2009 Annual Report

Greater Yellowstone Whitebark Pine Monitoring Working Group

Monitoring Whitebark Pine in the Greater Yellowstone Ecosystem

Introduction

Whitebark pine (*Pinus albicaulis)* is a high-elevation tree of the Northern Rocky Mountains, forming open woodlands on relatively xeric slopes (Arno and Hammerly 1977). In the conifer forests of eastern Idaho and western Wyoming, whitebark pine forest habitat types extend downslope from upper timberline on dry exposed ridges on sites too severe for subalpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmannii*). On less severe sites, whitebark pine extends further downslope and is a minor seral species in subalpine fir, Douglas fir (*Pseudotsuga menziesii*) and lodgepole pine (*Pinus contorta*) habitat types (Steele et al. 1983).

In the Greater Yellowstone Ecosystem (GYE), whitebark pine, in mixed or dominant stands, occupies just over 2 million acres of the 24 million acres that comprise the area (Greater Yellowstone Coordinating Committee Whitebark Pine Subcommittee [GYCCWPS] 2010). While its relative inaccessibility and sometimes crooked growth form lead to low commercial value as timber, it is a highly valuable species ecologically and is often referred to as a "keystone" species (Tomback et al. 2001). Whitebark pine is considered a foundation species capable of changing forest structure and ecosystem dynamics (Ellison et al. 2005) in the subalpine zone. The relatively large seeds serve as an important high-energy food source for a variety of wildlife species, including red squirrels (*Tamiascurus hudsonicus*), Clark's nutcrackers (*Nucifraga columbiana*), and grizzly bears (*Ursus arctos horribilis*).

Whitebark pine has exhibited extensive declines over the past 50 years throughout major parts of its range (Kendall and Keane 2001). White pine blister rust (*Cronartium ribicola*) has already devastated the tree in parts of the Pacific Northwest (Kendall and Keane 2001, Koteen 2002) and the disease is well established throughout the Greater Yellowstone Ecosystem (Greater Yellowstone Whitebark Pine Monitoring Working Group [GYWPMWG] 2008). Mountain pine beetles (*Dendroctonus ponderosae*) are normally present at low population levels (Brown 1975, Baker and Veblen 1990), but periodic outbreaks have caused dramatic mortality events in the northern Rocky Mountains over the past century (Arno and Hoff 1990) including Yellowstone National Park in the 1970s (Despain 1990) and throughout the interior west more recently (Gibson 2006, Gibson et al. 2008).

Interagency Whitebark Pine Monitoring Program

Given the ecological importance of whitebark pine in the GYE and concerns over the long-term persistence of the tree species, the National Park Service Inventory & Monitoring program and others in the GYE collaborate on a long-term interagency monitoring program unified through the Greater Yellowstone Coordinating Committee. A monitoring working group of the Whitebark Pine Subcommittee works to integrate common interests, goals and resources of each agency into one unified monitoring program for the GYE. 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 monitoring data collected between 2004 and 2009 from this long-term monitoring project.

Monitoring objectives

The focus of the monitoring program is to detect how rates of blister rust infection change and to track the survival and regeneration of whitebark pine over time. A protocol for monitoring whitebark pine throughout the GYE was completed by the working group (GYWPMWG 2007*a*) and approved in 2007 by the NPS Intermountain Region Inventory and Monitoring Coordinator. Approved monitoring protocols are a key component of quality assurance helping to ensure methods are repeatable and detected changes are truly occurring in nature and not simply a result of measurement differences. The complete protocol is available at: http://www.greateryellowstonescience.org/subproducts/14/72.

Our monitoring objectives are to monitor the health of whitebark pine relative to levels of white pine blister rust and, to a lesser extent, mountain pine beetle.

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

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

Objective 3 - To estimate survival of individual whitebark pine trees >1.4 m tall explicitly taking into account the effects of blister rust infection rates and severity, mountain pine beetle activity, fire and other damaging agents.

This monitoring effort provides critical information on the status of whitebark pine on a regional scale — that of the Greater Yellowstone Ecosystem. Monitoring results will help tell us whether whitebark pine is persisting as a functional part of the ecosystem and monitoring data can be used to justify and guide restoration and protection efforts.

Study Area

Our study area is within the GYE and includes six National Forests and two National Parks (the John D. Rockefeller Memorial Parkway is included with Grand Teton National Park) (Figure 1). The target population is all whitebark pine trees in the GYE. The sample frame includes stands of whitebark pine approximately 2.5 ha or greater within the grizzly bear Recovery Zone and was derived from the cumulative effects model for grizzly bears (Dixon 1997). Outside the Recovery Zone, the sample frame includes whitebark stands mapped by the US Forest Service. Areas that burned since the 1988 fires were excluded from the sample frame.

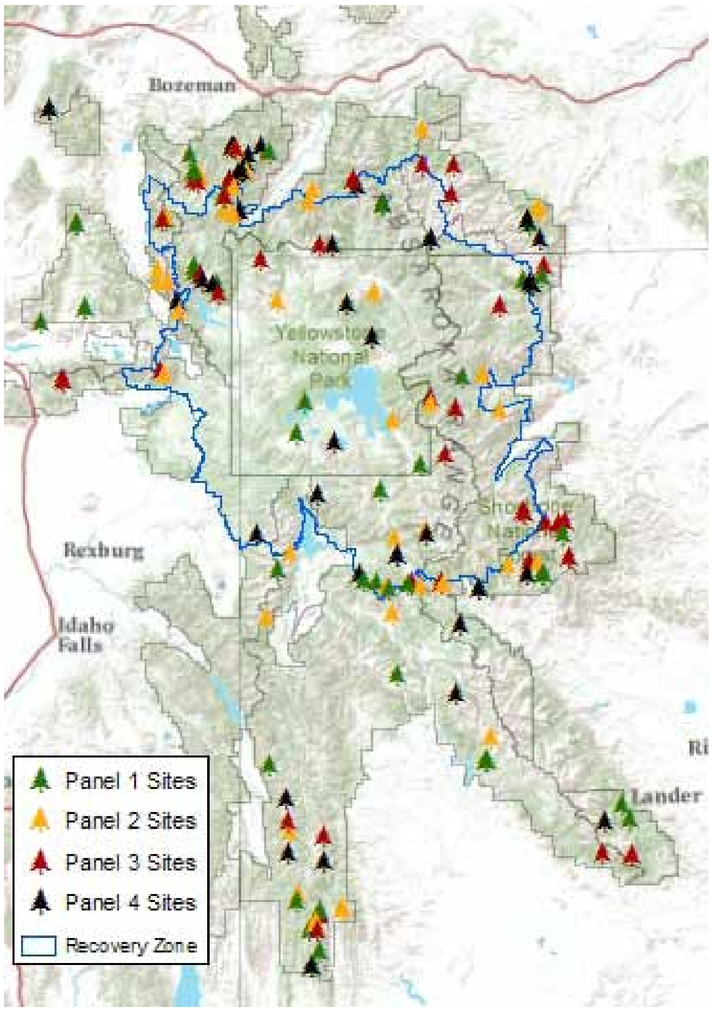

Figure 1. Location of whitebark pine survey transects, Greater Yellowstone Ecosystem. Panel 1 and 2 had a full resurvey for white pine blister rust infection in 2008 and 2009, respectively. Tree survival and indicators of mountain pine beetle were recorded on all but one transect.

Methods

Details of our sampling design and field methodology can be found in the Interagency Whitebark Pine Monitoring Protocol for the Greater Yellowstone Ecosystem (GYWPMWG 2007*a*) and in past project reports (GYWPMWG 2005, 2006, 2007*b*, 2008, and 2009). The 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. The sample of 176 transects is a probabilistic sample that provides statistical inference to the GYE.

Initial establishment of permanent transects took place between 2004 and 2007. During this period 176 permanent transects in 150 whitebark pine stands were established and 4,774 individual live trees >1.4 m tall were permanently marked to estimate changes in white pine blister rust infection and survival rates over an extended period. In addition, the diameter at breast height, tree height class and indicators of mountain pine beetle were recorded for standing dead whitebark pine within the transects at the time of transect establishment. Dead trees were recorded as *recently dead* if the tree had persistent non-green needles.

In response to the current outbreak of mountain pine beetle, we doubled our monitoring efforts and resurveyed 175 transects between 2008 and 2009 to determine the survival

of the permanently tagged trees and to record indicators of mountain pine beetle. Eighty-five transects were resurveyed in 2008 and another 90 in 2009 by two, 2-person crews. One crew was led by the NPS Greater Yellowstone Inventory & Monitoring Network; the other was led by the USGS Interagency Grizzly Bear Study Team. Half of all the permanent transects, essentially all the transects in panels 1 and 2, were resurveyed for changes in white pine blister rust infection in 2008 and 2009, respectively.

White Pine Blister Rust

For each live tree in panels 1 and 2, the presence or absence of indicators of white pine blister rust infection was 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 white pine blister rust, at least three of five ancillary indicators are needed to be present. Ancillary indicators of white pine blister rust included flagging, rodent chewing, oozing sap, roughened bark and swelling (Hoff 1992).

Mountain Pine Beetle

For each live tree in panels 1though 4, pitch tubes and boring dust were recorded as evidence that the tree had been invaded with mountain pine beetle. Pitch tubes are small, popcorn-shaped resin masses produced by a tree as a means to stave off a mountain pine beetle attack. Boring dust is created during a mountain pine beetle attack and can be found in bark crevices and around the base of an infested tree. We checked beneath the bark of dead trees to look for J-shaped galleries where adult mountain pine beetle and their larvae live and feed.

Recruitment

At each 2 x 50 m belt transect, we count the number and determine the status of blister rust infection on all live trees <1.4 m tall. Recruitment that has grown to or above the 1.4m threshold are permanently tagged and added to our live tree database.

Analysis Methods

The proportion of trees infected with white pine blister rust is calculated using a design-based ratio estimator that accounts for the total number of mapped stands within and outside the grizzly bear Recovery Zone.

We continue to investigate the role of observer variability in blister rust detection (see Huang 2006) and detection of mountain pine beetle indicators. Each field season, 25% (approximately 10) of the full blister rust survey transects are subject to the double observer survey described in the working group protocol (GYWPMWG 2007*a*). We periodically examine the consistency between observers and correct problems through improved training and retention of trained and experienced observers. If the observer variability is found to be a large contributor to the standard error for our estimated parameters, we will assess this in our data analysis.

Results

Status of tree survival and presence of mountain pine beetle

There is currently widespread mortality of whitebark pine in the GYE associated with the current mountain pine beetle outbreak. Large diameter trees are the hardest hit during a mountain pine beetle outbreak as beetles preferentially attack large trees over small trees (Gibson et al. 2008).

We examined all permanently tagged trees >1.4 m tall in panels 1 through 4 to determine the living status of each tree. Out of the 4,748 whitebark pine trees examined, 10% (n = 492) had died. We looked for J-shaped galleries beneath the bark of each dead tree for evidence of mountain pine beetle infestation and found that 60% (n = 294) of the dead trees had J-shaped galleries. Consistent with mountain pine beetle preference for larger sized trees, tree mortality since 2004 was much greater in the large tree size class. Of the 429 trees >30 cm at DBH, we found 36% (n = 156) had died, whereas of the 4,317 trees ≤30 cm at DBH, only 8% (n = 335) had died during the same time period.

Based on these data, we calculate the survival of whitebark pine in our sample population at 90%. Field crews also recorded fading crowns, pitch tubes and boring dust, as indicators of mountain pine beetle attack on living trees. Eight percent of the living trees had pitch tubes indicative of mountain pine beetle infestation.

We added the standing dead trees that still had persistent non-green needles at the time of transect establishment to calculate the proportion of live and dead trees >1.4 m tall by size class shown in Figure 2. This same dataset was used to recalculate the percent of dead trees >30 cm or ≤30 cm at DBH that have died over approximately the last 10 years. Cumulatively, of the 475 standing trees >30 cm at DBH, 43% (*n* = 202) have died, whereas of the 4,468 trees ≤30 cm at DBH, 11% (*n* = 486) have died. Among all 688 standing dead trees believed to have died in the last decade, 57% (*n* = 395) had J-shaped galleries beneath the bark.

In a summary of mountain pine beetle impacts in high elevation five-needle pines, Gibson et al. (2008) state that they "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." Tree size is an important measure of host susceptibility. Furniss and Carolin (1977) report that trees from 10 to 12.5 cm in diameter up to those of the largest size may be attacked by mountain pine beetle. Waring and Six (2005) report that trees <5.08 cm (2") DBH are considered too small to support bark beetles. We found 3 trees <13.2 cm DBH with J-shaped galleries, with the smallest being 6.9 cm, however J-shaped galleries began to increase on trees ≥12 cm DBH. Based on tree size alone, 38% of the remaining live whitebark pine trees in our monitoring study are in the size class (≥12 cm) most susceptible to mountain pine beetle attack.

Besides mountain pine beetle, fire burned 4 of our monitoring transects and 13% (*n* = 66) of the dead trees had been scorched by fire.

An important distinction between this monitoring and that of Aerial Detection Survey (ADS) methods is that we use ground based search efforts to detect trees of all size

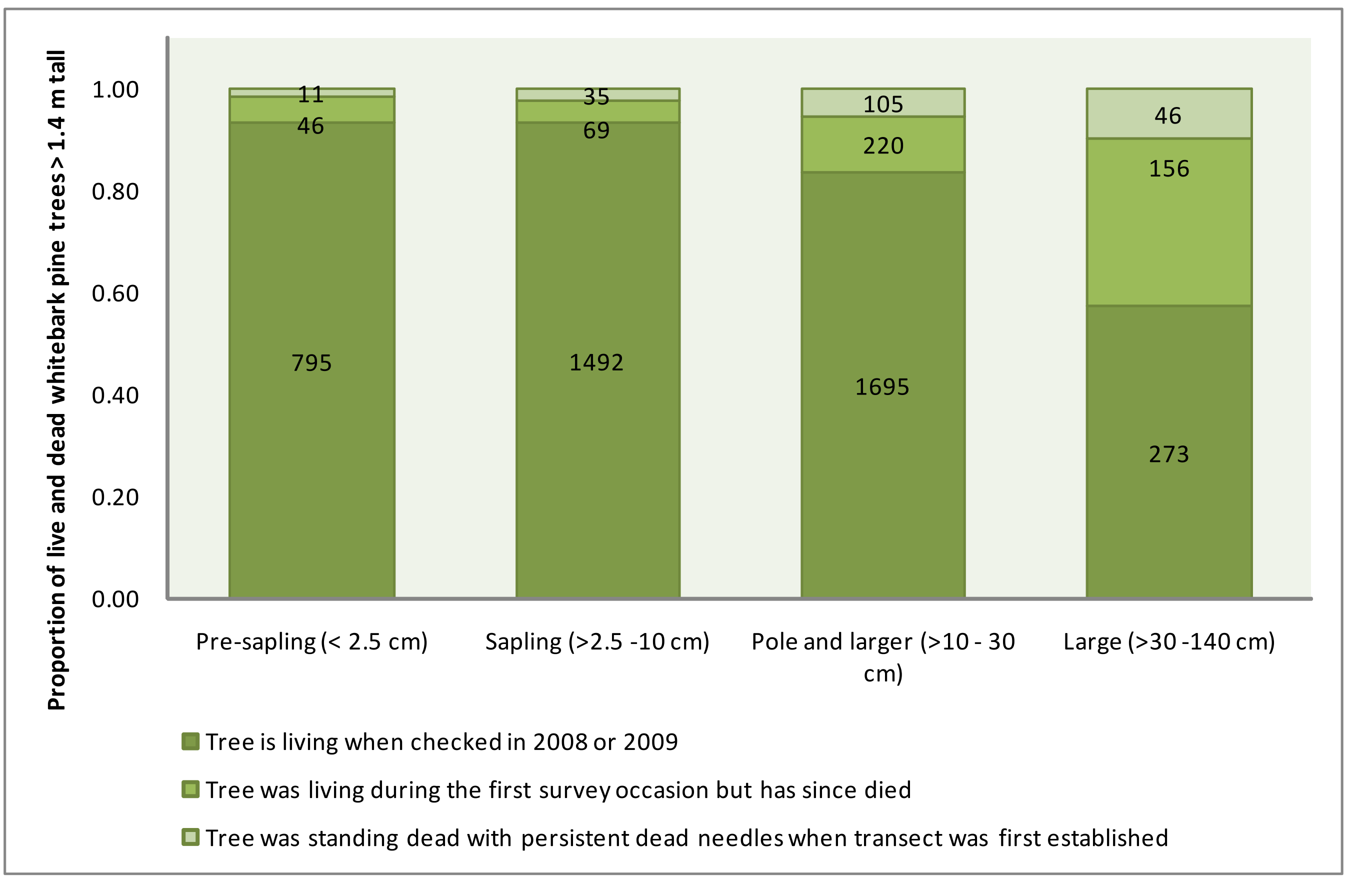

Figure 2. Proportion of living, dead and recently dead whitebark pine trees >1.4 m tall by size class. Categories show the status of trees that were alive and permanently tagged when transects were established and trees that were recently dead during the first survey. Transects were established between 2004 and 2007. A recently dead tree has persistent non-green needles and a dead tree has shed all its needles.

classes whereas ADS and other remote sensing methods use airborne platforms to search for and/or measure changes in the forest canopy. This distinction explains why our mortality estimates differ from aerial detection surveys and mortality assessments recently completed by the USDA Forest Service (Gibson 2006, Gibson et al. 2008), the Forest Service Remote Sensing Application Center (Goetz et al. 2009), and a more recent aerial detection of mountain pine beetle-caused mortality effort completed by Macfarlane et al. (2010).

Status of White Pine Blister Rust

The 2007 baseline estimate of the proportion of live trees with blister rust in the GYE was 0.20 (± 0.037 se) (GYWPMWG 2008). This estimate was based on data from 4,774 individual live trees in 176 transects collected over a 4-year period between 2004 and 2007 after all transects and tree records were established. We report here in Table 1 estimates of the proportion of whitebark pine trees infected with white pine blister rust based on the resurveys of panels 1 and 2, conducted in 2008 and 2009, respectively (Figure 3). We are presenting the results from each panel separately until after 2011 when all panels have been resurveyed at least once and we can combine data for trend analysis.

Changes in the count of infected trees by transect over time and its variability is shown in Figure 3. Blister rust infection has increased in some transects and decreased in others. In some transects, decreases in blister rust infection can be explained by the death of infected trees either by wildfire or after having been infested with mountain pine beetle. Increases in blister rust infection can only be explained by the increased number of trees with evidence of blister rust infection however we cannot say exactly when the increase took place. Burns et al. (2008) explain that increases in blister rust infection generally occur when cool temperatures and high relative humidity favor disease spread and intensification. As such the incidence of pine infection may increase substantially during years when optimum environmental conditions coincide with spore production dissemination, germination, and infection. They refer to these events as “wave years” (Burns et al.

Table 1. Design based ratio estimates for the proportion of infected whitebark pine >1.4 m tall in panel 1 and 2 and other summary information (Irvine 2010).

	2008 [Panel 1]		
Location	**Within Recovery Zone**	**Outside Recovery Zone**	**Total for GYE**
Total number of mapped polygons/stands	2,362	8,408	10,770
Number of stands	15	22	37
Number of transects	15	27	42
Number of unique trees sampled	323	661	984
Proportion of transects infected	13 of 15	19 of 27	32 of 42
CI for proportion of trees infected in 2008	[0.018 , 0.255]	[0.205 , 0.357]	[0.186 , 0.312]
Proportion of trees infected in 2008	0.137 (se = 0.055)	0.28 (se = 0.036)	0.249 (se = 0.031)
	2009 [Panel 2]		
Location	**Within Recovery Zone**	**Outside Recovery Zone**	**Total for GYE**
Total number of mapped polygons/stands	2,362	8,408	10,770
Number of stands	16	21	37
Number of transects	16	28	44
Number of unique trees sampled	295	684	979
Proportion of transects infected	13 of 16	26 of 28	39 of 44
CI for proportion of trees infected in 2009	[0.0184 , 0.301]	[0.3436, 0.595]	[0.295 , 0.501]
Proportion of trees infected in 2009	0.159 (se = 0.066)	0.465 (se = 0.062)	0.398 (se = 0.051)

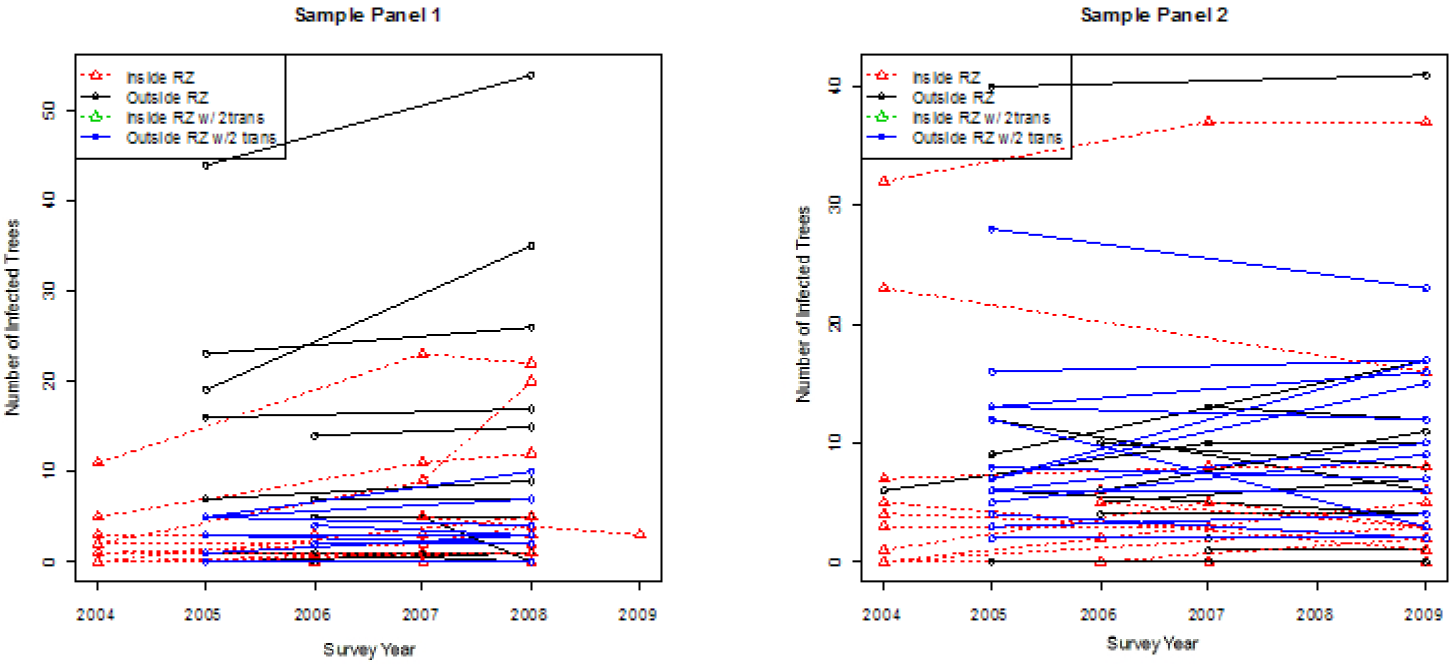

Figure 3. The count of live trees >1.4 m tall infected with white pine blister rust by transect on each survey occasion. Sample panels 1 and 2 are shown separately. Some transects inside the Recovery Zone have been resurveyed 3 times (Irvine 2010).

2008). Our ability to detect blister rust infection soon after an infection event, such as a wave year, is confounded by the year or more that it takes for the aecia to break through the infected bark and our revisit schedule for resurveying transects.

Whitebark pine surviving the current mountain pine beetle outbreak will continue to be stressed by white pine blister rust. Blister rust affects all aspects of the forest regeneration process. Unlike mountain pine beetle that attack larger trees, white pine blister rust infects all size classes and causes mortality in both young and old trees. High levels of blister rust can affect the sustainability of the population (Schoettle and Sniezko 2007) and influence ecosystem recovery long after the current beetle epidemic is over. Long term monitoring conducted by the Interagency Whitebark Pine Monitoring Working Group will detect how rates of blister rust infection change and track the survival and generation of whitebark pine in the Greater Yellowstone Ecosystem over time.

Whitebark Pine Recruitment

We use ground based methods to monitor recruitment of young trees into the reproductive population by tracking and recording the presence of cones or cone scars on individual trees. Twenty-four percent of the live trees >1.4 m tall are mature enough to have produced cones at least once. Counts of unique small trees <1.4 m tall within transects document densities of live trees in the understory ranging from 0 to 12,500 per hectare ($\bar{x}$ = 865, SE = 114, n = 176). Since 2007, 145 trees have grown up to or above the 1.4 m tall threshold and were subsequently tagged and added to the live tree database in 2008 or 2009.

Future Directions

In 2010 we plan to conduct a full resurvey for each transect in panel 3 and a partial resurvey focused on mountain pine beetle indicators in panel 1. As before, both surveys will record tree status as live, dead, or recently dead. If adequate funding is available, we will resurvey another 2 panels in 2011. Once we have a complete resurvey for white pine blister rust at the end of 2011, we can determine changes in the proportion of trees with white pine blister rust in the GYE.

The USGS Status and Trend program has funded the Interagency Grizzly Bear Study Team to conduct an integrated synthesis and analysis of our whitebark pine data. This project will explore the rate of blister rust infection and mountain pine beetle mortality in the GYE using spatial regression models and a suite of spatially explicit covariates. The NPS Greater Yellowstone Inventory & Monitoring Network staff and statisticians from Department of Mathematics Sciences at Montana State University are collaborating with the study team on this project.

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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
Northern Rocky Mountain Science Center
National Biological Information Infrastructure

Montana State University
Department of Mathematical Sciences.

Greater Yellowstone Whitebark Pine Monitoring Working Group

Current Working Group Participants[a]

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

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Copies of this, and other products from this project can be found at the Greater Yellowstone Science Learning Center at: http://www.greateryellowstonescience.org/topics/biological/vegetation/whitebarkpine.