



Monitoring Whitebark Pine in the Greater Yellowstone Ecosystem

2012 Annual Report

Natural Resource Data Series NPS/GRYN/NRDS—2013/498



ON THE COVER

High country in the Greater Yellowstone Ecosystem.
Photograph by: Rachel Simons

Monitoring Whitebark Pine in the Greater Yellowstone Ecosystem

2012 Annual Report

Natural Resource Data Series NPS/GRYN/NRDS—2013/498

Authors

Greater Yellowstone Whitebark Pine Monitoring Working Group
Bozeman, Montana 59715

Editor

Nina Chambers
Northern Rockies Conservation Cooperative
P.O. Box 2705
Jackson, WY 83001

June 2013

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols. This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from <http://science.nature.nps.gov/im/units/gryn/.index.cfm> and the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/nrpm/>).

Please cite this publication as:

Greater Yellowstone Whitebark Pine Monitoring Working Group. 2013. Monitoring whitebark pine in the Greater Yellowstone Ecosystem: 2012 annual report. Natural Resource Data Series NPS/GRYN/NRDS—2013/498. National Park Service, Fort Collins, Colorado.

Contents

- Abstract v
- Acknowledgments vi
- List of Acronyms.....vii
- Introduction 1
 - Interagency Whitebark Pine Monitoring Program.....1
 - Monitoring Objectives.....2
- Study Area 3
- Methods 5
 - Time-Step Assignment 5
 - Full Survey: White Pine Blister Rust and Mountain Pine Beetle Surveys (BR&MPB).....5
 - Mountain Pine Beetle Only/Mortality Survey (MPB only) 6
 - Recruitment and Understory Individuals.....6
 - Plot Data Collection 6
 - Additional Plot Attributes.....7
 - Data Management.....7
- Results 9
 - Time-step Considerations for Whitebark Pine Health and Status 9
 - Monitored Transects 9
 - White Pine Blister Rust Infection in the GYE 9
 - White Pine Blister Rust Infection on Panel 1.....9
 - Infection Transition.....10
 - Mortality on Panels 1 and 3 10
 - Recruitment of Whitebark Pine into the Sample Frame 11
 - Recruitment Plots.....11
 - Comparing Living Trees from Baseline (T0) to Most Recent (2011 and 2012) 11
 - Health Status Indicators at Time of Death 12
 - Presence of Mountain Pine Beetle.....12
- Discussion 15
- Literature Cited 17

Figures

Figure 1. Location of whitebark pine survey transects, Greater Yellowstone Ecosystem.	3
Figure 2. Panel sampling revisit schedule that includes full surveys for blister rust (BR) and mountain pine beetle (MPB) and mountain pine beetle/mortality only surveys (MPB only). This table denotes the designated time series for each Time-Step assignment (Time0 [T0]: 2004-2007, Time1 [T1]: 2008-2011, Time2 [T2]: 2012-2015).	5
Figure 3. Recruitment plot layout within established whitebark pine monitoring transect where the red dots represents the beginning, center, and end monument spikes. The radius of the circular plot is 2.08 meters (1/300 th acre).	6
Figure 4. Species and height-class bins as presented on field data sheet used to collected recruitment data on whitebark pine (PIAL) and limber pine (PIFL) in sub-plots of the established monitoring transects.	7
Figure 5. The chart to the left shows the difference in proportion of infection from Panel 1 in Timestep 0 (T0) to Timestep 1 (T1). The change in the proportion of trees infected on Panel 1 transects from 2008 and 2012 is normally distributed.	9
Figure 6. Blister rust infection transition among live tagged trees on Panel 1 transects in 2008 and again in 2012.	10
Figure 7. Mortality of 156 tagged trees in Panels 1 and 3 with observed health status indicators such as fire, MPB, BR, a combination of factors, or other factors by size class.	10
Figure 8. A comparison of counts of living whitebark pine trees in the Greater Yellowstone Ecosystem by DBH groups between two time periods (transect establishment in 2004-2007, dark blue and most recent revisit surveys in 2011-2012, light blue).	11
Figure 9. Mortality of tagged trees from 2008 through 2012 with associated potential causes of mortality. Evidence of fire, mountain pine beetle [Mpb], white pine blister rust [Br], a combination of the three, or other were recorded for each dead tagged tree by DBH size class (≤ 2.5 cm, >2.5 -10 cm, >10 -30 cm, and >30 cm).	13
Figure 10. Location of transects throughout the Greater Yellowstone Ecosystem with and without evidence of mountain pine beetle infestation as of 2012.	14
Figure 11. Preliminary map of the ratio of whitebark pine trees within each transect as alive, dead or with the presence of blister rust infection from surveys 2009-2012. The infection status ranges from a tree with a single canker on a branch to a tree that may have a bole canker.	15

Tables

Table 1. Daubenmire cover classes for estimating percent cover of plot characteristics (Daubenmire 1959).	8
---	---

Abstract

Whitebark pine (*Pinus albicaulis*) occurs at high elevations and in subalpine communities in the Pacific Northwest and Northern Rocky Mountains. It is a key component in the upper ranges of these ecosystems where it provides a variety of ecological roles, including regulating snowpack and providing high-energy food sources to birds and mammals. As a stone pine species, it produces indehiscent cones and relies primarily on birds for seed dispersal.

In mixed and dominant stands, whitebark pine occurs in over two million acres within the six national forests and two national parks that comprise the Greater Yellowstone Ecosystem (GYE). Currently, whitebark pine is impacted by multiple ecological disturbances. White pine blister rust (*Cronartium ribicola*), mountain pine beetle (*Dendroctonus ponderosae*), wildfires, and climate change all pose significant threats to the persistence of healthy whitebark pine populations on the landscape. Substantial declines in whitebark pine populations have been documented throughout its range. In 2004, an interagency whitebark pine long-term monitoring program was established. The objectives of the whitebark pine monitoring program are to detect and monitor changes in the health and status of whitebark pine populations across the GYE due to infection by white pine blister rust, attack by mountain pine beetle, and damage by other environmental and anthropogenic agents. This report is a summary of data collected in 2012, which marks the beginning of the second scheduled panel revisit to all established transects for the long-term monitoring of the health and status of whitebark pine in the GYE.

Acknowledgments

We thank our current and past field technicians Tyson Roth, McLean Worsham, Kyle Orozco, Nick Miles, Megan Podolinsky, Chris Olsen, John Fothergill, Adam Morris, Chad Hockenbary, Carson Lindbeck, David Brodhead, Rachel Simons, Jennifer Birdsall, Polly Buotte, Justin Hof, Karla Sartor, Jonathan Ball, and Amy Jesswein. We thank former Greater Yellowstone Network ecologist Rob Bennetts for his contribution to the sample design and development of the monitoring protocol, and Steve Cherry from Montana State University for ensuring statistical validity to the sampling regime. We also thank Katie Banner, Nancy Bockino, Marcus Engler, Megan Higgs, Cathie Jean, Ellen Jungck, Bill Oliver, Andy Pils, Jamie Thornton, and Karrie West for their advice and/or field and logistic support. Base funding for this program was provided by the NPS Greater Yellowstone Inventory & Monitoring Network. Additional funding and in-kind support for this program is provided by USFS Forest Health Monitoring, USFS Evaluation Monitoring, USGS (Interagency Grizzly Bear Study Team), the Greater Yellowstone Coordinating Committee (GYCC), the U.S. Fish and Wildlife Service, the U.S. Forest Service, and from Yellowstone and Grand Teton National Parks.

Members of the Greater Yellowstone Whitebark Pine Working Group include:

Jodie Canfield, Forest Biologist
USDA Forest Service
Gallatin District, Gallatin National Forest

Gregg DeNitto, Forest Pathologist
USDA Forest Service
Forest Health Protection

Karl Buermeyer, Subcommittee Chair
USDI Greater Yellowstone Coordinating Committee
Whitebark Pine Subcommittee

Frank VanManen, Study Team Leader
USDI Geological Survey
Interagency Grizzly Bear Study Team

Kathi Irvine, Statistician
USDI Geological Survey

Kristin Legg, Program Manager
Rob Daley, Data Manager
Erin Shanahan, Field Ecologist/Crew Leader
USDI National Park Service
Greater Yellowstone Inventory and Monitoring Network

Kelly McCloskey, Vegetation Ecologist
USDI National Park Service
Grand Teton National Park

Dan Reinhart, Vegetation Resources Program Manager
USDI National Park Service
Yellowstone National Park

Dave Roberts, Department Head
Montana State University
Department of Ecology

List of Acronyms

BR	blister rust
CI	confidence interval
DBH	diameter at breast height
GRYN	Greater Yellowstone Inventory & Monitoring Network
GYCC	Greater Yellowstone Coordinating Committee
GYCCWPS	Greater Yellowstone Coordinating Committee Whitebark Pine Subcommittee
GYE	Greater Yellowstone Ecosystem
GYWPMWG	Greater Yellowstone Whitebark Pine Monitoring Working Group
IGBST	Interagency Grizzly Bear Study Team
MPB	mountain pine beetle
MSU	Montana State University
NPS	National Park Service
RZ	Recovery Zone (grizzly bear)
SE	standard error
USFS	United States Forest Service
USGS	United States Geological Survey

Introduction

Coniferous forests throughout western North America are undergoing large scale change from a variety of disturbances. Climate change, forest insect and pathogen upsurges, and other disturbance regimes have the potential to alter forest ecosystem structure, function, and species composition (McKinney et al. 2013). Foundation species are those organisms that are essential in the architecture of local communities and therefore, the loss of foundation tree species can upset vital ecosystem processes (Ellison et al. 2005). Whitebark pine (*Pinus albicaulis*) occurs in the Pacific Northwest and northern Rocky Mountains where it is a foundation species in the subalpine zone due to the important role it plays in regulating the biodiversity of these areas. Whitebark pine influences multiple species and processes in montane ecosystems where it is a food source for a variety of wildlife, facilitates establishment of other vegetative species in otherwise inhospitable habitat, and helps to regulate soil erosion and snow pack retention (Tomback and Kendall 2001).

Over the last decade, U.S. Forest Service (USFS) and National Park Service (NPS) lands in the Greater Yellowstone Ecosystem (GYE) have experienced declines in the whitebark pine population. A disproportionate number of these deaths have occurred in the mature, overstory assemblages as a result of the recent mountain pine beetle (*Dendroctonus ponderosae*) epidemic (GYWPMWG 2008, 2009, 2010, 2011a, Logan et al. 2010). In addition to the mountain pine beetle outbreak, other ecological disturbances, such as white pine blister rust (*Cronartium ribicola*) and wildland fires, act simultaneously to exacerbate losses among all cohorts in the whitebark pine population. These decreases have generated considerable concern regarding the fate of whitebark pine in the ecosystem. As a result, the loss of mature, overstory whitebark pine in the GYE in combination with population declines in other regions has prompted the U.S. Fish and Wildlife Service (USFWS) to list whitebark pine as warranted, but precluded under the Endangered and Threatened Species Act (USFWS 2011).



ERIN SHANAHAN

Pole-sized stand of whitebark pine.

This annual report provides a summary of the data collected in 2012 and a brief overview on the life history status of all monitored trees in 176 sample transects from 2011 and 2012.

Interagency Whitebark Pine Monitoring Program

Under the auspices of the Greater Yellowstone Coordinating Committee (GYCC), the National Park Service Inventory and Monitoring Program, and several other agencies began a collaborative, long-term monitoring program to track and document the health and status of whitebark pine across the GYE. This alliance resulted in the formation of the Greater Yellowstone Whitebark Pine Monitoring Working Group (GYWPMWG), which consists of representatives from the U.S. Forest Service, National Park Service, U.S. Geological Survey (USGS), and Montana State University (MSU). A protocol for monitoring the health and status of the whitebark pine population in the GYE was developed between 2004 and 2007 by the GYWPMWG. After rigorous peer review, the Interagency Whitebark Pine Monitoring Protocol for the Greater Yellowstone Ecosystem received final approval in 2007 and was recently updated in 2011 (GYWPMWG 2011b). The complete protocol is available at: <https://irma.nps.gov/App/Reference/Profile/660369> (accessed June 13, 2013).

Monitoring Objectives

Generally, the objectives of the whitebark pine monitoring program are to detect and monitor changes in the health and status of the whitebark pine population across the GYE due to infection by white pine blister rust, attack by mountain pine beetle, and damage by other environmental and anthropogenic agents.

Specifically, the Interagency Whitebark Pine Monitoring Protocol (GYWPMWG 2011b) addresses the following four objectives:

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 white pine blister rust infection rates and severity, mountain pine beetle activity, and fire.

Objective 4 - To assess and monitor recruitment of whitebark pine understory individuals (≤ 1.4 m tall) into the cone producing population.



ERIN SHANAHAN

Salt Range in Wyoming.

Study Area

The 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 hectares or greater within and outside of the grizzly bear recovery zone (RZ). A total of 10,770 mapped whitebark polygons or stands were identified in the

mapping process with 2,362 located within the RZ and 8,408 located outside of the RZ. Stands within the RZ were derived from the cumulative effects model for grizzly bears while outside the RZ, the sample frame includes whitebark stands mapped by each of the six separate USFS units (Dixon 1997, pers. com. L. Landenburger, 2012). Areas that burned between 1971 and 2002 were excluded from the sample frame.

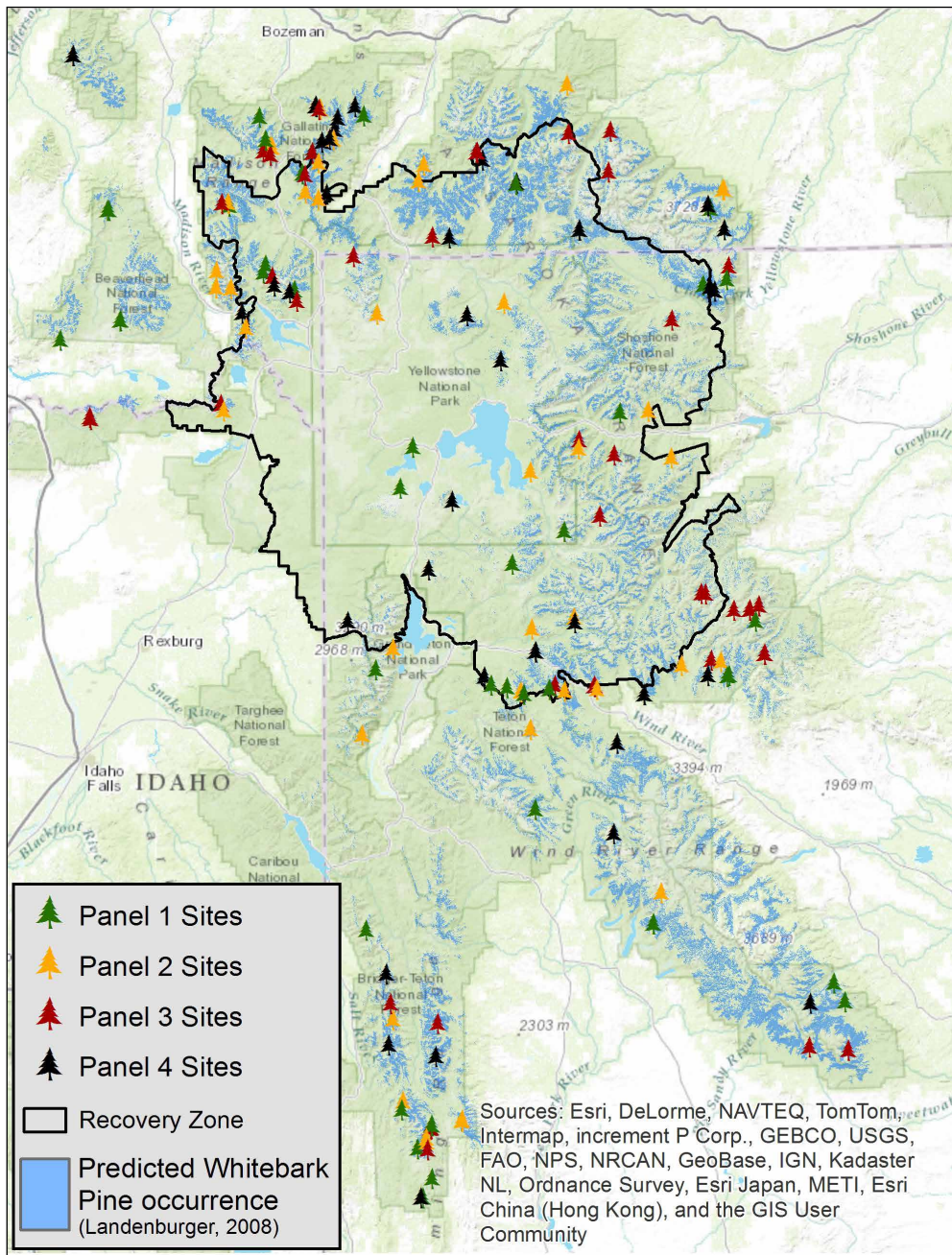
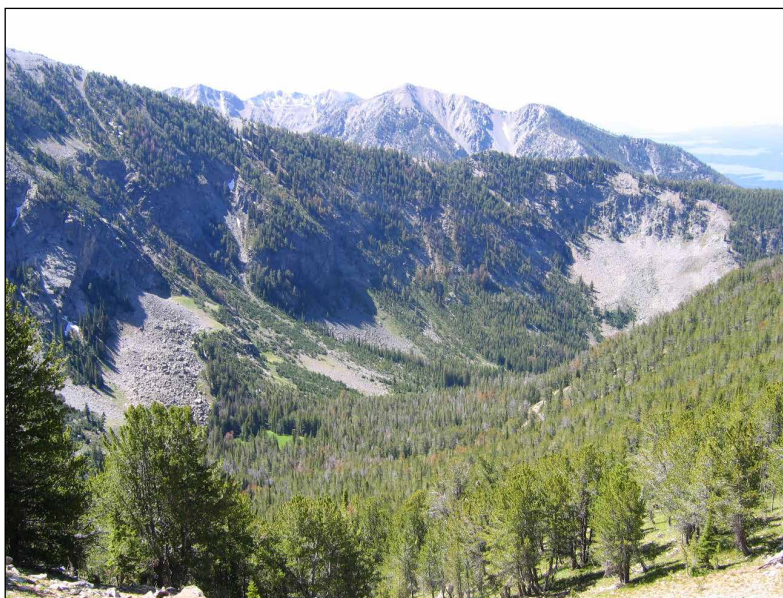
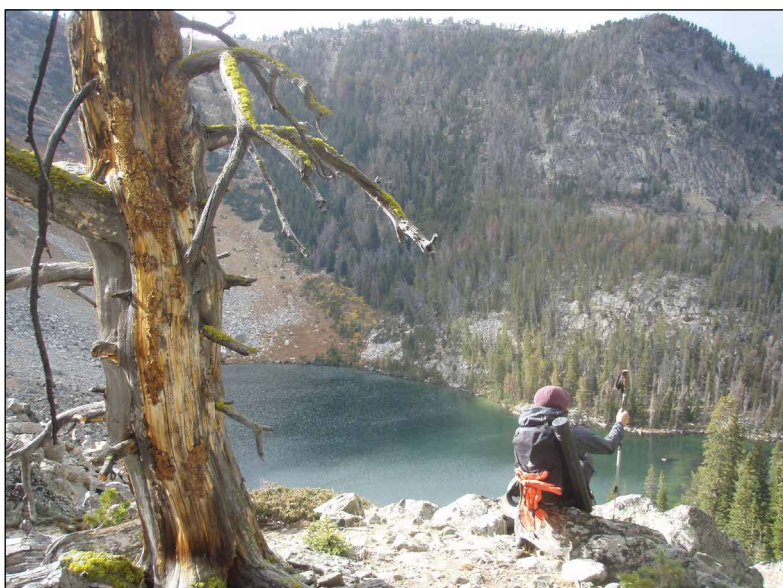


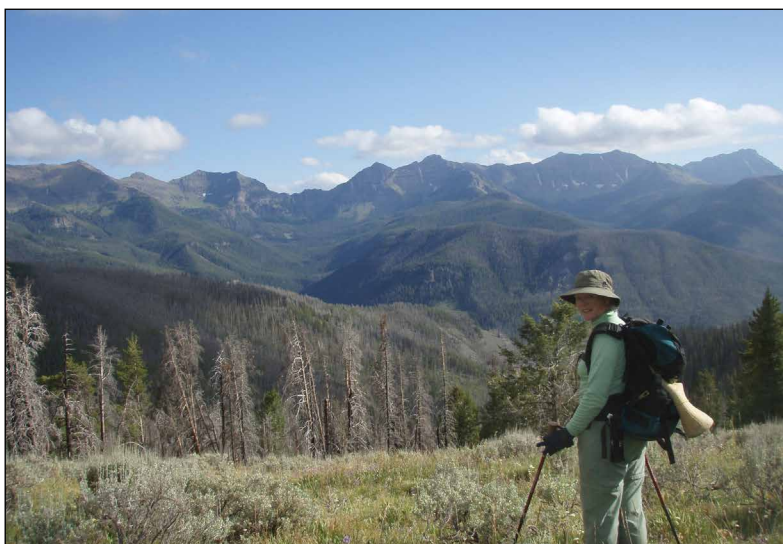
Figure 1. Location of whitebark pine survey transects, Greater Yellowstone Ecosystem.



JOHN POTTERGILL



ERIN SHAMAHAN



ERIN SHAMAHAN

Photos from top: Gallatin Range, Hidden Lakes, Absaroka Range from Pyramid Mountain to Mill Creek—all on the Gallatin National Forest.

Methods

Details of the sampling design and field methodology can be found in the Interagency Whitebark Pine Monitoring Protocol for the GYE (GYWPMWG 2011b) and in past program reports (GYWPMWG 2005, 2006, 2007, 2008, 2009, 2010, 2011a, and 2012). The basic approach is a two-stage cluster design in which stands of whitebark pine are the primary units, and 10x50 meter transects within stands are the secondary units. 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 all individual whitebark pine trees >1.4 m tall were permanently marked in order to estimate changes in white pine blister rust infection and survival rates over an extended period. The sample of 176 transects is a probabilistic sample that provides statistical inference to the GYE.

In 2008, individual transects were randomly assigned to one of four panels; each panel consists of approximately 44 transects. This is the number of transects that can be realistically visited in a given field season by a two-person field crew. Sampling every four years is sufficient to detect change in blister rust infection; however, sites in each panel were surveyed every other year from 2008 through 2012 to incorporate the dynamic nature of the current mountain pine beetle epidemic. These extra surveys focused solely on mountain pine beetle indicators

(Figure 2). Both surveys record tree status as live, dead, or recently dead.

Time-Step Assignment

In order to evaluate step-trends in white pine blister rust infection, infection transition, and overall mortality, every four-year revisit period has been classified as a time-step (T#) interval. Time-step 0 (T0) consists of the 176 transects established in the period from 2004 to 2007 and is considered the baseline. Time-step 1 (T1) is comprised of Panels 1 through 4 that were revisited between 2008 and 2011. Time-step 2 (T2) was initiated in 2012 and will be completed in 2015 once all four panels are revisited a second time (Figure 2).

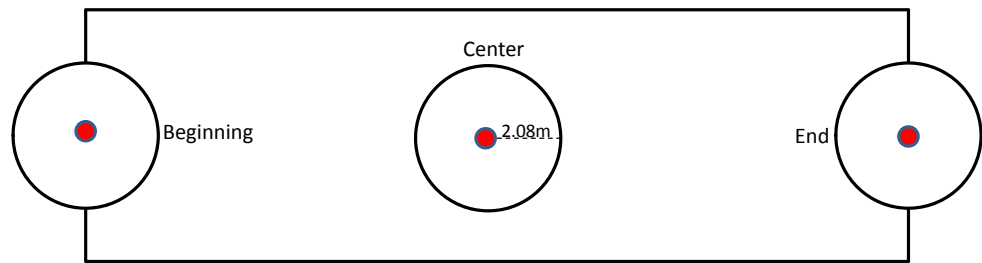
Full Survey: White Pine Blister Rust and Mountain Pine Beetle Surveys (BR&MPB)

During a full survey visit, the presence or absence of white pine blister rust infection is recorded for all live trees in the transect. A tree is 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 needed to be present (GYWPMWG 2011b). Ancillary indicators of white pine blister rust included flagging, rodent chewing, oozing sap, roughened bark, and swelling (Hoff 1992). For each

Survey Schedule		Time0	Time1				Time2				Continued Monitoring 2016 Forward
Sample Panel	Sites per panel	2004 thru 2007	2008	2009	2010	2011	2012	2013	2014	2015	
1	43	initial surveys for all 176 transects	BR & MPB		MPB only		BR & MPB				
2	45			BR & MPB		MPB only		BR & MPB			
3	44		MPB only		BR & MPB		MPB only		BR & MPB		
4	44			MPB only		BR & MPB		MPB only		BR & MPB	

Figure 2. Panel sampling revisit schedule that includes full surveys for blister rust (BR) and mountain pine beetle (MPB) and mountain pine beetle/mortality only surveys (MPB only). This table denotes the designated time series for each Time-Step assignment (Time0 [T0]: 2004-2007, Time1 [T1]: 2008-2011, Time2 [T2]: 2012-2015).

Figure 3. Recruitment plot layout within established whitebark pine monitoring transect where the red dots represents the beginning, center, and end monument spikes. The radius of the circular plot is 2.08 meters (1/300th acre).



live tree, observers record whether pitch tubes and frass are present from mountain pine beetle activity. Pitch tubes are small, popcorn-shaped resin masses produced by a tree as a means to stave off a mountain pine beetle attack. Frass or 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. A section of bark is removed from dead trees to observe and record whether J-shaped galleries exist, which indicate that adult mountain pine beetle and their larvae occupied the tree (GYWPMWG 2011b).

Mountain Pine Beetle Only/ Mortality Survey (MPB only)

For mountain pine beetle only/mortality surveys, data are collected on mountain pine beetle indicators and tree health status. As described above, each live tree is examined for pitch tubes and frass, while all dead trees are investigated for J-shaped galleries.

Recruitment and Understory Individuals

During a full survey visit, all whitebark pine trees ≤ 1.4 m tall on a given transect are counted and observed for white pine blister rust infection. Once a tree has reached a height greater than 1.4 m, it is permanently tagged and assessed in a manner consistent with all other live, marked trees in the sample frame.

In 2012, Objective 4 of the Interagency Whitebark Pine Monitoring Protocol was initiated to assess and monitor recruitment of whitebark pine understory individuals (≤ 1.4 m tall) at an enhanced level. This objective was designed and integrated into the established transect surveys as an effort to detect trends in the understory population of whitebark pine. We provide a general description of the methods for measuring recruitment in this report. These methods will be further expanded to include analysis methodology and peer review for inclusion in the protocol.

Three plots were partially nested within each of the 85 panel 1 and 3 transects surveyed in 2012. The three circular recruitment plots, each with a radius of 2.08 meters (1/300th acre), were placed such that the center of each circular plot corresponded to the beginning, center, and end monument reference points (Figure 3).

Plot Data Collection

Data are recorded for a variety of attributes for each plot. The date of survey, established monitoring transect ID, and observer names are recorded. Within each plot, all seedling/sapling trees ≤ 1.4 m tall are recorded and binned into categories according to species



Whitebark pine seedling.

Beginning Point	Tree Count by Size Class			
Species	10-49.9 cm	50-99.9 cm	100-140 cm	>140 cm
PIAL/PIFL (BR absent)				
PIAL/PIFL (BR present)				
PICO				
FIR				
SPRUCE				
Other (Specify)				
PIAL/PIFL Emergents (<10 cm) Present? (circle one) Yes / No	Limber Pine Present in Stand? Yes / No (circle one)			

Figure 4. Species and height-class bins as presented on field data sheet used to collect recruitment data on whitebark pine (PIAL) and limber pine (PIFL) in sub-plots of the established monitoring transects.

and height class (Figure 4). When cones are not present, positively discerning between whitebark pine and limber pine is extremely difficult. Due to this uncertainty, any ≤ 1.4 m tall five-needle seedlings/saplings that are located within the plot are placed in a whitebark pine/limber pine species bin. All five-needle seedlings/saplings are examined for evidence of white pine blister rust following the protocol (GYWPMWG 2011b). Any whitebark pine/limber pine <10 cm tall (characterized as “emergent”) are noted as present on the plot. In addition, the presence of positively identified limber pine anywhere in the stand is documented.

A tree or cluster of trees was included in a plot survey so long as the middle of the trunk or cluster of trunks, at ground level, was within 2.08 m from the center of the plot.

Additional Plot Attributes

In addition to seedling/sapling counts, other plot characteristics are recorded. For overstory density estimation, a handheld densiometer is used to evaluate canopy cover at each plot. Visual estimation of percent bare ground/litter cover, dominant vegetative species or group (i.e. forb, graminoid, shrub) within or overhanging the circular plot is estimated using cover-class bins (Daubenmire 1959; Table 1). A value for each of the cover categories is recorded following this bin system.

Data Management

All field observations and measurements are recorded on paper and then entered in a Microsoft Access database. Quality assurance and quality control (QA/QC) procedures include data value domain enforcement during data entry, checking

Table 1. Daubenmire cover classes for estimating percent cover of plot characteristics (Daubenmire 1959).

Cover-Class Bin	Percent Cover
1	0-5%
2	6-25%
3	26-50%
4	51-75%
5	76-95%
6	96-100%

for missing values, and logic checks. All geospatial data for the project are stored in ESRI GIS file formats on GRYN servers.

Following the detailed interagency whitebark pine monitoring protocol minimizes errors during fieldwork and in data management, analysis, and reporting. However, complex and variable operating conditions can cause a generally insignificant amount (typically <1%) of variability when comparing data between reporting periods. Maintaining a highly structured, complex data set is

an ongoing process needed to ensure quality data management, both during data collection and in the office. Additional factors responsible for slightly different summary values among reports include retroactive updates to the master database when previously undiscovered issues are corrected, and potential inconsistencies with the complex data processing criteria and logic required to summarize parameter values for an accumulating and multivariate data set.



ERIN SHANAHAN

Whitebark pine monitoring crew on Table Mountain in the Centennial Range of Idaho.

Results

Time-step Considerations for Whitebark Pine Health and Status

Status and trend assessments are more meaningful after many years of monitoring as comparable data accumulate over time (Witwicki 2012). For the Whitebark Pine Monitoring Program, more intensive evaluation of monitoring data is scheduled at four-year intervals after all 176 transects are resurveyed. Comparisons between years based on a single panel revisit are misleading, because each panel is comprised of an entirely different set of transects. Data summaries from transects surveyed in 2012 (Panels 1 and 3) do not reflect the entire sample of transects, and therefore, do not represent the estimated status or long-term trend of the overall GYE population of whitebark pine. The reader is cautioned not to draw wide-reaching conclusions from the summary of data collected in 2012.

Monitored Transects

In 2012, 85 transects were resurveyed between June and September from Panels 1 and 3 by a two-person crew led by the GRYN and another two-person crew led by the USGS Interagency Grizzly Bear Study Team (IGBST). This marks the second revisit to Panel 1 in our time-step series (first

panel resurveyed in T2) for full survey data collection (BR and mortality), and the third revisit to Panel 3 for MPB only/mortality.

White Pine Blister Rust Infection in the GYE

Based on the ratio estimator derived from the live trees remaining at the end of T1 on Panels 1 through 4, our results indicate that the proportion of trees infected with BR in the GYE ranges between 20% to 30% (Shanahan et al. in prep).

White Pine Blister Rust Infection on Panel 1

Approximately 885 live tagged trees in 43 transects from Panel 1 were examined for BR infection in 2012. This number includes the new trees added during the 2012 survey to Panel 1. Results from a paired Student t-test comparing the proportion of trees infected with BR on a transect level for Panel 1 between 2008 and 2012 revealed no significant evidence of a change in the percent of live trees ≥ 1.4 m tall infected with BR (paired t-test $df=42$, $P\text{-value}=0.08$, 95% CI for difference of proportion initial to revisit -13% to 0.7%) (Figure 5).

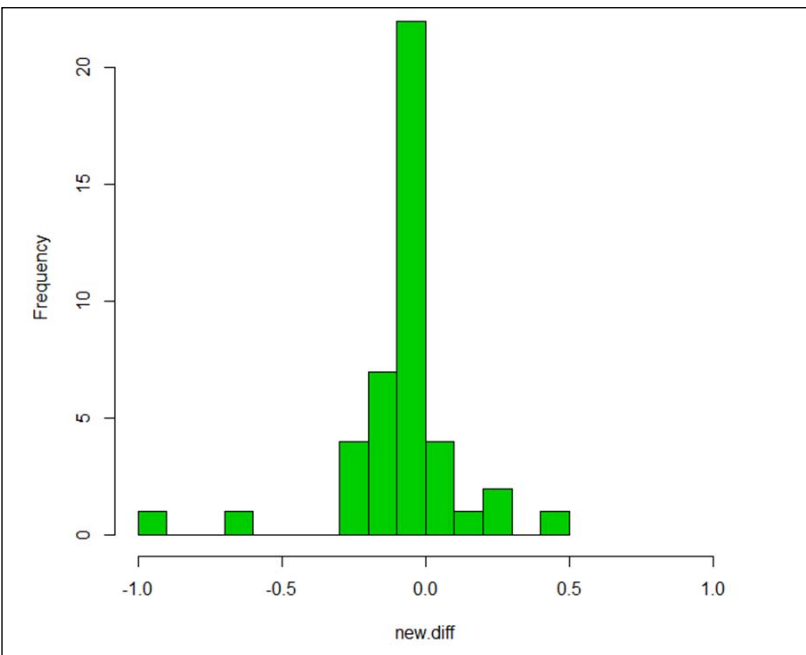


Figure 5. The chart to the left shows the difference in proportion of infection from Panel 1 in Timestep 0 (T0) to Timestep 1 (T1). The change in the proportion of trees infected on Panel 1 transects from 2008 and 2012 is normally distributed.

Infection Transition

Of the 807 trees that were surveyed in Panel 1 transects in 2008 and again in 2012, approximately 66% (531) had no evidence of blister rust infection, 19% (155) were infected in both years, 7% (59) transitioned from no evidence of infection to infected, and 8% (62) went from infected to uninfected (Figure 6). A transition from infected to uninfected could be the result of factors such as observer error, an earlier-documented infection based on indicators that upon resurvey no longer meets the established standards of three indicators in the same location, or infected branches that broke and fell off.

Mortality on Panels 1 and 3

In 2012, we observed a total of 1,801 live tagged trees and 156 newly dead tagged trees from Panels 1 and 3. Of the 156 dead trees, 69% or 108 trees occurred in the >10-30 cm size class with approximately 56% of those having evidence only of mountain pine beetle infestation. The remaining 44% of the >10-30 cm size class died with signs of fire; BR; a combination of fire, MPB, and/or BR; or with other factors, such as wind damage, animal damage, or unknown (Figure 7).

Figure 6. Blister rust infection transition among live tagged trees on Panel 1 transects in 2008 and again in 2012.

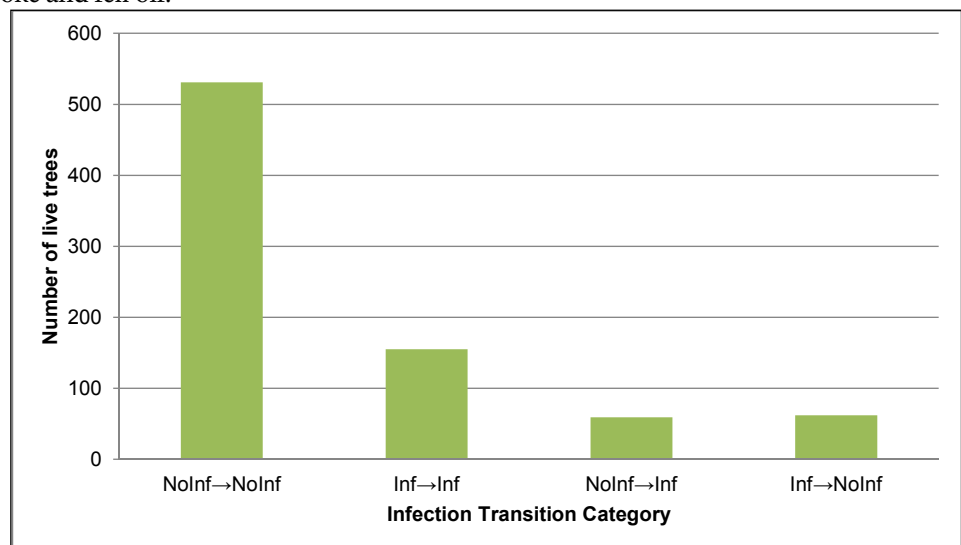
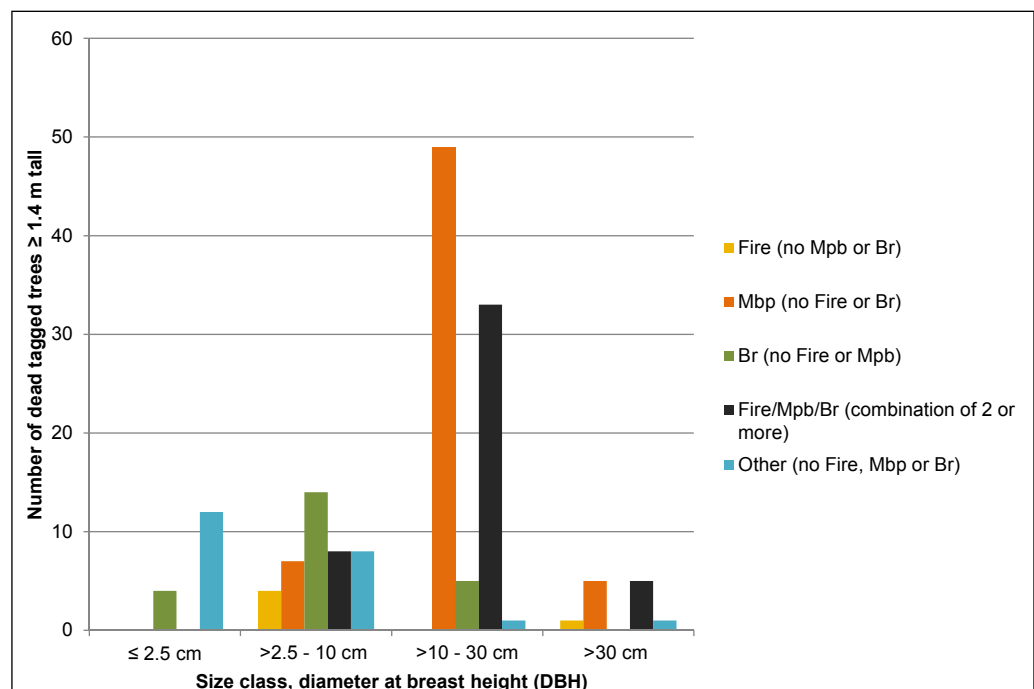


Figure 7. Mortality of 156 tagged trees in Panels 1 and 3 with observed health status indicators such as fire, MPB, BR, a combination of factors, or other factors by size class.



Recruitment of Whitebark Pine into the Sample Frame

While transects are experiencing varying degrees of mortality, they are also experiencing varying degrees of recruitment. Once a whitebark pine tree within the transect boundary reaches a height >1.4 m tall, it is permanently tagged and included in the live tree sample. In 2012, we tagged a total of 85 new trees (42 on Panel 1 and 43 on Panel 3).

Recruitment Plots

A total of 255 recruitment plots (three per transect) were completed on Panels 1 and 3. Comparisons of changes in recruitment between time-step intervals will be assessed at the end of T3 (2019).



Comparing Living Trees from Baseline (T0) to Most Recent (2011 and 2012)

To determine whitebark pine survival, we resurvey all transects to record the status of permanently tagged trees >1.4 m tall. Figure 8 represents all living tagged trees since 2008 greater than 1.4 m tall up to the most recent surveys conducted (2011: Panels 2 and 4 and 2012: Panels 1 and 3). The majority of trees that have been added to the sample frame fall within the ≤ 2.5 cm DBH size class; this cohort has experienced a net increase of roughly 25%.

The snapshot of living whitebark pine trees by DBH group shows that while there has been an overall decline in the number of live trees, the number of smaller-DBH live trees grew during the period, and the larger-DBH trees experienced the most mortality. Based on monitoring observations, trees ≤ 2.5 cm DBH can reproduce; it will be informative to track how this metric changes as more data are collected in future years, particularly as the mountain pine beetle outbreak wanes.

Clump of whitebark pine emergents.

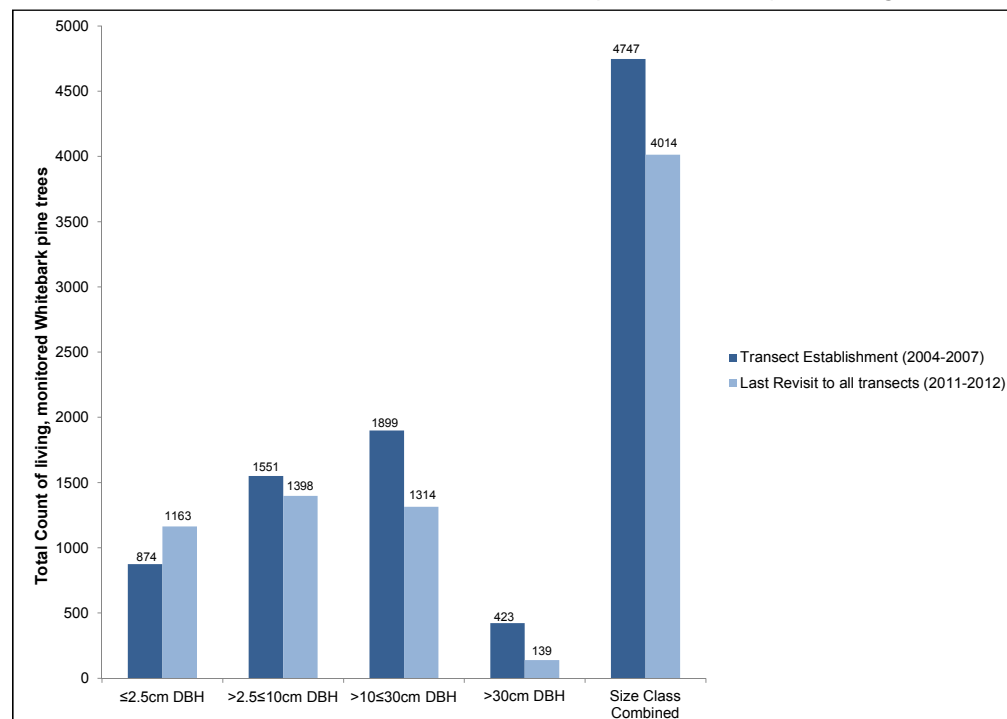


Figure 8. A comparison of counts of living whitebark pine trees in the Greater Yellowstone Ecosystem by DBH groups between two time periods (transect establishment in 2004-2007, dark blue and most recent revisit surveys in 2011-2012, light blue).



Following a successful attack, the canopy of an infested whitebark pine rapidly starts to fade from green to red (upper photo). Mountain pine beetle enter host trees through the bark; and as a defense mechanism, the infested tree will attempt to pitch out the beetle resulting in a pitch tube (lower left). Beetles feed in galleries under the bark of the host tree (below right).



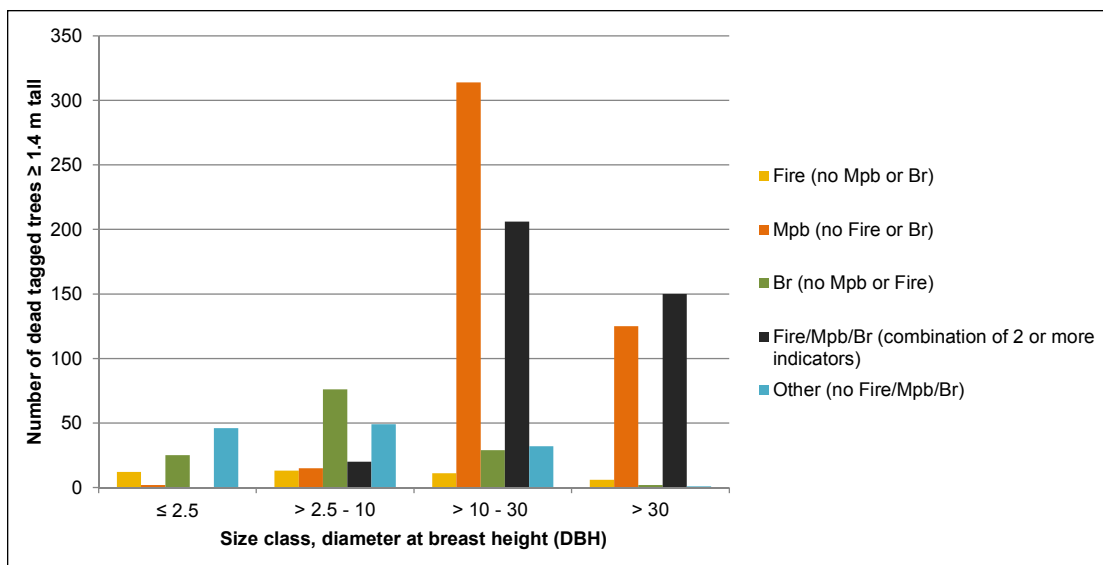
Health Status Indicators at Time of Death

As of 2012, approximately 1,134 tagged trees have died since transect establishment. Figure 9 presents health status indicators (fire, mountain pine beetle, white pine blister rust, a combination of the three, or other) that were recorded for each dead tagged tree by DBH size class (<2.5 cm, >2.5-10 cm, >10-30 cm, and >30 cm).

Presence of Mountain Pine Beetle

Trees in high-elevation forests across the GYE are experiencing elevated mortality as

a result of the current mountain pine beetle epidemic. Mountain pine beetle primarily attack whitebark pine trees that are 10 cm and greater DBH. Trees that are equal to or less than 10 cm DBH are typically not large enough to successfully support mountain pine beetle brood (Amman et al. 1977); consistent with this observation, tree mortality observed in transects was much greater in trees >10 cm DBH (Figure 9). Of the 1,134 tagged trees that have died since T0, approximately 788 (69%) have exhibited evidence of MPB. We found that 96% (n=756) of these infested trees were >10 cm DBH, while only 4% (n=32) were ≤10 cm.



ERIN SHANAHAN

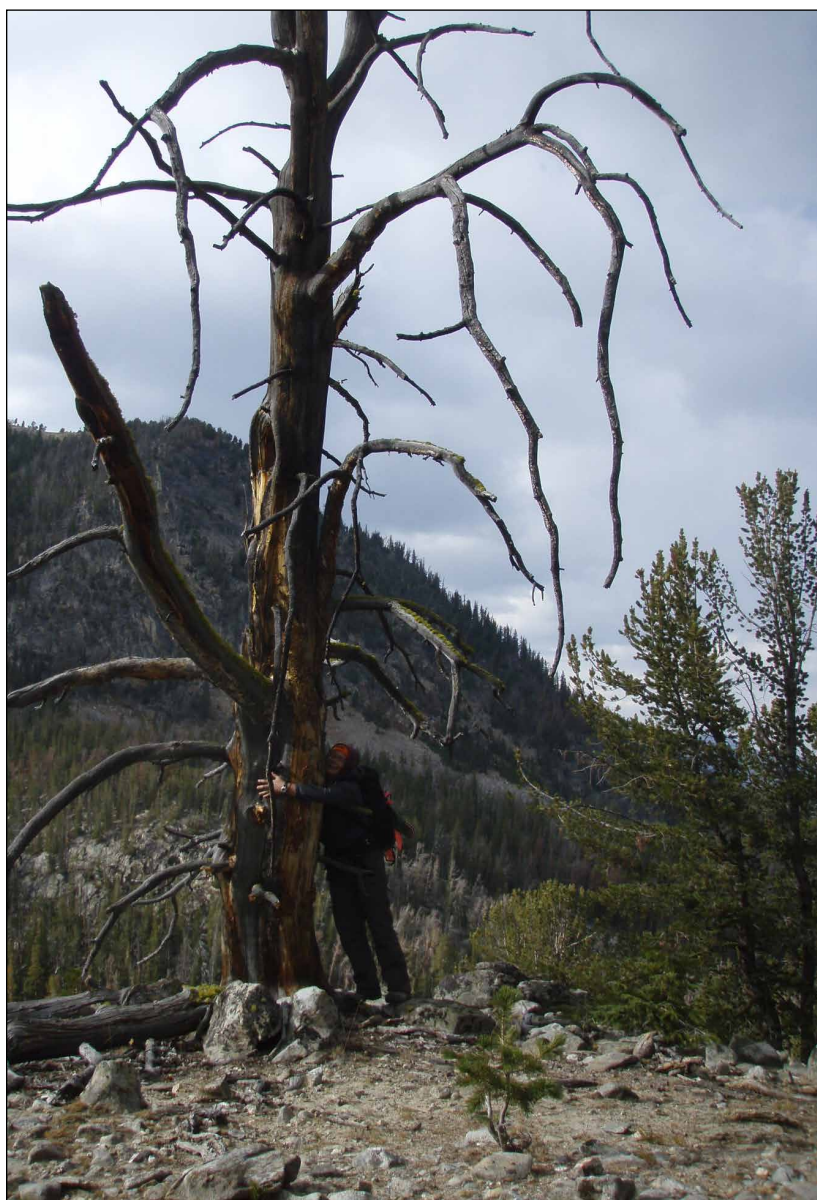


Figure 9. Mortality of tagged trees from 2008 through 2012 with associated potential causes of mortality. Evidence of fire, mountain pine beetle [Mpb], white pine blister rust [Br], a combination of the three, or other were recorded for each dead tagged tree by DBH size class (≤2.5 cm, >2.5-10 cm, >10-30 cm, and >30 cm).

As a result of their deep and sturdy roots, whitebark pine snags, often referred to as ghost trees, remain an iconic fixture on the landscape for decades.

Similar to white pine blister rust infection, the mountain pine beetle infestation is widespread and varies in severity throughout the GYE. Of the 176 established transects,

123 have recorded evidence of mountain pine beetle infestation while 53 have no observed evidence of mountain pine beetle infestation by the end of 2012 (Figure 10).

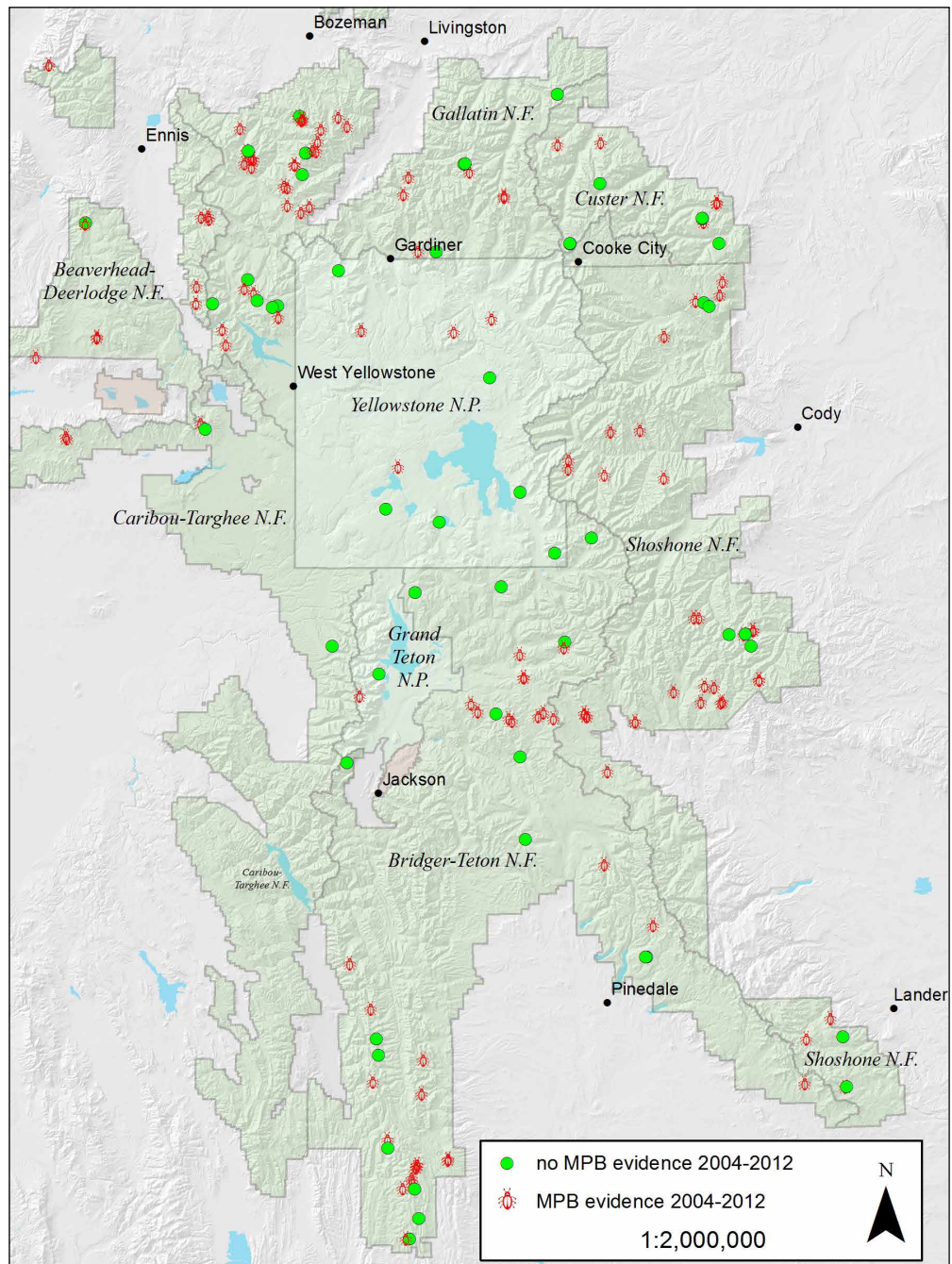


Figure 10. Location of transects throughout the Greater Yellowstone Ecosystem with and without evidence of mountain pine beetle infestation as of 2012.

Discussion

White pine blister rust infection remains widespread and variable across the ecosystem. Our proportional estimate of a 20% to 30% infection rate for the GYE reflects the geographical differences that exist throughout the sample frame (Figure 11). Preliminary analysis showed that blister rust infection in Panel 1 transects remained relatively stable with no indication of significant increases or decreases between the 2008 and 2012 surveys. Our data suggest that the rate of mortality of tagged trees

has decreased in the transects compared to mortality levels from previous years. These findings lend support to a waning MPB outbreak as articulated by other federal agencies and private entities (Hayes 2013, Olliff et al. 2013).

Following the panel revisit schedule, both Panels 2 and 4 are scheduled for resurvey in 2013. In a deviation from the monitoring schedule, crews will conduct full survey visits on both panels during the 2013 season

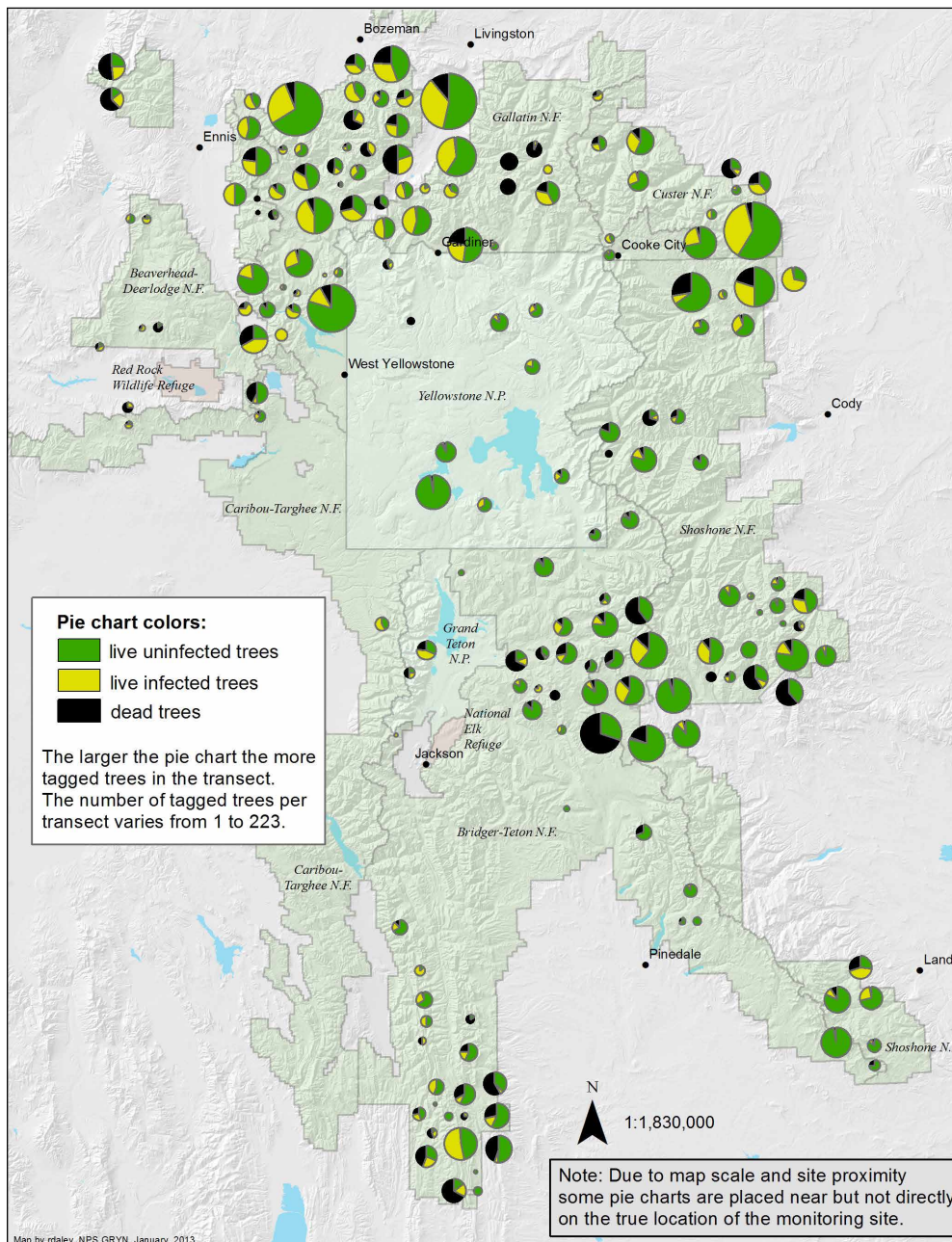


Figure 11. Preliminary map of the ratio of whitebark pine trees within each transect as alive, dead or with the presence of blister rust infection from surveys 2009-2012. The infection status ranges from a tree with a single canker on a branch to a tree with a bole canker.

in order to help determine if the established 4-year revisit interval sufficiently captures blister rust infection spread and transition. We will continue to collect data on Objective 4 of the protocol to assess and monitor the recruitment of whitebark pine understory individuals. A step-trend analysis of data collected between 2004 and 2011 will be completed (Irvine et al. in prep, Shanahan et al. in prep). In addition, we will establish whitebark pine monitoring transects on BLM lands in Wyoming following the Interagency Whitebark Pine Monitoring Protocol (GYWBPMG 2011b). And finally, we will continue to collaborate with other research endeavors that are taking place in the ecosystem as well as participate on

the Greater Yellowstone Coordinating Committee Whitebark Pine Subcommittee.

This long-term monitoring program provides critical information that will help determine the likelihood of whitebark pine persisting as a functional and vital part of the ecosystem. In addition, data from this program are currently being used to inform managers, guide management strategies and restoration planning, and substantiate conservation efforts throughout the GYE. The interagency protocol has also been a valuable resource for a variety of agencies embarking on five-needle pine monitoring including the Greater Yellowstone Coordinating Committee's Whitebark Pine Strategy for the Greater Yellowstone Area (GYCCWPS 2011).

RACHEL FEIGLEY



Continued monitoring will be critical to increase our understanding of whitebark pine and limber pine mortality and recruitment in the Greater Yellowstone Ecosystem.

Literature Cited

- Ammen, G. D., M. D. McGregor, D. B. Cahill, and W. H. Klein. 1977. Guidelines for reducing losses of lodgepole pine to the mountain pine beetle in unmanaged stands in the Rocky Mountains. USDA For. Serv. Gen. Tech. Rep. INT-36, 19 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.
- Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. *Northwest Sci.* 33:43-64.
- Dixon, B. G. 1997. Cumulative effects modeling for grizzly bears in the Greater Yellowstone Ecosystem. Thesis Montana State University. 143 pages plus appendices. Bozeman, Montana.
- Ellison, A. E., M. S. Banks, B. D. Clinton, E. A. Colburn, K. Elliott, C. R. Ford, D. R. Foster, B. D. Kloeppel, J. D. Knoepp, G. M. Lovett, J. Mohan, D. A. Orwig, N. L. Rodenhouse, W. V. Sobczak, K. A. Stinson, J. K. Stone, C. M. Swan, J. Thompson, B. Von Holle, and J. R. Webster. 2005. Loss of foundation species: Consequences for the structure and dynamics of forested ecosystems. *Frontiers in Ecology and the Environment* 39:479-486.
- Greater Yellowstone Whitebark Pine Monitoring Working Group (GYWPMWG). 2012. Monitoring whitebark pine in the Greater Yellowstone ecosystem: 2011 annual report. Natural Resource Data Series NPS/GRYN/NRDS—2012/278. National Park Service, Fort Collins, Colorado.
- Greater Yellowstone Whitebark Pine Monitoring Working Group (GYWPMWG). 2011a. Monitoring whitebark pine in the Greater Yellowstone Ecosystem: 2010 annual report. pages 56-65 in C. C. Schwartz, M. A. Haroldson, and K. West, editors. Yellowstone grizzly bear investigations: Annual report of the Interagency Grizzly Bear Study Team, 2009. U.S. Geological Survey, Bozeman, Montana.
- Greater Yellowstone Whitebark Pine Monitoring Working Group (GYWPMWG). 2011b. Interagency whitebark pine monitoring protocol for the Greater Yellowstone Ecosystem, version 1.1. Greater Yellowstone Coordinating Committee, Bozeman, Montana.
- Greater Yellowstone Whitebark Pine Monitoring Working Group (GYWPMWG). 2010. Monitoring whitebark pine in the Greater Yellowstone Ecosystem: 2009 annual report. pages 56-65 in C. C. Schwartz, M. A. Haroldson, and K. West, editors. Yellowstone grizzly bear investigations: Annual report of the Interagency Grizzly Bear Study Team, 2009. U.S. Geological Survey, Bozeman, Montana.
- Greater Yellowstone Whitebark Pine Monitoring Working Group (GYWPMWG). 2009. Monitoring whitebark pine in the Greater Yellowstone Ecosystem: 2008 annual report. pages 62-68 in C. C. Schwartz, M. A. Haroldson, and K. West, editors. Yellowstone grizzly bear investigations: Annual report of the Interagency Grizzly Bear Study Team, 2008. U.S. Geological Survey, Bozeman, Montana.
- Greater Yellowstone Whitebark Pine Monitoring Working Group (GYWPMWG). 2008. Monitoring whitebark pine in the Greater Yellowstone Ecosystem: 2007 annual report. pages 50-56 in C. C. Schwartz, M. A. Haroldson, and K. West, editors. Yellowstone grizzly bear investigations: Annual report of the Interagency Grizzly Bear Study Team, 2007. U.S. Geological Survey, Bozeman, Montana.
- Greater Yellowstone Whitebark Pine Monitoring Working Group (GYWPMWG). 2007. Monitoring whitebark pine in the Greater Yellowstone Ecosystem: 2006 annual report. pages 46-54 in C. C. Schwartz, M. A. Haroldson, and K. West, editors. Yellowstone grizzly bear investigations: Annual report of the Interagency Grizzly

- Bear Study Team, 2006. U.S. Geological Survey, Bozeman, Montana.
- Greater Yellowstone Whitebark Pine Monitoring Working Group (GYWPMWG). 2006. Monitoring whitebark pine in the Greater Yellowstone Ecosystem: 2005 annual report. pages 73-80 in C. C. Schwartz, M. A. Haroldson, and K. West, editors. Yellowstone grizzly bear investigations: Annual report of the Interagency Grizzly Bear Study Team, 2005. U.S. Geological Survey, Bozeman, Montana.
- Greater Yellowstone Whitebark Pine Monitoring Working Group (GYWPMWG). 2005. Interagency whitebark pine health monitoring program for the Greater Yellowstone Ecosystem, 2004 annual report. pages 92-125 in C. C. Schwartz, M. A. Haroldson, and K. West, editors. Yellowstone grizzly bear investigations: Annual report of the Interagency Grizzly Bear Study Team, 2004. U.S. Geological Survey, Bozeman, Montana.
- Greater Yellowstone Coordinating Committee Whitebark Pine Subcommittee (GYCCWPS). 2011. Whitebark pine strategy for the Greater Yellowstone Area. Greater Yellowstone Coordinating Committee. Bozeman, Montana.
- Hayes, C. 2013. Montana: forest insect and disease conditions and program highlights-2012. Report 13-02. USDA Forest Service, Forest Health Protection, Missoula, Montana.
- Hoff, R. J. 1992. How to recognize blister rust infection on whitebark pine. USDA Forest Service, Intermountain Research Station, Research Note INT-406, Ogden, Utah.
- Irvine, K. M., C. Holliman, E. K. Shanahan, and K. L. Legg. In prep. Conservation implications for synergistic effect of an introduced pathogen and native bark beetle on whitebark pine mortality.
- Landenburger, L., R. L. Lawrence, S. Podruzny, and C. C. Schwartz. 2008. Mapping regional distribution of a single tree species: Whitebark pine in the Greater Yellowstone Ecosystem. *Sensors* 8(8):4983-4994.
- Logan, J. A., W. W. Macfarlane, and L. Willcox. 2010. Whitebark pine vulnerability to climate-driven mountain pine beetle disturbance in the Greater Yellowstone Ecosystem. *Ecological Applications* 20:895-902.
- McKinney, S. T., T. Rodhouse, L. Chow, A. Chung-MacCoubrey, G. Dicus, L. Garrett, K. Irvine, S. Mohren, D. Odion, D. Sarr, and L. A. Starceovich. 2013. Monitoring white pine (*Pinus albicaulis*, *P. balfouriana*, *P. flexilis*) community dynamics in the Pacific West Region: Klamath, Sierra Nevada, and Upper Columbia Basin Networks. Narrative version 1.1. Unpublished protocol revision update, April 2013.
- Olliff, S. T., R. A. Renkin, D. P. Reinhart, K. A. Legg, E. M. Wellington. 2013. Exotic fungus acts with natural disturbance agents to alter whitebark pine communities. pages 236-251 in P. J. White, R. A. Garrott, and G. E. Plumb, eds. Yellowstone's wildlife in transition. Harvard University Press, Cambridge, Massachusetts.
- Shanahan, E. K., K. Irvine, C. Holliman, K. L. Legg. In prep. Health and status of whitebark pine in the Greater Yellowstone Ecosystem: A trend analysis from 2004-2007 and 2008-2011.
- Tomback, D. F. and K. C. Kendall. 2001. Biodiversity losses: The downward spiral. pages 243-262 in D. F. Tomback, S. F. Arno, and R. E. Keane, eds. Whitebark pine communities: Ecology and restoration. Island Press, Washington, D.C.
- U.S. Fish and Wildlife Service (USFWS). 2011. Listing of whitebark pine ruling at: <http://www.fws.gov/mountain-prairie/species/plants/whitebarkpine>
- Witwicki, D. 2012. Integrated upland monitoring in Black Canyon of the Gunnison National Park and Curecanti National Recreation Area: annual report 2010 (non-sensitive version). Natural Resource Technical Report NPS/NCPN/NRTR—2012/542. National Park Service, Fort Collins, Colorado.