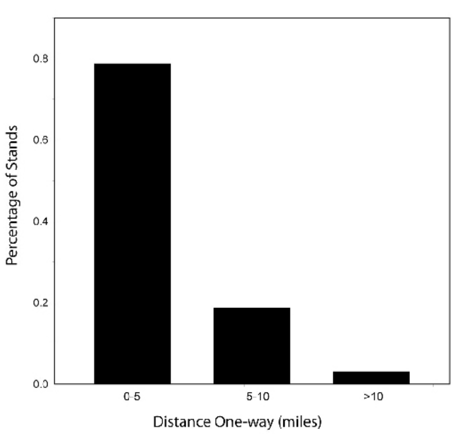

Figure 5. The percentage of stands in each of three distance classes from the closest access by road.

limiting factor. Rather, the number of trees and level of infection often played a greater role in the time required to survey a plot on any given day.

Discussion

As previously stated, this study concentrates on the health and status of whitebark pine in the Greater Yellowstone area. Although WbP is important to an array of wildlife including the grizzly bear, it is important to reiterate that the focus of this project is on WbP as opposed to any of the species with which it may be associated. It is also important to be very clear about what we are reporting. When examining reports of blister rust infection, it often is not clear whether the rates of infection being reported are the proportion of plots (e.g., transects) that have some indication of infection, or the proportion of trees that have some level of infection. In this report, we consider the proportion of transects that show the presence of blister rust as an indication of how widespread blister rust is within the GYE. Our preliminary results indicate that the occurrence of white pine blister rust is widespread throughout the GYE (i.e, 81% of all transects had some level of infection). We consider the proportion of trees infected and the number and location (branch or bole) of cankers as indicators of the severity of blister rust infections. As such, our preliminary results indicate that most trees had very few cankers and of those, most were located on branches. Branch cankers are generally considered to be less lethal (Koteen 2002). Thus our preliminary data indicate that blister rust is quite widespread throughout the ecosystem, but that the severity of infections is still relatively low.

It should be noted that the results presented here are preliminary and some caution in interpretation is warranted. First, we have yet to establish a complete sample of the ecosystem. We will complete our sample set with an additional 10–12 stands, surveyed during the 2007 season. These remaining stands will provide us with an even distribution of transects

across the 2 Parks and 6 Forests. Therefore, our estimates to date comprise only a subset of what will be a complete sample of the ecosystem. An additional caution to take into consideration is that the results presented here are estimates from a specific protocol of sampling design and field methods. Few, if any other efforts within the GYE have selected sites using a probabilistic sampling design specifically intended for deriving inference to the GYE population as a whole. Thus, comparison with results from efforts using different field methods or sampling designs is likely to produce questionable conclusions. It is largely for this reason, that we have attempted a consistent approach for the entire GYE.

At this point in time, our preliminary estimates apply only to the current status. Estimates of change in infection within the GYE will be derived from repeated sampling of our selected sites over time; thus have not yet been assessed.

Our overall estimate of blister rust infections is likely conservative. Our criteria of having aecia or at least three of the other indicators (rodent chewing, flagging, oozing sap, roughened bark or swelling) present to confirm infection, may result in the rejection of questionable cankers. We are continuing to evaluate the efficacy of these criteria for future sampling. As previously mentioned, our data indicate that observer variability plays an important role when reporting infection estimates. This should be taken into consideration for all whitebark pine and other long-term monitoring efforts.

Mountain Pine Beetle

Although we record incidents of mountain pine beetle when observed, this program was not designed to detect initial pine beetle attacks. We view our program as complimentary to other efforts such us the USFS aerial detection surveys. Because we mark individual trees and repeatedly sample them over time, we do expect to obtain reliable estimates of mortality after stands have been revisited. Aerial surveys are probably a better approach to detecting areas and intensity of initial attacks, which can be later complimented with our estimates of actual mortality.

Observer Effects

Our results indicate that observer variability may be an important issue for monitoring whitebark pine health. Because of the variability among observer assessments, caution should be exhibited when reporting estimates of the proportion of infected trees and estimates of the proportion of trees with aecia. Two simple ways of handling these concerns might be to (1) delete points associated with disagreement between observer assessments of the presence or absence of infection or aecia or (2) when observers disagree, only use the recorded assessment of the more experienced observers. However, both of these solutions assume that assessments are being made by more than one observer, which is unlikely for most monitoring projects.

The general tendency toward increasing agreement over time indicates that training and experience may play a key role in obtaining consistent results. However, experience alone does not seem to account for all of the variation. For example, agreement among observers, at least early in the season, was generally lower in 2005 than 2004. Given that agreement generally increased over each season highlights the need to:

- *Invest sufficient resources into training at the beginning of the program.*
- *Take the time for field biologists to work together at the beginning of each season.*
- *Try to minimize turnover of field biologists.*

Our results further indicate that attempts to shortcut these steps to save money are likely to be a false savings if the resulting estimates are unreliable.

The results of this effort are still being analyzed and will be reported in detail in a separate manuscript intended for publication. However, as a result of these findings, we will continue to assess this issue in order to understand and minimize observer variability.

Future Directions

With the addition of 10-12 transects to be surveyed in 2007, we will have a sufficient sample to expect reasonable inference about changes in blister rust infection over time. Our current sample of 160 permanently marked transects plus the 10-12 surveyed in the 2007 season will remain our final sample for estimating blister rust infection and associate mortality at approximately 5-year intervals. However, with the exception of seedling counts on existing transects, our sampling thus far is focused on mortality. Of equal concern is the ability for whitebark pine to be reproductively viable. The decline of whitebark pine can result either from increased mortality (e.g., as a result of blister rust and/or mountain pine beetle), or it can result from a lack of recruitment into the reproductive population. A lack of recruitment can result from changes in a variety of life history stages from decreased cone production to recruitment of immature trees into the cone-producing population. Cone production

itself is currently being monitored by the Interagency Grizzly Bear Study Team, and other interested groups. The number and survival of seedlings is also an area of relevance; however, seedlings naturally exhibit very high mortality rates. Therefore, we are more concerned about the recruitment of those individuals that have survived into the mature population. The next phase of this project will focus on the recruitment of immature trees into the cone-producing population. Future efforts also may include the effects of forest succession.

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Cooperating Organizations:

Greater Yellowstone Coordinating Committee (GYCC)

USDA Forest Service

Forest Health Protection
Beaverhead-Deerlodge National Forest
Bridger-Teton National Forest
Caribou-Targhee National Forest
Custer National Forest
Gallatin National Forest
Shoshone National Forest

USDI National Park Service

Greater Yellowstone Inventory and Monitoring Network
Grand Teton National Park
John D. Rockefeller, Jr. Memorial Parkway
Yellowstone National Park

USDI Geological Survey

Interagency Grizzly Bear Study Team
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[a] This project represented a collaboration in the truest sense of the word, such that distinguishing order of participants with respect to relative contribution was virtually impossible. Consequently, order of participants is alphabetical.

Photo courtesy Anne Schrag

Overlooking Lamar Valley

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