



Monitoring Whitebark Pine in the Greater Yellowstone Ecosystem

2019 Annual Report

Natural Resource Data Series NPS/GRYN/NRDS—2020/1273





ON THIS PAGE

Monitoring crew at work along a whitebark transect, Custer Gallatin National Forest, Montana.
NPS/KYLE MARVINNEY, 2019.

ON THE COVER

Whitebark pine stand in the Basin Creek area of the Beartooth Mountains, Custer Gallatin National Forest, Montana.
NPS/KYLE MARVINNEY, 2019.

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are 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.

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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.

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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 plays 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 cones with wingless seeds and relies primarily on birds for seed dispersal.

In mixed and dominant stands, whitebark pine occurs in over two million acres within the five national forests, three national parks, and Wyoming Bureau of Land Management lands that make up 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 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 2019 on Panel 4 of the four total sample panels (Panels 1 through 4) and marks the sixteenth year of monitoring.

Acknowledgments

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List of Acronyms

WY-BLM:	Wyoming Bureau of Land Management
DBH:	diameter at breast height
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
MSU:	Montana State University
NPS:	National Park Service
RZ:	Recovery Zone (grizzly bear)
USFS:	United States Forest Service
USGS:	United States Geological Survey

Introduction

High-elevation forests of the American West have experienced significant changes in composition and structure over the past 50 years (Logan et al. 2009, Westerling et al. 2011; Keane et al. 2012). An iconic species of these subalpine forests is whitebark pine (*Pinus albicaulis*), a five-needle conifer that, in addition to performing multiple, critical ecological functions, holds a distinct aesthetic value in these mountainous environments. A changing climate has enabled native pests, such as mountain pine beetle (*Dendroctonus ponderosae*), to reach epidemic proportions in whitebark pine forests where historically beetles have had only a minor presence (Logan et al. 2009). Consequently, widespread infestations of mountain pine beetle in these high elevation stands have resulted in the mortality of expansive swaths of whitebark pine (Logan et al. 2009). Furthermore, introduced pathogens, such as white pine blister rust (*Cronartium ribicola*; blister rust), have proliferated throughout the region where they can impact whitebark pine cone production and damage young trees (Tomback et al. 1995). In the last century, blister rust has resulted in significant whitebark pine mortality in the Pacific Northwest and parts of the northern Rockies, including Glacier National Park (Arno 1986).

In concert, these two stressors have shifted the assemblage of whitebark pine forests to smaller sized trees and threaten whitebark pine reproduction and overall survival (Shanahan et al. 2016). In addition, fire regimes, which have historically been important for whitebark pine persistence, are changing where winter snowpack melts earlier and faster due to increasing temperatures (Westerling et al. 2011). In consideration of whitebark pine's ecological importance and the multiple agents that threaten its perseverance, it was designated as a candidate species for protection under the Endangered Species Act in 2011, with continuation of candidate status in 2016 (USFWS 2016). Long-term monitoring of whitebark pine as a vital sign in the Greater Yellowstone Ecosystem (GYE) is essential for understanding contemporary trends in insect, disease, and regeneration in order to help guide management decisions and actions into the future.

This annual report provides a summary of the data collected in 2019 as part of the long-term Interagency Whitebark Pine Monitoring Program for the GYE.

Interagency Whitebark Pine Monitoring Program

Under the auspices of the Greater Yellowstone Coordinating

Committee (GYCC), the National Park Service (NPS) Inventory and Monitoring Division, and several other agencies, a collaborative, long-term monitoring program was initiated to track and document the health 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 (USFS), NPS, U.S. Geological Survey (USGS), Bureau of Land Management (BLM), and Montana State University (MSU).

A protocol for monitoring the health 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* was approved in 2007 and updated in 2011 (GYWPMWG 2011). The complete protocol is available at:

<https://www.nps.gov/im/gryn/whitebark-pine.htm>

Time-step Considerations for Whitebark Pine Health and Status

Status and trend assessments are more meaningful after many years of monitoring with comparable data accumulated 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 (divided into four annual panels) are resurveyed. Comparisons between years based on a single panel are misleading because each panel is composed of an entirely different set of transects. Data summaries from transects surveyed in 2019 (Panel 4) 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 solely from the summary of data collected in 2019.

Monitoring Objectives

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

Specifically, the interagency whitebark pine monitoring protocol (GYWPMWG 2011) addresses the following four objectives:

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

Objective 2 - Within infected transects, determine the relative severity of infection in whitebark pine trees >1.4 m tall (as indicated by canker location) and estimate the change in severity over time.

Objective 3 - 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, and fire.

Objective 4 - Assess and estimate survival rates of understory whitebark pine ≤ 1.4 m tall as influenced by overall species composition and species density; determine the proportion of trees ≤ 1.4 m tall infected with blister rust; and estimate the rate at which infection of trees is changing over time.

Study Area

The GYE study area includes five national forests and three national parks (throughout the rest of this report the John D. Rockefeller Jr. Memorial Parkway is included as part of Grand Teton National Park), and Wyoming Bureau of Land Management (WY-BLM) lands (Figure 1). The target population is all whitebark pine trees in the GYE. The sample frame includes stands of whitebark pine approximately 2.0 ha or greater within and outside of the grizzly bear recovery zone (RZ). A total of 10,770 mapped whitebark pine

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 five separate USFS units (Dixon 1997; pers. comm. with L. Landenburger, Grizzly Bear GIS Database Coordinator, 2012). Areas that burned after 1970 were excluded from the sample frame.

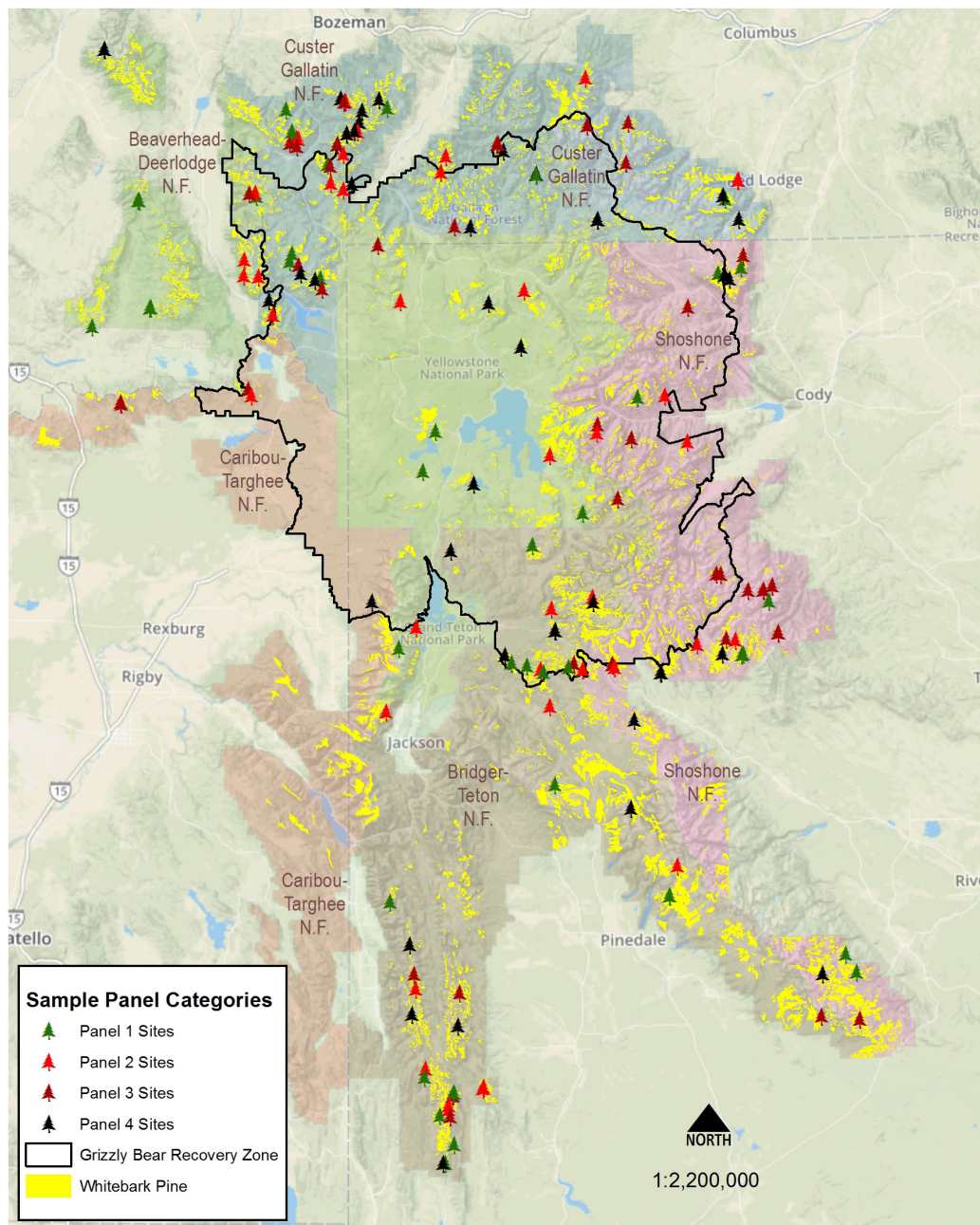


Figure 1. Location of whitebark pine survey transects within the Greater Yellowstone Ecosystem. This map does not depict Wyoming Bureau of Land Management study areas due to scaling limitations

Methods

Details of the sampling design and field methodology can be found in the *Interagency Whitebark Pine Monitoring Protocol for the Greater Yellowstone Ecosystem* (GYWPMWG 2011) and in the 2007 and 2011 annual reports (GYWPMWG 2008, 2012). The basic approach is a two-stage cluster design in which stands of whitebark pine are the primary units, and 10 × 50 m 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 with a numbered tag in order to estimate changes in 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 (GYWPMWG 2011); however, sites in each panel were surveyed every other year from 2008 through 2013 to incorporate the dynamic nature of the recent mountain pine beetle epidemic. These extra surveys focused on mortality associated with mountain pine beetle indicators (Table 1). Both surveys record tree status as live, dead, or recently dead. In 2019, we completed a third full resurvey of all Panel 4 transects.

Time-step Assignment

In order to evaluate step-trends (i.e., overall change) in

blister rust infection, infection severity and transition, and overall mortality, every four-year visit period is classified as a time-step (T#) interval. Time-step 1 (T1) consists of the 176 transects established in the period from 2004 to 2007 and is considered the baseline. Time-step 2 (T2) is composed of Panels 1 through 4 that were revisited between 2008 and 2011. Time-step 3 (T3) was initiated in 2012 and was completed in 2015 following successful revisits to all four panels. Time-step 4 (T4) was begun in 2016 and completed in September 2019 (Table 1). A fifth time step (T5) will begin with revisiting Panel 1 in 2020.

Full Survey: White Pine Blister Rust and Mortality Surveys

During a full survey visit, the presence or absence of blister rust infection is recorded for all live trees on the 50-meter belt transect. A tree is considered infected if either aecia or cankers are present. For a canker to be conclusively identified as resulting from blister rust, at least three of five ancillary indicators need to be present (GYWPMWG 2011). Ancillary indicators of blister rust included flagging, rodent chewing, oozing sap, roughened bark, and swelling (Hoff 1992). To document the severity of infection, the location of blister rust canker is recorded as occurring in the canopy or on the bole of an infected tree.

For each 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

Table 1. Panel sampling revisit schedule that includes full surveys of whitebark pine for blister rust and mortality and for mortality only surveys. This table denotes the designated time series for each time-step assignment (Time Step 1: 2004–2007, Time Step 2: 2008–2011, Time Step 3: 2012–2015, Time Step 4: 2016–2019).

Sample Panel (transects per panel)	Time Step 1 (baseline)	Time Step 2				Time Step 3				Time Step 4			
	2004 thru 2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1 (43 transects)	Set up surveys; record initial health status	blister rust & mortality	–	mortality only	–	blister rust & mortality	–	–	–	blister rust & mortality	–	–	–
2 (45 transects)	Set up surveys; record initial health status	–	blister rust & mortality	–	mortality only	–	blister rust & mortality	–	–	–	blister rust & mortality	–	–
3 (44 transects)	Set up surveys; record initial health status	mortality only	–	blister rust & mortality	–	mortality only	–	blister rust & mortality	–	–	–	blister rust & mortality	–
4 (44 transects)	Set up surveys; record initial health status	–	mortality only	–	blister rust & mortality	–	mortality only	–	blister rust & mortality	–	–	–	blister rust & mortality



A whitebark pine monitoring transect on the Beaverhead-Deerlodge National Forest, Montana, with high whitebark mortality. Mountain pine beetle egg galleries are visible in the majority of dead trees. NPS/KYLE MARVINNEY, 2019

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 2011).

Recruitment and Understory Individuals

There are three indices of whitebark pine recruitment derived from the transect surveys: the number of trees ≤ 1.4 m tall, the number of trees that grow to >1.4 m tall, and the number of live tagged trees, regardless of height, that show signs of reproductive activity. During a full survey visit, all whitebark pine trees ≤ 1.4 m tall on a transect are counted and observed for blister rust infection. Once a tree has reached a height >1.4 m, it is permanently tagged and assessed in a manner consistent with all other live, marked trees in the sample frame. In addition, three nested circular plots at the beginning, center, and end of the transect (1/300th acre for each circle), are evaluated for the occurrence and infection status of whitebark pine ≤ 1.4 m tall and species composition (GYWPMWG 2012). Finally, all live, tagged trees are assessed for signs of past or present reproduction as evident by the presence of cones or cone scars.

Data Management

Prior to analysis, all data are subjected to rigorous quality assurance and quality control (QA/QC) procedures as outlined in the protocol (GYWPMWG 2011). Due to minor retroactive updates to the master database as part of ongoing quality controls, there may be an insignificant amount of variability

(typically $<1\%$ difference) when comparing data reported in previous years. All computational analyses and corresponding charts and graphs were produced using Microsoft Excel and the statistical computing language R (R Development Core Team 2019).



A cone-producing whitebark pine amidst extensive 5-needle pine mortality on the Bridger-Teton National Forest, Wyoming. NPS/KYLE MARVINNEY, 2019

Results

Monitored Transects

In 2019, all of the 44 transects assigned to Panel 4 were resurveyed between June and September by NPS crews. Two of the transects had significant snow cover at the time of the survey visit, therefore recruitment and understory data were not collected (trees ≤ 1.4 m tall on the transect and recruitment circles) on these transects. This is the third revisit to all Panel 4 transects for full survey data collection (blister rust and mortality; Table 1).

White Pine Blister Rust Infection—Panel 4

A total of 996 live tagged trees in 41 out of 44 transects from Panel 4 were examined for blister rust infection in 2019. This number includes 77 new live trees added during the 2019 survey. Three of the 44 transects no longer have live tagged trees due to fire or other causes of mortality, though one of these transects did have small trees (≤ 1.4 m tall) present. Of the 41 transects with live tagged trees, 34 (83%), were documented with blister rust infection on the transect and 7 (17%) had no infection present. Of the 996 live trees, 267 (27%) showed signs of blister rust infection. Of these 267 infected trees, 194 (73%) had bole infections (Figure 2).

Infection Transition

Of the 917 live trees that were surveyed on Panel 4 transects in 2015 and again in 2019, approximately 636 (69%) had no evidence of blister rust infection, 191 (21%) were infected in both years, 71 (8%) transitioned from no evidence of infection to infected, and 19 (2%) went from infected to uninfected (Table 2). 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 meet the established standards of three indicators in the same location, or infected branches that self-pruned.

Table 2. Blister rust infection and transition status among live, tagged whitebark pine trees on Panel 4 transects between 2012 to 2015 and 2016 to 2019.

Infection Status	Number of Live Trees (n = 917)
Remained Uninfected	636 (69%)
Remained Infected	191 (21%)
Uninfected to Infected	71 (8%)
Infected to Uninfected	19 (2%)

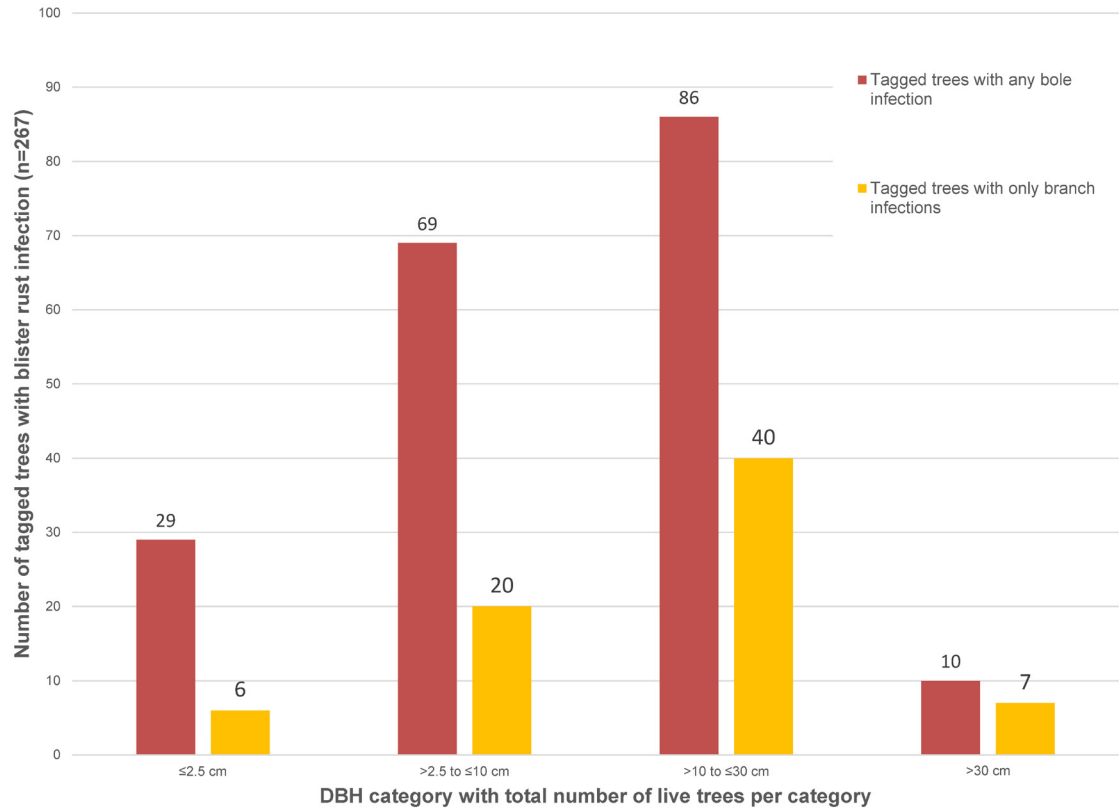


Figure 2. Size class by DBH (diameter at breast height) category and blister rust location on the 267 infected whitebark pine trees on Panel 4 transects in 2019, as categorized by trees with any bole infection(s) or only branch infections.

Mortality on Panel 4

In 2019, we observed 83 newly dead tagged trees on Panel 4 transects. Of these, 28 (34%) were ≤ 2.5 cm DBH, 37 (45%) were >2.5 and ≤ 10 cm DBH, and 18 (21%) were >10 cm DBH. A total of 58 (70%) of the dead trees died with only signs of blister rust infection, while one tree in the >10 cm DBH category died with signs of blister rust and mountain

pine beetle (Figure 3). Fourteen (17%) of the dead trees had previously been recorded with evidence of cone production. Three Panel 4 transects no longer had live, tagged trees, though one was documented with five-needle pine regeneration (≤ 1.4 m tall). All three of these transects experienced stand replacing burns (2012 Millie Fire and 2012 Dewdrop Fire).

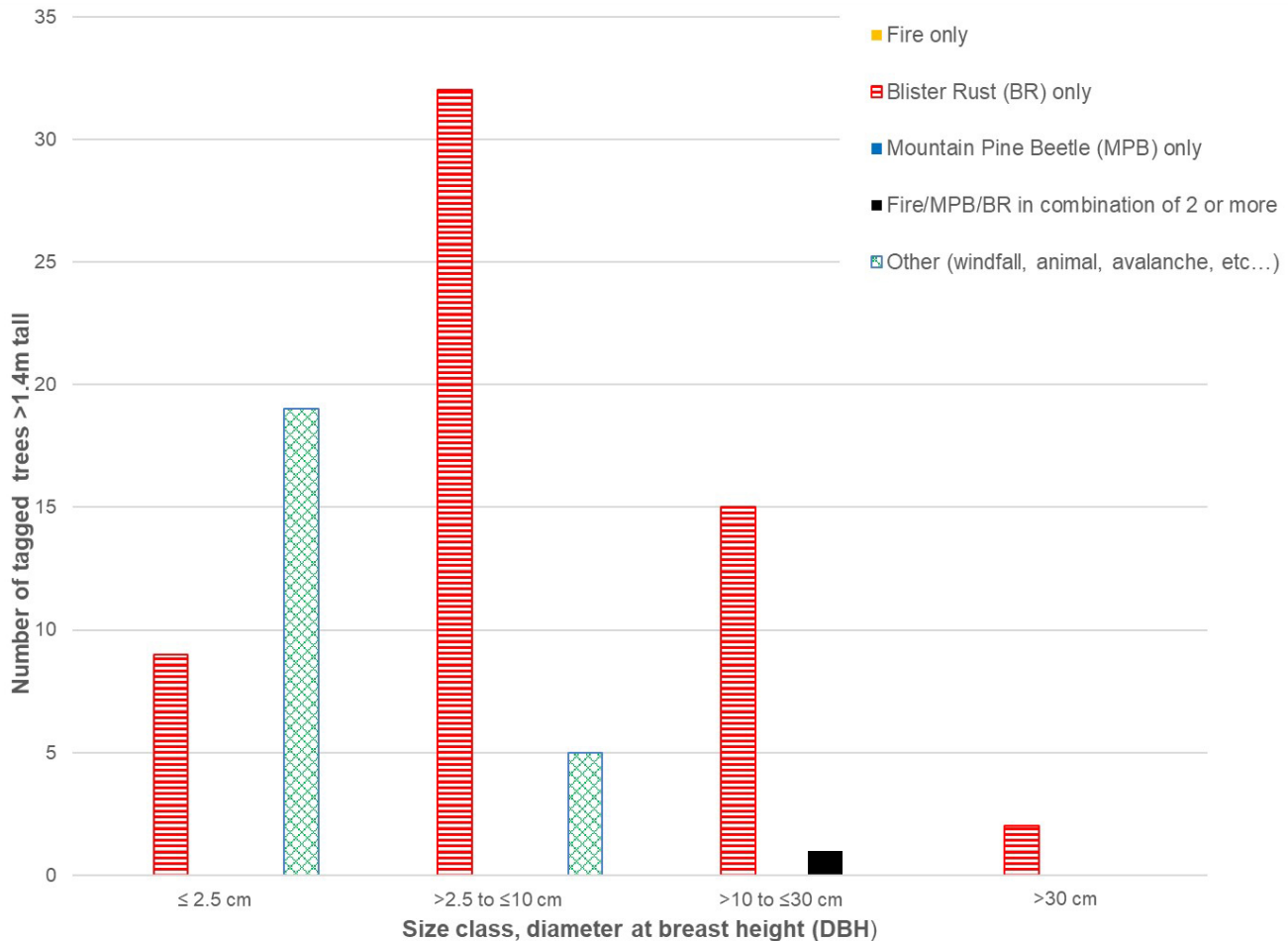


Figure 3. Eighty-three dead tagged whitebark pine trees on Panel 4 transect in 2019 categorized by size class and mortality influencing agent. Note that not all legend categories were observed.

Recruitment and Understory Individuals

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 of >1.4 m, it is permanently tagged and included in the live tree sample. In 2019, we tagged 77 new trees over 19 transects. Five (6%) of the newly tagged trees had evidence of blister rust infection. We counted 2,428 understory five-needle pines (≤ 1.4 m tall) on 42 transects; small trees were not counted on two transects due to snow cover. This equates to a density of approximately 58 small

trees per transect. Of the small trees, we observed 14 ($<1\%$) to be infected with blister rust.

In 2019, 126 recruitment plots (three per transect) were completed and six recruitment plots were not surveyed on the two transects that had snow cover. Analysis of an overall step-trend in recruitment change will be conducted at the end of T4, which will be the first possible comparison interval.

Cone production evidence (current year cones or previous year cone scars) was recorded for 116 live, tagged trees in

2019. The majority of these reproducing trees had a DBH >10 cm (94%). Based on previous monitoring observations, trees ≤ 2.5 cm DBH have been documented with evidence of reproduction but represent a minor fraction of the reproducing tree population. In 2019, there was no evidence of cone production on any tree ≤ 2.5 cm DBH. Of the trees with cone evidence, 53 (46%) had signs of blister rust infection, with 27 (23%) noted as bole infected. For reproducing trees, the number of cones are counted and categorized into five bins; 0 = no cones, 1 = 1–5 cones visible, 2 = 6–10 cones visible, 3 = >10 cones visible, and S = cone scars but no current year

cones visible. Of the Panel 4 trees documented with cones, the largest number fall into category 1 with 48 (41%) trees producing a range of 1–5 cones. The remaining trees were spread more evenly across categories 2, 3, and S (Figure 4). An additional 108 live tagged trees have previously been recorded with evidence of cone production, but no signs of reproduction were observed on these trees in 2019. Tracking the occurrence of cone production will provide insight on the trajectory of recruitment as data is collected into the future.

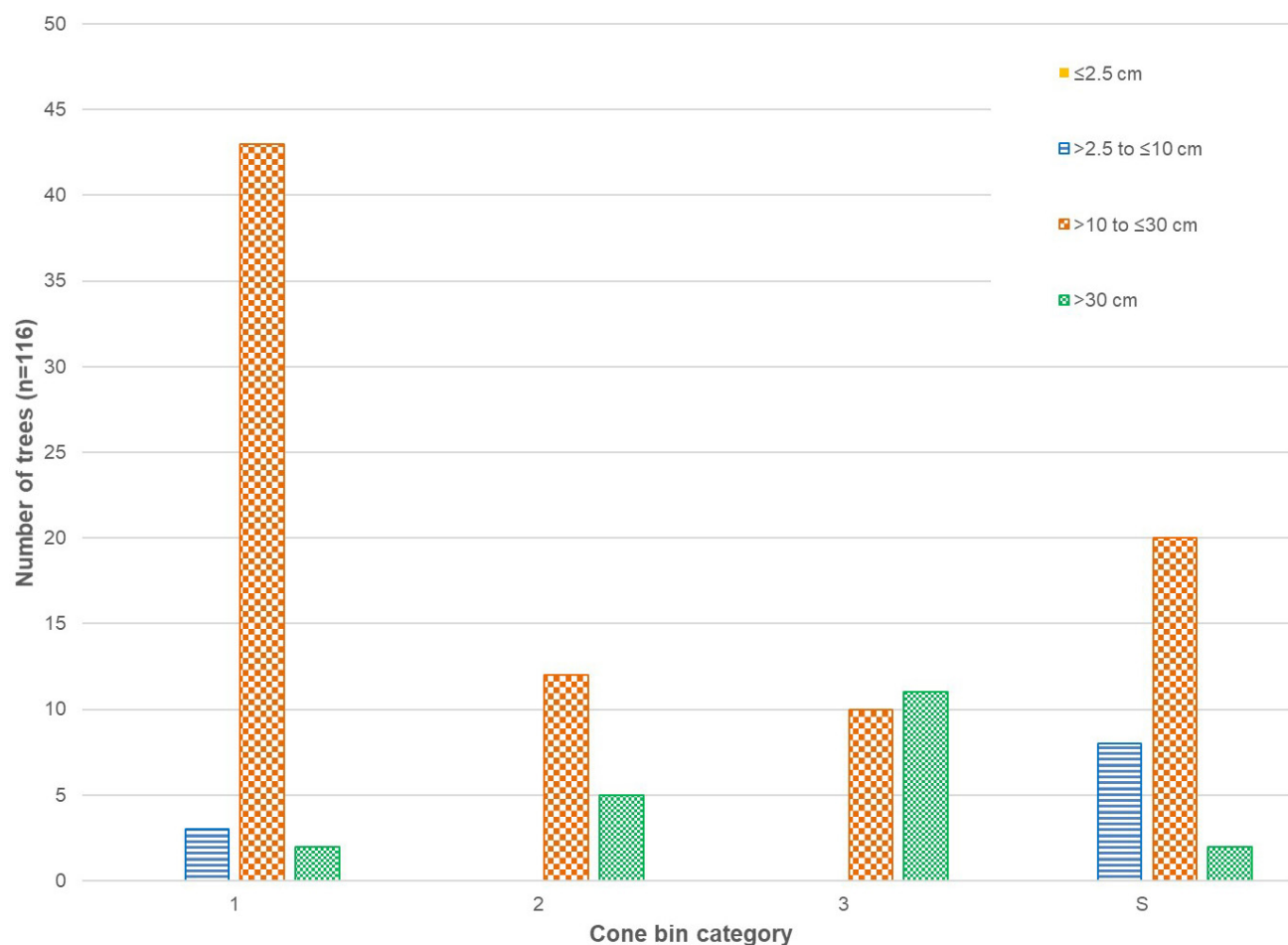


Figure 4. Number of cone producing whitebark pine trees by cone bin and DBH category on Panel 4 transects in 2019. The cone bin categories are 0 = no cones, 1 = 1–5 cones visible, 2 = 6–10 cones visible, 3 = >10 cones visible, and S = cone scars. We observed no trees ≤ 2.5 cm DBH with evidence of cone production.

Discussion

Blister Rust

Blister rust infection is widespread throughout the GYE yet varies in intensity depending on location (Figure 5). Based on monitoring data collected from 2012 to 2015, estimated rates of infection among whitebark pine ranged from 14 to 26% (Shanahan et al. 2017). The overall infection rate will be re-examined for the 2016 to 2019 time-step with the completion of Panel 4 surveys and discussed in a separate step-trend report. Blister rust infection contributes to tree mortality and leads to reduced cone production when upper branches, where cones are produced, and tree boles are girdled and killed either directly by aecia spores or indirectly by rodents and insects that consume the sweet cankers (Tomback et al. 1995). As such, infections in the bole of the tree, with the potential to affect the entire crown, are

considered more severe than in the branches alone (Koteen 2002, Newcomb 2003). Of the infected trees on Panel 4 in 2019, 194 (73%) were recorded with bole infections. In addition, mortality following the recent mountain pine beetle outbreak (Logan et al. 2009) has resulted in a shift to smaller-sized whitebark pine in the GYE (Shanahan et al. 2016). Smaller diameter trees die more rapidly once infected with blister rust than larger infected trees (Shanahan et al. 2016). Furthermore, many of the cone producing trees surveyed in 2019 (53 or 46%) had some level of blister rust infection (branch or bole). With this potential reduction in seed source and regeneration, monitoring trends in the overall condition of young trees, cone production, and infection location are of continued importance.

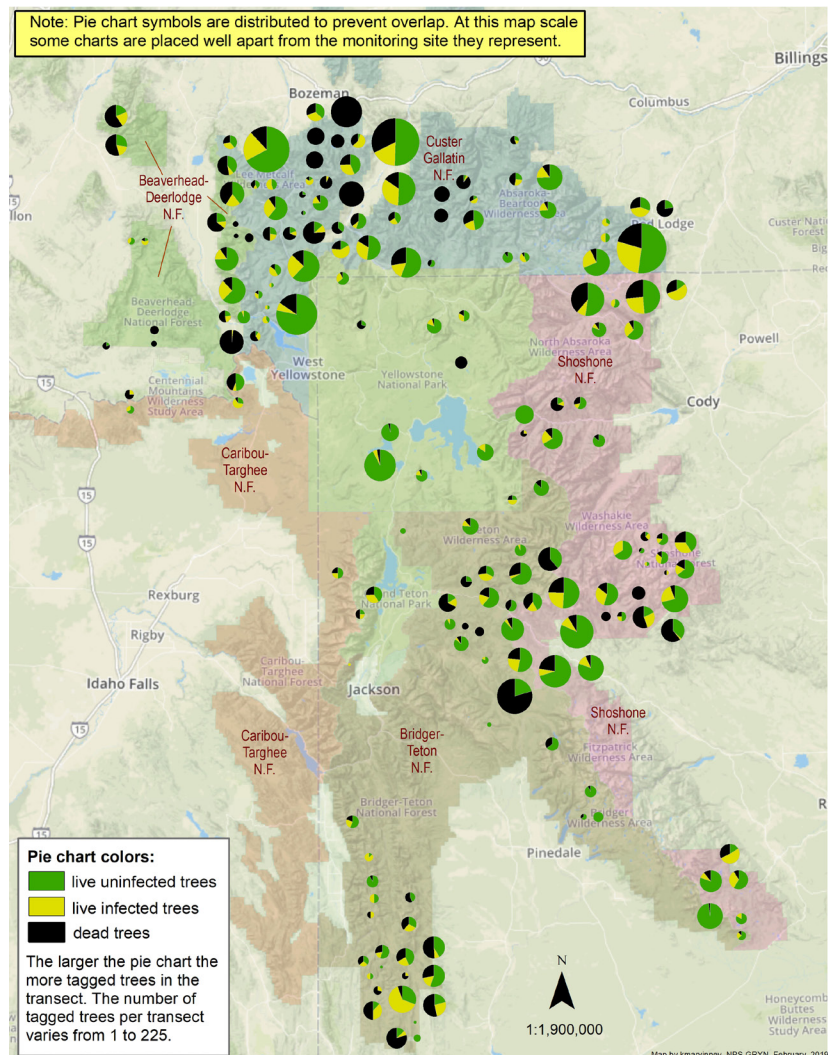


Figure 5. Infection and mortality status of whitebark pine trees for all transects in the Greater Yellowstone Ecosystem between 2015 and 2019. The infection status ranges from a tree with a single canker on a branch to a tree with a bole canker.

Mountain Pine Beetle

In 2019, there were no increases in the number of transects with evidence of mountain pine beetle (Figure 6). Only one tree recorded as dead in 2019 had evidence of mountain pine beetle infestation. While this observation may be attributed to lower, endemic levels of mountain pine, eight live tagged trees were also noted with current mountain pine beetle attacks on three different Panel 4 transects. All three of these transects had previously been documented with

mountain pine beetle outbreaks. In addition, several active mountain pine beetle outbreaks have also been reported in southern portions of the ecosystem, albeit affecting only a small number of trees, by other agency personnel (Nancy Bockino, Grand Teton N.P., pers. comm. and Avery Byer, Caribou-Targhee N.F., pers. comm.). We intend a more in-depth investigation into these recent findings using auxiliary climate indicators.

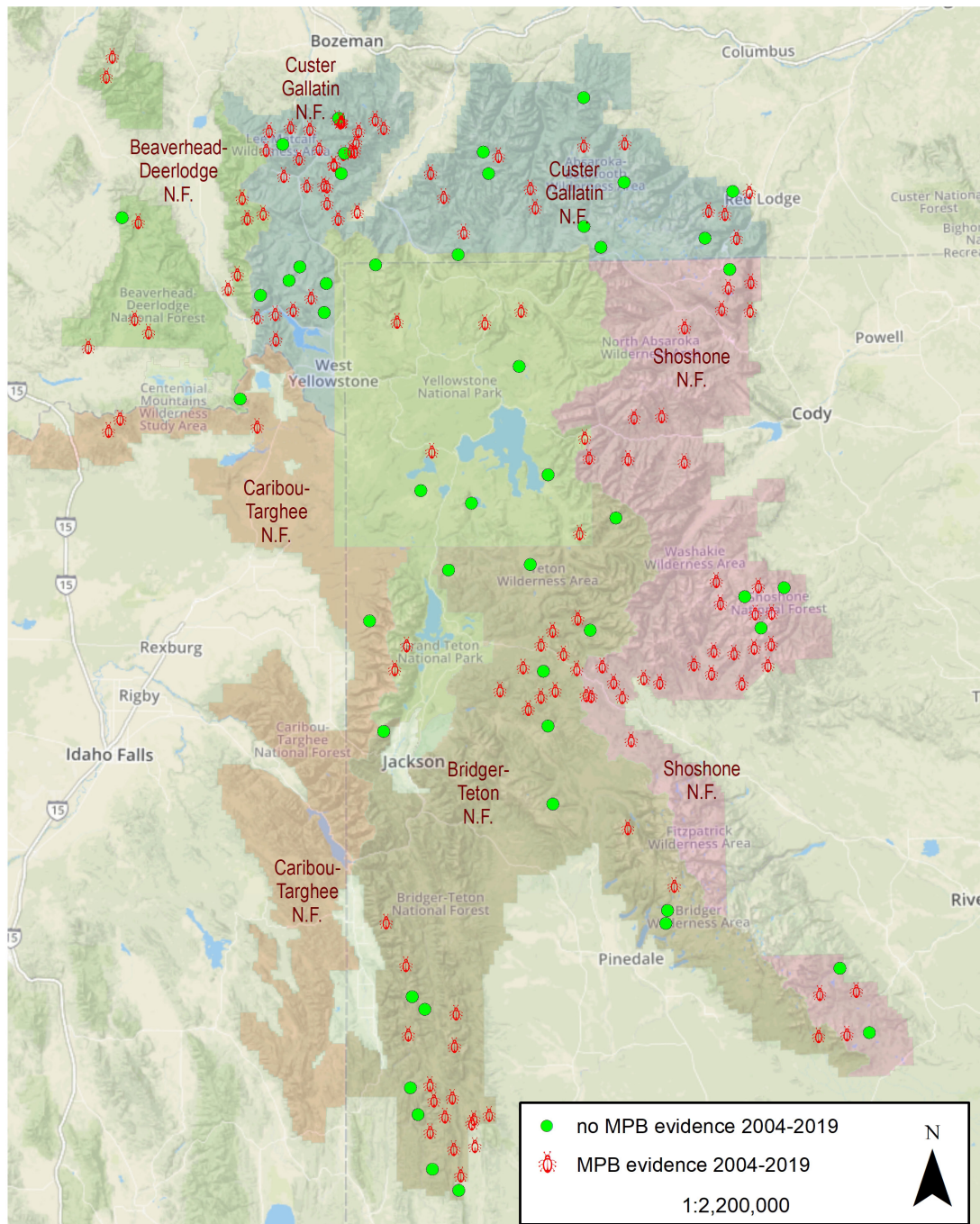


Figure 6. Location of whitebark pine transects throughout the Greater Yellowstone Ecosystem with and without evidence of mountain pine beetle (MPB) infestation between 2004 and 2019.

Wildland Fire

Though wildland fire continues to influence forests throughout the GYE, none of the live, tagged trees on Panel 4 transects were affected by fire between the last survey in 2015 and the current survey in 2019. One transect is within the area of a 2017 wildfire (2017 Pole Creek Fire, Wyoming), but none of its live, tagged trees showed evidence of wildfire damage when visited in 2019. Three Panel 4 transects have no live, tagged trees due to wildfires in 2012: the Millie Fire (Montana) and the Dewdrop Fire (Yellowstone National Park) (Figure 7). The transect in the Dewdrop Fire had five-needle pine regeneration (≤ 1.4 m tall) present.

Since 2008, approximately 254 tagged trees on 17 transects have experienced damage from wildland fire. The majority of these burns have been stand-replacing fires. As an early colonizer species, whitebark pine benefits from stand-replacing fires that create favorable conditions for regeneration by eliminating competing tree species and opening space for seed caching by Clark's Nutcrackers (Arno and Hoff 1990, Keane et al. 2012). Monitoring regeneration patterns in disturbed stands and monitoring for blister rust in the young trees will be important for informing management actions.

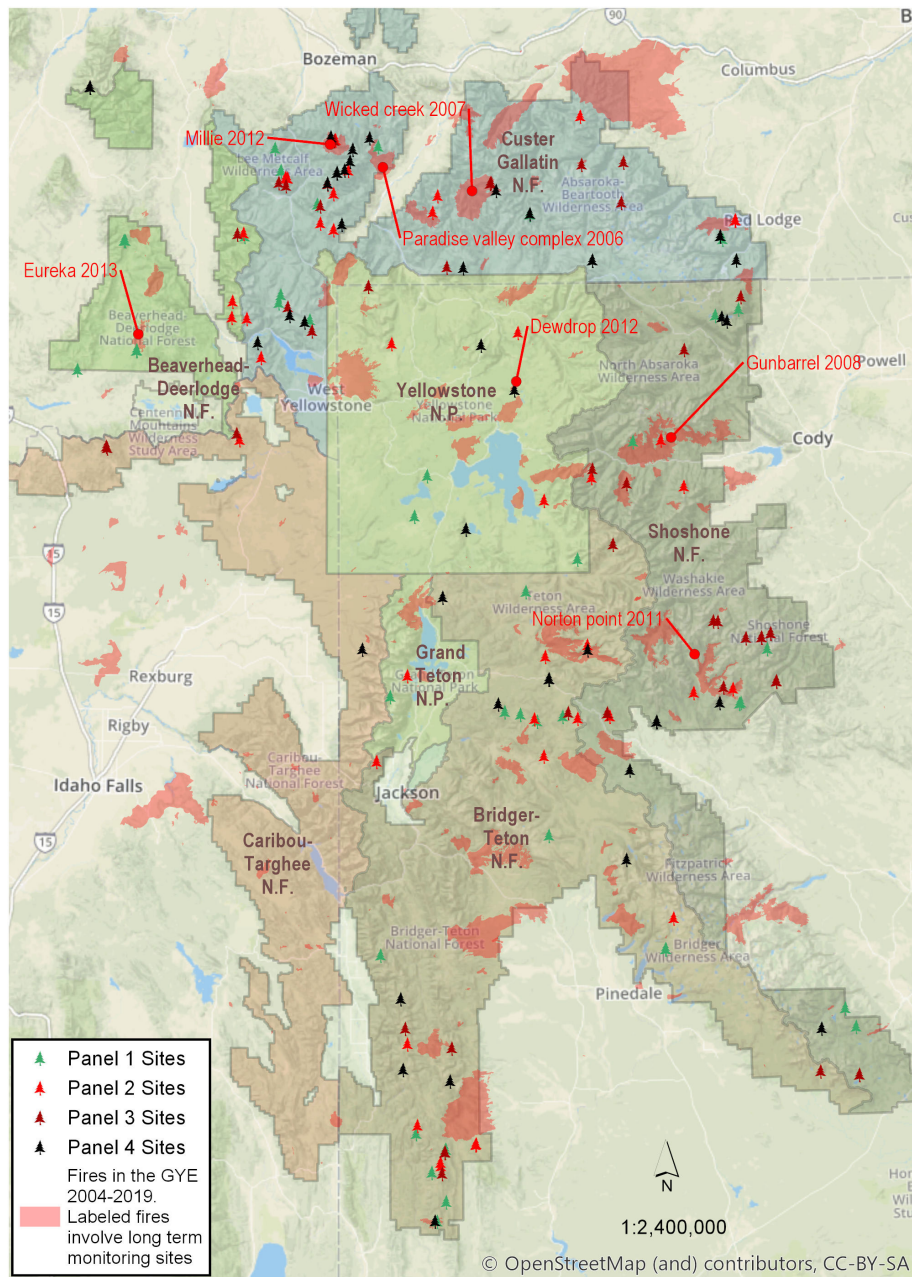


Figure 7. Location of whitebark pine transects throughout the Greater Yellowstone Ecosystem (GYE) affected by wildland fire between 2004 and 2019.

Mortality

We will continue to investigate the nuances related to changes in the proportion and severity of blister rust infection in whitebark pine with more detailed analysis presented through subsequent step-trend reports. Though we have not completed the 2016 to 2019 step-trend analysis, results from 2004 to 2013 suggest that mortality from blister rust may become more pronounced than mortality from mountain pine beetle in earlier years of monitoring (Shanahan et al. 2016). Given the episodic nature of mountain pine beetle outbreaks, we expect that these two agents will continue to impact whitebark pine at different intensities through time.

Additional Activities Related to Five-Needle Pine

In addition to the regular whitebark pine monitoring in 2019, we revisited two permanent monitoring transects and evaluated 40 rapid assessment transects on Bureau of Land Management lands in two areas of Wyoming. We report these WY-BLM survey results separately, but provide a brief

overview here. On the two permanent monitoring sites, 15 live tagged trees were surveyed and four ≤ 1.4 m tall trees were documented. Three of the tagged trees were recorded as having died since last visited in 2015. On the 40 rapid assessment transects, 322 live, five-needle pine trees (whitebark pine and limber pine, *Pinus flexilis*) were examined for blister rust and mountain pine beetle following the methodology in the rapid assessment protocol (Shanahan et al. 2018).

We continue to participate in the multiagency, cross-jurisdictional National Whitebark Pine Restoration Strategy as the primary representative for the National Park Service (NPS). The goal of this collaborative effort is to develop a landscape-wide restoration plan for whitebark pine.

NPS crews also assisted in identifying pika (*Ochotona princeps*) populations in the GYE, where crews documented pika locations and recorded habitat metrics. This information is provided to the Craighead Institute as part of its pika research effort.

Greater Yellowstone Inventory and Monitoring Network whitebark pine crew surveying for five-needle pine seedlings at a recruitment circle on a whitebark pine monitoring transect in the Custer-Gallatin National Forest, Montana.
NPS/ERIN SHANAHAN, 2019



Future Monitoring and Reporting

In 2020, we will revisit Panel 1 transects, which marks the beginning of the next time-step cycle (2020–2023). We will also revisit WY-BLM permanently established transects and conduct rapid assessment transects associated with these stands. Further, we will continue our collaboration with other research efforts taking place throughout the GYE ecosystem and 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. Data from this program are currently being used to inform managers, guide management strategies and restoration planning, support other whitebark pine research,

and substantiate conservation efforts throughout the GYE. Two step-trend reports have been completed following two revisit series (2008–2011; 2012–2015) to all panel transects (Shanahan et al. 2014; Shanahan et al. 2017). A third step-trend (2016–2019) is forthcoming as 2019 marks the completion of three revisit series. This and all other reports and studies related to the whitebark pine long-term monitoring program are available on the Greater Yellowstone Network website (<https://www.nps.gov/im/gryn/whitebark-pine.htm>). The interagency protocol, also available on the network website, has been a valuable resource for other entities embarking on five-needle pine monitoring and has helped inform the Greater Yellowstone Coordinating Committee's *Whitebark Pine Strategy for the Greater Yellowstone Area* (GYCCWPS 2011).



Mature whitebark pine trees in the Absaroka-Beartooth Wilderness on the Custer-Gallatin National Forest near Red Lodge, Montana. NPS/KYLE MARVINNEY, 2019

Literature Cited

- Arno, S. F. 1986. Whitebark pine crops - A diminishing source of wildlife food? *Western Journal of Applied Forestry* 3:92-94.
- Arno, S. F., and R. J. Hoff. 1990. *Pinus albicaulis* Engelm.: Whitebark pine. Pages 530-554 in R. M. Burns & B. H. Honkala (eds.). *Silvics of North America: 1. Conifers*. US Department of Agriculture, Forest Service, Agricultural Handbook 654, Ogden, Utah.
- Dixon, B. G. 1997. Cumulative effects modeling for grizzly bears in the Greater Yellowstone Ecosystem. Thesis. Montana State University, 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.
- Greater Yellowstone Whitebark Pine Monitoring Working Group (GYWPMWG). 2008. Monitoring whitebark pine in the Greater Yellowstone Ecosystem: 2007 annual report. Pp. 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). 2011. 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). 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.
- Hoff, R. J. 1992. How to recognize blister rust infection on whitebark pine. Research Note INT-406. USDA Forest Service, Intermountain Research Station, Ogden, Utah.
- Keane, R. E. D. F. Tomback, C. A. Aubry, A. D. Bower, E. M. Campbell, C. L. Cripps, M. B. Jenkins, M. F. Mahalovich, M. Manning, S. T. McKinney, M. P. Murray, D. L. Perkins, D. P. Reinhart, C. Ryan, A. W. Schoettle, and C. M. Smith. 2012. A range-wide restoration strategy for whitebark pine (*Pinus albicaulis*). USDA, Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado.
- Koteen, L. 2002. Climate change, whitebark pine, and grizzly bears in the Greater Yellowstone Ecosystem. Pp. 343-414 in S. H. Schneider and T. L. Root, editors. *Wildlife responses to climate change: North American case studies*. Island Press, Washington, D.C.
- Logan, J. A., W. W. Macfarlane, and L. Willcox. 2009. Effective monitoring as a basis for adaptive management: a case history of mountain pine beetle in Greater Yellowstone Ecosystem whitebark pine. *iForest* 2:19-22. Available at <https://iforest.sisef.org/abstract/?id=ifor0477-002>.
- Newcomb, M. 2003. White pine blister rust, whitebark pine, and *Ribes* species in the Greater Yellowstone Area. Thesis. University of Montana, Missoula.
- R Development Core Team. 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <http://www.R-project.org>.
- Shanahan, E., K. Legg, and R. Daley. 2017. Status of whitebark pine in the Greater Yellowstone Ecosystem: A step-trend analysis with comparisons from 2004 to 2015. Natural Resource Report NPS/GRYN/NRR—2017/1445. National Park Service, Fort Collins, Colorado.
- Shanahan, E., K. Legg, R. Daley, K. M. Irvine, S. Wilmoth, and J. Jackson. 2018. Monitoring five-needle pine on Bureau of Land Management lands in Wyoming: Summary report for 2013, 2014, 2016, 2017. Natural Resource Report NPS/GRYN/NRR—2019/1931. National Park Service, Fort Collins, Colorado.
- Shanahan, E., K. M. Irvine, D. Roberts, A. Litt, K. Legg, and R. Daley. 2014. Status of whitebark pine in the Greater Yellowstone Ecosystem: A step-trend analysis comparing 2004-2007 to 2008-2011. Natural Resource Technical Report NPS/GRYN/NRTR—2014/917. National Park Service, Fort Collins, Colorado.
- Shanahan, E., K. M. Irvine, D. Thoma, S. Wilmoth, A. Ray, K. Legg, and H. Shovic. 2016. Whitebark pine mortality related to white pine blister rust, mountain pine beetle outbreak, and water availability. *Ecosphere* 7:e01610.10.1002/ecs2.1610.

- Tomback, D. F., J. K. Clary, J. Koehler, R. J. Hoff, and S. F. Arno. 1995. The effects of blister rust on post-fire regeneration of whitebark pine: the Sundance Burn of Northern Idaho (USA). *Conservation Biology* 9(3):654-664.
- U.S. Fish and Wildlife Service (USFWS). 2016. *Pinus albicaulis*. 2016 Candidate Assessment. https://ecos.fws.gov/docs/candidate/assessments/2016/r6/R00E_P01.pdf
- Westerling, A. L., H. G. Hidalgo, D. R. Cayan, and T. W. Swetnam. 2006. Warming and earlier spring increase western U.S. forest activity. *Science* 313(5789):940-943.
- Westerling, A. L., M. G. Turner, E. A. H. Smithwick, W. H. Romme, and M. G. Ryan. 2011. Continued warming could transform Greater Yellowstone fire regimes by mid-21st century. *Proceedings of the National Academy of Sciences of the United States of America* 108(32):13165-13170.
- Witwicks, 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.

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