This document archives text and figure content from the 2020 (original) version of this article series, including metadata.

Whitebark Pine Monitoring in the Greater Yellowstone Ecosystem

(nps.gov article series)



Whitebark pine are well-adapted to the thin soils and cold, windy conditions at high elevation. This hardy stand of whitebark pine stakes its claim high up in the Clark's Fork Canyon of Wyoming.

Listing Description (255 char limit):

Whitebark pine trees are vital to the health of subalpine environments throughout the western US. Learn why and how the Greater Yellowstone Network monitors whitebark pine throughout the Greater Yellowstone Ecosystem and what they are finding. Data summary articles in this series are updated each year.

Lead-in (500 character limit):

Whitebark pine trees are vital to the health of subalpine environments throughout the western US. Their persistence is threatened, however, by a convergence of stressors, including infection by white pine blister rust, mountain pine beetle attack, and more. This article series describes why and how the Greater Yellowstone Network monitors whitebark pine throughout the Greater Yellowstone Ecosystem and what they are finding. Data summary articles in this series are updated each year.

Tags:

Gryn, whitebark pine, im, Yellowstone national park, grand teton national park, monitoring, greater Yellowstone network, series

Article 1:

Interagency Whitebark Pine Monitoring Program in the Greater Yellowstone Ecosystem - Overview



Whitebark pine on a side slope of Commissary Ridge in the Bridger-Teton National Forest, Wyoming.

This article begins the article series, *Whitebark Pine Monitoring in the Greater Yellowstone Ecosystem*.

Whitebark pine (*Pinus albicaulis*) is an iconic species of subalpine forests. In these mountainous environments, it is a keystone species, playing a critical role in ecosystem dynamics by regulating many ecological processes and influencing biodiversity (Tomback and Kendall 2001; Ellison et al. 2005). Whitebark pine is also considered a “pioneer” species due to its tolerance of harsh environmental conditions and ability to establish and persist where other species cannot. In doing so, whitebark pine can alter the microclimate and enable species such as subalpine fir (*Abies lasiocarpa*) to establish in these otherwise inhospitable regions (Tomback et al. 1993). Although whitebark pine has very little commercial value, its seeds provide seasonal forage for a variety of wildlife, including grizzly bears

(*Ursus arctos horribilis*), red squirrels (*Tamiasciurus hudsonicus*), Clark's nutcrackers (*Nucifraga columbiana*), and a variety of granivorous small mammals. Whitebark pine is one of two "five-needle pine" species in the Greater Yellowstone Ecosystem, the other being limber pine *(Pinus flexilis*).

High-elevation forests throughout 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), and whitebark pine is no exception. Whitebark pine populations have experienced declines due to several factors: 1) white pine blister rust (blister rust) caused by an introduced fungus, *Cronartium ribicola*, 2) native mountain pine beetle (*Dendroctonus ponderosae*), 3) wildland fire, and 4) climate change. Blister rust has proliferated throughout its range, impacting whitebark pinecone production and damaging 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 (Arno 1986). Between 2000 and 2010 widespread infestations of mountain pine beetle in high elevation stands have killed expansive swaths of mature whitebark pine forest (Logan et al. 2009). In the Greater Yellowstone Ecosystem (GYE) the combination of blister rust damage and mortality from mountain pine beetles has shifted whitebark pine populations to smaller sized trees and threatened whitebark pine reproduction and overall survival (Shanahan et al. 2016). Furthermore, fire regimes, which have historically been important for whitebark pine persistence, are becoming more frequent and increasing in intensity as snowpack melts earlier and faster due to rising temperatures (Westerling et al. 2011).

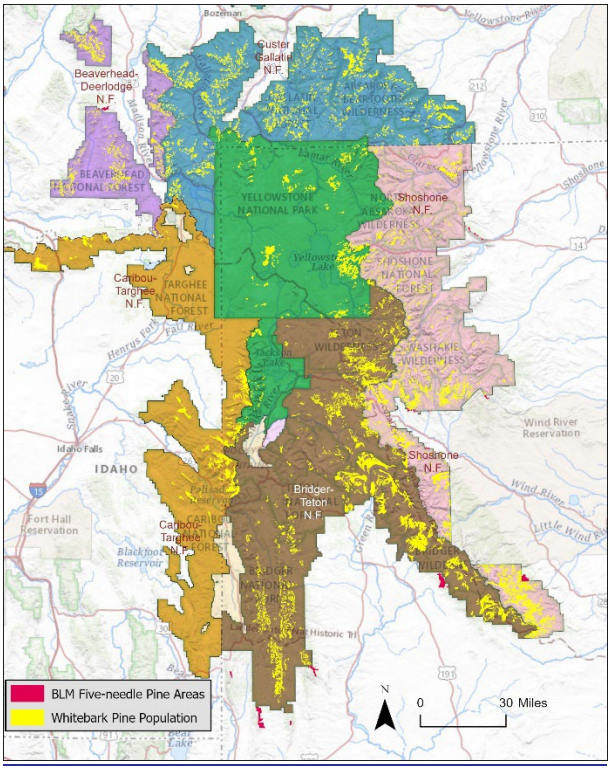
The loss of a foundational tree species such as whitebark pine has the potential to cause major changes in biological diversity and possibly trigger irreversible shifts in community composition and structure (Ebenman and Jonsson 2005). For these reasons, the persistence of whitebark pine across its historical range is of great concern. As a result, whitebark pine was proposed for listing as threatened under the Endangered Species Act by the U.S. Fish and Wildlife Service in December 2020. Whitebark pine is considered Endangered in Canada (circa 2012).

Long-term monitoring of whitebark pine as a vital sign in the GYE is essential for understanding contemporary trends in disease, insect infestation, and whitebark pine regeneration. This information helps guide management decisions and actions into the future. Under the auspices of the Greater Yellowstone Coordinating Committee (GYCC), the National Park Service (NPS) Inventory and Monitoring Division (Greater Yellowstone Network) and several other agencies initiated a collaborative, long-term

monitoring program 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 NPS, U.S. Forest Service (USFS), U.S. Geological Survey, Bureau of Land Management (BLM), and Montana State University. Since 2004, the Greater Yellowstone Network has spearheaded this multiagency whitebark pine monitoring program on NPS and U.S. Forest Service lands.

As a basis for this cross-jurisdictional monitoring program, the GYWPMWG developed a protocol between 2004 and 2007 for monitoring the health status of the whitebark pine population in the GYE. 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). Find the complete protocol on the Greater Yellowstone Network website.

In 2013, the Wyoming BLM began monitoring whitebark pine and limber pine on mapped stands of five-needle pines (Shanahan et al. 2019). Expanding monitoring to these areas provides more contiguous and inclusive information for evaluating the overall health of five-needle pine species in the region. However, data from five-needle pine monitoring on Wyoming BLM lands are not included in the data summary articles (2–4) of this article series, which are specific to whitebark pine populations on NPS and USFS lands.



The Greater Yellowstone Ecosystem includes three national parks, five national forests, and Bureau of Land Management lands.

Long-term Monitoring Objectives

The objectives of the GYE interagency whitebark pine monitoring program aim to answer two questions that will help land managers understand and act to protect the health of whitebark pine in the GYE:

- Is white pine blister rust increasing in the GYE?
- Is the resulting mortality of whitebark pine sufficient to warrant consideration of management intervention, such as active protection and/or restoration?

Objective 1 – Estimate the proportion of whitebark pine trees more than 1.4 meters (>1.4 m) tall infected with white pine 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 aecia or canker location) and estimate the change in severity over time.

Objective 3 – Estimate survival of individual whitebark pine trees >1.4 m tall, explicitly accounting for the effects of white pine blister rust infection, mountain pine beetle activity, and wildfire.

Objective 4 –Document the recruitment of understory whitebark pine into the reproductive population and assess the multiple factors that influence regeneration and recruitment success over time.

As we learn more about the dynamic nature of the multiple biotic and abiotic conditions impacting whitebark pine in the GYE, our analysis techniques and data collection procedures will remain adaptable as novel situations arise to meet contemporary management needs.

Articles 2 to 4 in this article series present monitoring results for each of the four individual objectives. Article 5 describes methods. Article 6 describes whitebark pine protection and restoration efforts.

References (will be hidden behind a collapsing panel)

Arno, S. F. 1986. Whitebark pine cone crops: A diminishing source of wildlife food. Western Journal of Applied Forestry 1:92-94.

Ebenman, B., and T. Jonsson. 2005. Using community viability analysis to identify fragile systems and keystone species. Trends in Ecology and Evolution 20:568-575.

Ellison, A. M., M. S. Bank, B. D. Clinton, E. A. Colburn, K. Elliot, C. R. Ford, et al. 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). 2011. Interagency whitebark pine monitoring protocol for the Greater Yellowstone Ecosystem, version 1.1. Greater Yellowstone Coordinating Committee, Bozeman, Montana.

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.

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.

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.

Shanahan, E., K. Legg, R. Daley, K. M. Irvine, S. Wilmoth, and J. Jackson. 2019. 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.

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 (U.S.A). Conservation Biology 9:654-664.

Tomback, D. F., and K. Kendall. 2001. Biodiversity losses: a downward spiral. Ch 12, pages 243-262 *in* D. F. Tomback, S. F. Arno, and R. E. Keane, editors. Whitebark pine communities: ecology and restoration. Island Press, Washington, DC.

Tomback, D. F., S. K. Sund, and L. A. Hoffman. 1993. Post-fire regeneration of *Pinus albicaulis*: height-age relationships, age structure, and microsite characteristics. Canadian Journal of Forestry Research 23:113-119.

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 regime by mid-21st century. Proceedings of the National Academy of Science of the United States of America 108(32): 3165-13170. Published online 2011 July 25. doi: 10.1073/pnas.1110199108 PMCID: PMC3156206.

Article 2:

White Pine Blister Rust Infection in Whitebark Pine in the Greater Yellowstone Ecosystem – Data Summary of Monitoring in 2020

This is the second article in the article series, Whitebark Pine Monitoring in the Greater Yellowstone Ecosystem.

Articles 2 to 4 of this article series summarize data from 30 Panel 1 transects surveyed between July and September 2020. This is the fourth revisit to these 30 transects for full survey data collection (blister rust and mortality; Figure 3 in Article 5: Monitoring Methods). Due to COVID-19 precautions and restrictions, 13 panel 1 transects were not surveyed in 2020. These 13 transects were surveyed in 2021.

This article presents results for Objectives 1 and 2 in the *Interagency Whitebark Pine Monitoring Protocol for the Greater Yellowstone Ecosystem.*

> *Objective 1 – Estimate the proportion of whitebark pine trees more than 1.4 meters (>1.4 m) tall infected with white pine 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 aecia or canker location) and estimate the change in severity over time.*

Overview of Methods

(For detailed methods, see Article 5 and the monitoring protocol.)

During a full survey visit, the presence or absence of blister rust infection is recorded for all live trees within a 10 meter wide by 50 meter long (10 × 50 m) belt transect. A tree is considered infected if either aecia or cankers are present. To document the severity of infection, the location of blister rust canker is recorded as occurring in the canopy (branches) or on the bole (trunk) of an infected tree.

Results for Objective 1

White Pine Blister Rust Infection on Panel 1 Trees



White pine blister aeciospores erupt from a canker caused by the nonnative fungus, *Cronartium ribicola*. The canker will kill the underlying bark on this branch, including the cambium layer. This prevents nutrients from reaching areas of the branch above the canker. NPS photo.

A total of 717 live tagged trees in 30 out of 43 transects from Panel 1 were examined for blister rust infection in 2020. This number includes 56 live trees newly tagged during 2020 surveys because they had grown taller than 1.4 m since the last survey in 2016. Four of the 30 transects no longer have live tagged trees due to fire effects and animal or mechanical damage as well as blister rust infection in some trees, though all four of these transects did have small trees (≤1.4 m tall) present. Of the 26 transects with live tagged trees, 20 (77%), were documented with blister rust infection on the transect and 6 (23%) had no infection present. Of the 717 live trees, 173 (24%) showed signs of blister rust infection. Of these 173 infected trees, 89 (51%) had bole infections (Figure 1).

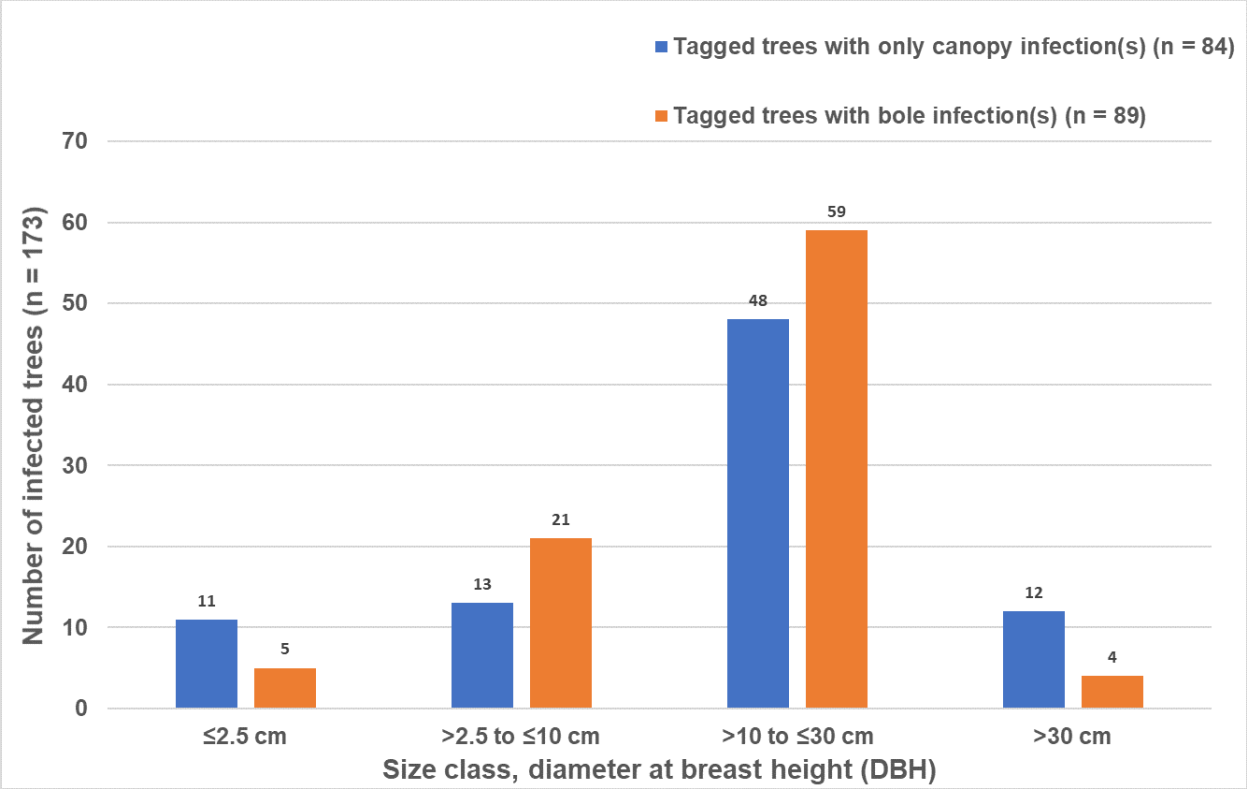


Figure 1. Blister rust infection was detected on 173 live whitebark pine trees during 2020 surveys of Panel 1 transects. Trees are grouped by size class and blister rust location (canopy only or bole infection).

Change of Infection Over Time: Status of Panel 1 Tagged Trees Live in 2016 and 2020

Of the 652 live trees that were surveyed on Panel 1 transects in 2016 and again in 2020, approximately 453 (69%) had no evidence of blister rust infection, 108 (17%) were infected in both years, 56 (9%) transitioned from no evidence of infection to infected, and 35 (5%) went from infected to uninfected (Table 1). 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 1. Blister rust infection and transition status among live, tagged whitebark pine trees on Panel 1 transects surveyed in 2016 and again in 2020.

Infection Status	Number of Live Trees (n = 652)
Remained Uninfected	453 (69%)
Remained Infected	108 (17%)

Uninfected to Infected	56 (9%)
Infected to Uninfected	35 (5%)

Results for Objective 2

Infection Transition on Panel 1

Infection location changed for 25 trees that were documented with blister rust in 2016 and again in 2020 (Figure 2). Fourteen (23%) of the 62 trees with canopy infections in 2016 transitioned to a more severe state of infection in the bole by 2020. This transition occurred in the larger size class trees >10 cm DBH.



Orange aeciospores erupt from a canker on the bole of a tagged whitebark pine tree. Cankers on the bole of a tree cause more systemic, and therefore, severe damage than cankers on the branch of a tree. NPS photo

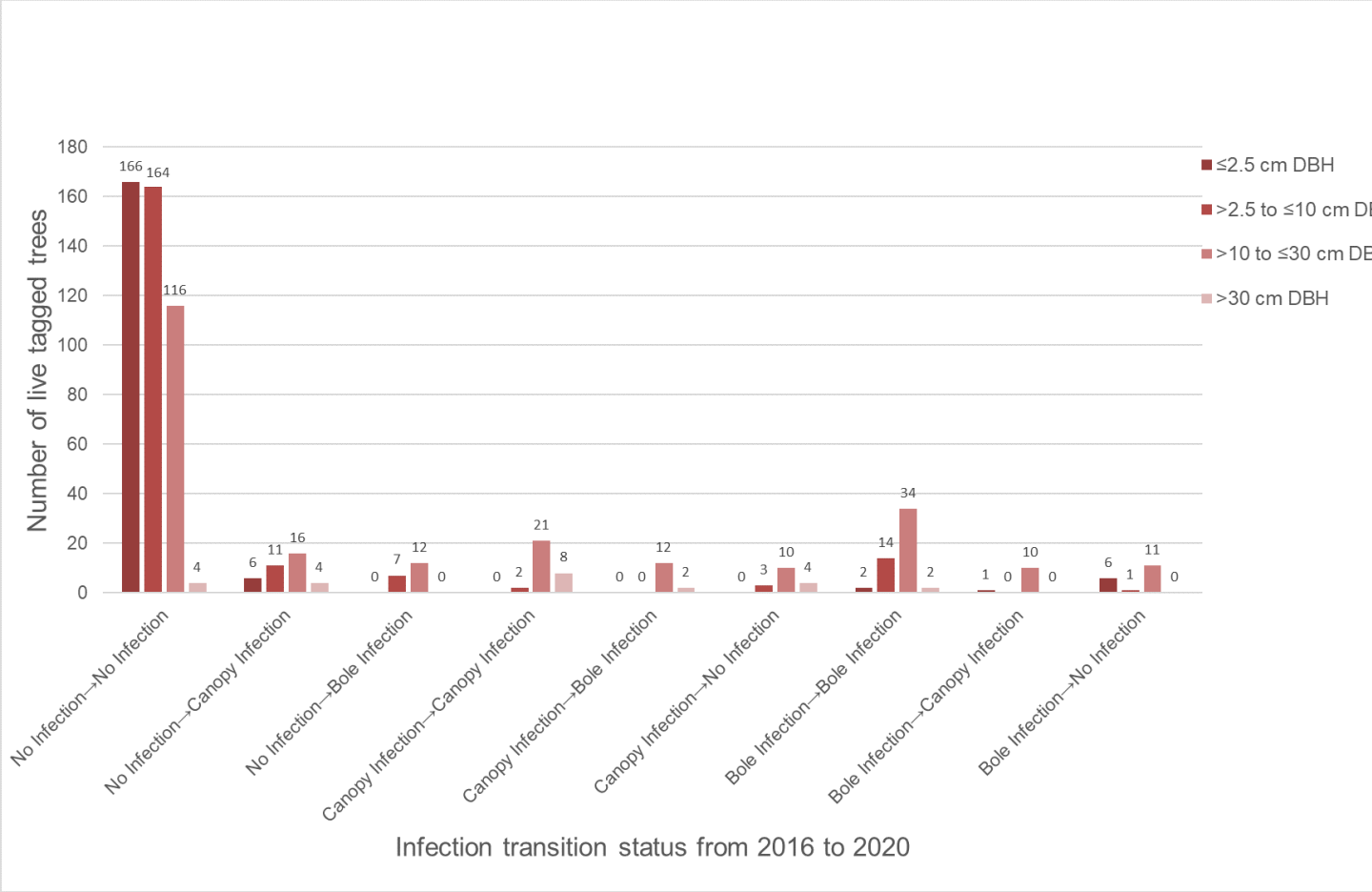


Figure 2. Infection transition status by DBH (diameter at breast height) category for live, tagged whitebark pine trees on Panel 1 transects surveyed in 2016 and again in 2020. The total count of live tagged trees surveyed in both years was 652. Three trees in the "No Infection→No Infection" category had unknown DBH measurements and thus are not included in this figure.

Learn More

These results are summarized in a resource brief for 2020. For more results from past years please visit the Greater Yellowstone Network website .

Article 3:

Whitebark Pine Mortality in the Greater Yellowstone Ecosystem – Data Summary of Monitoring in 2020

This is the third article in the article series, Whitebark Pine Monitoring in the Greater Yellowstone Ecosystem.

Articles 2 to 4 of this article series summarize data from 30 Panel 1 transects surveyed between July and September 2020. This is the fourth revisit to these 30 transects for full survey data collection (blister rust and mortality; Figure 3 in Article 5: Monitoring Methods). Due to COVID-19 precautions and restrictions, 13 panel 1 transects were not surveyed in 2020. These 13 transects were surveyed in 2021.

This article presents results for Objective 3 in the *Interagency Whitebark Pine Monitoring Protocol for the Greater Yellowstone Ecosystem.*

> *Objective 3 - Estimate survival of individual whitebark pine trees more than 1.4 meters (>1.4 m) tall, explicitly accounting for the effects of white pine blister rust infection, mountain pine beetle activity, and wildfire.*

Overview of Methods

(For detailed methods, see Article 5 and the monitoring protocol.)

All trees in the tagged population (>1.4 m tall) within the 10 meter wide by 50 meter long (10 × 50 m) boundary of each transect were recorded as live or dead. For live trees, we recorded evidence of blister rust infection, mountain pine beetle attack (pitch tubes, frass), impact from fire, or other mortality influencing factors, such as windfall or avalanche. For dead trees we recorded any J-shaped galleries under the bark from mountain pine beetle activity.



Dark reddish “pitch tubes” on a whitebark pine tree. The tree exudes sap as a defense in an attempt to expel attacking mountain pine beetles. NPS photo

Results for Objective 3

Mortality on Panel 1

In 2020, we observed 34 newly dead tagged trees on Panel 1 transects (Figure 1). Of these, 11 (32%) were ≤2.5 cm DBH, 14 (41%) were >2.5 to ≤ 10 cm DBH, 8 (24%) were ≥10 to ≤30 cm DBH, and 1 was >30 cm DBH. Sixteen (47%) of the dead trees had evidence of blister rust infection from one or more previous surveys but no evidence of mountain pine beetle or fire effects. One dead tree (3%) had only beetle presence recorded from one or more previous surveys. One dead tree (3%; in the >10 cm DBH category) had signs of both blister rust and mountain pine beetle. Of the remaining 16 trees, 12 (35%) died with sign from other causes and 4 (12%) died of unknown causes. Nine (26%) of the dead trees had previously been recorded with evidence of cone production. Four Panel 1 transects no longer had live, tagged trees, though all four were documented with five-needle pine regeneration (≤1.4 m tall). Two of these transects experienced stand replacing burns in the 2013 Eureka Fire on the Beaverhead Deerlodge National Forest.

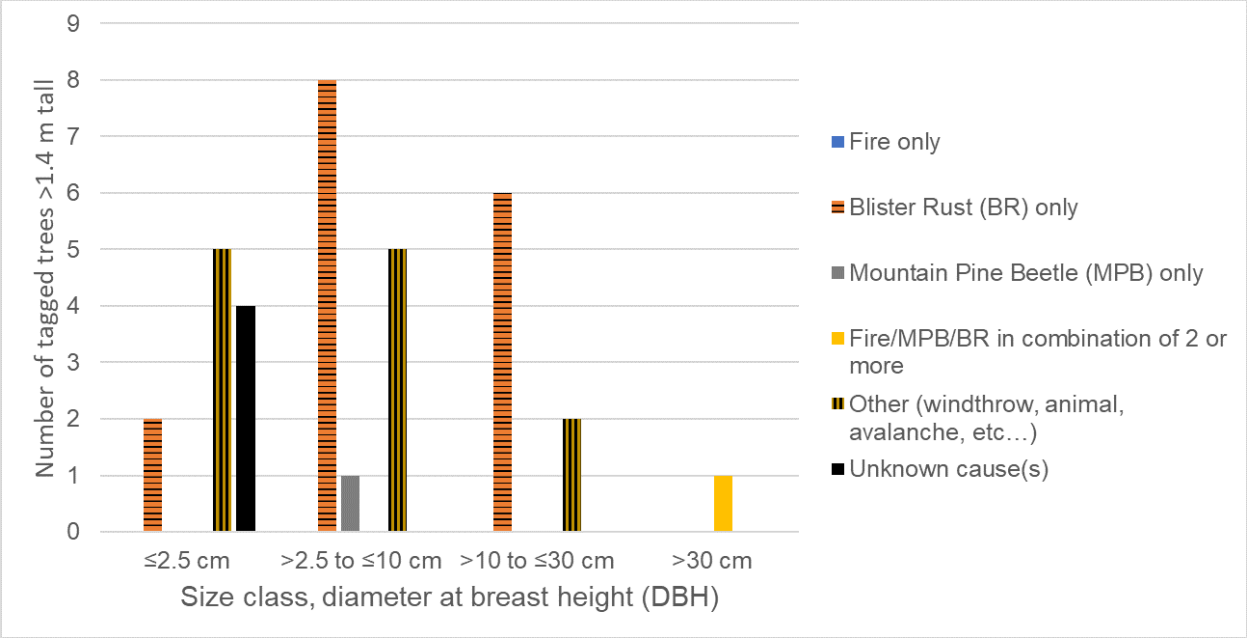


Figure 1. Thirty-four tagged whitebark pine trees were recorded as newly dead on Panel 1 transects in 2020. These trees are categorized by size class and mortality influencing agent. Note that "fire only" as a mortality agent was not observed in 2020.

Learn More

These results are summarized in a resource brief for 2020. For more results from past years please visit the Greater Yellowstone Network website.

[video of a beetle in a pitch tube]

Article 4.

Whitebark Pine Recruitment and Understory Individuals in the Greater Yellowstone Ecosystem – Data Summary of Monitoring in 2020

This is the fourth article in the article series, Whitebark Pine Monitoring in the Greater Yellowstone Ecosystem.

Articles 2 to 4 of this article series summarize data from 30 Panel 1 transects surveyed between July and September 2020. This is the fourth revisit to these 30 transects for full survey data collection (blister rust and mortality; Figure 3 in Article 5: Monitoring Methods). Due to COVID-19 precautions and restrictions, 13 panel 1 transects were not surveyed in 2020. These 13 transects were surveyed in 2021.

This article presents results for the fourth objective of the *Interagency Whitebark Pine Monitoring Protocol for the Greater Yellowstone Ecosystem* (see also Shanahan et al. 2017).

> *Objective 4* – Document the recruitment of understory whitebark pine into the reproductive population and assess the multiple factors that influence regeneration and recruitment success over time.

Overview of Methods

(For detailed methods, see Article 5 and the monitoring protocol.)

While whitebark pine tree mortality occurs in all 176 sample transects in the Greater Yellowstone Ecosystem, nearly every transect shows recruitment of new trees into the population. There are three indices of whitebark pine recruitment derived from the 10 meter wide by 50 meter long (10 × 50 m) transect surveys: the number of trees less than or equal to 1.4 meters (≤1.4 m) tall, the number of trees that grow to more than 1.4 meters (>1.4 m) tall, and the number of live tagged trees, regardless of height, that show signs of reproductive activity. Tracking cone-producing trees through time provides an indication of current and potential future tree recruitment.

Additional information about factors affecting recruitment, such as the abundance and composition of non-whitebark pine understory tree species, and ground cover, is collected in three circular 1/300 acre subplots partially overlapping each rectangular transect. Note that 2 five-needle pine species occur in

the Greater Yellowstone Ecosystem: whitebark pine and limber pine (*Pinus flexilis*). Because the two are difficult to distinguish as seedlings, some measurements are for "five-needle pine species" in general.



A cluster of five-needle pine seedlings. Whitebark pine cannot be distinguished from limber pine in the Greater Yellowstone Ecosystem without cones.

Results for Objective 4

Recruitment and Understory Individuals on Panel 1

10 x 50 m Belt Transects

Trees Transitioning from the Understory

In 2020, we tagged 56 new trees over 13 transects. Seven (13%) of the newly tagged trees had evidence of blister rust infection. We counted 2,275 understory five-needle pines (≤1.4 m tall) on 28 transects; small trees were not counted on the two remaining transects due to snow cover. This equates to an average density of approximately 81 small trees per transect. Of the small trees, we observed 98 (4%) to be infected with blister rust.

Cone Production

Cone production evidence (current year cones or previous year cone scars) was recorded for 98 live, tagged trees in 2020. The majority of these reproducing trees had a DBH >10 cm (75%). Of the trees with cone evidence, 45 (46%) had signs of blister rust infection, with 16 (36%) noted as bole infected. For reproducing trees, 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 1 trees documented with cones, the largest number fall into category 1, with 50 (51%) trees

producing a range of 1–5 cones. Cone scars were noted on 36 (37%) of reproducing trees. The remaining trees were spread more evenly across cone categories 2 and 3 (Figure 1). Tracking cone production will provide insight on the trajectory of recruitment as data are collected into the future.

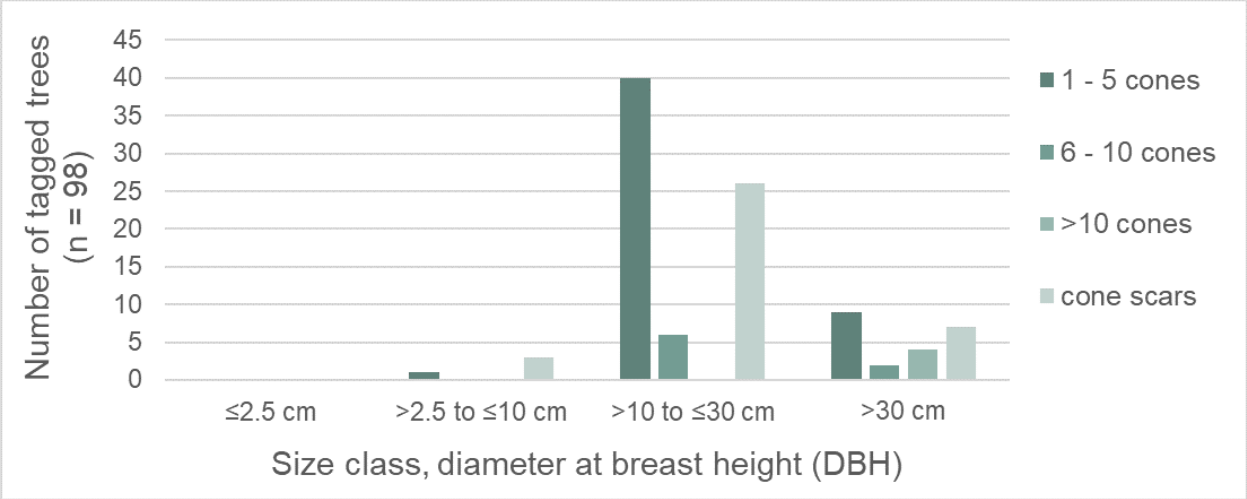


Figure 1. Number of cone-producing whitebark pine trees (98 total) grouped by number of cones visible (cone bin) and DBH category on Panel 1 transects in 2020. We observed no trees ≤2.5 cm DBH with evidence of cone production.



Inspecting a whitebark pine branch bearing its characteristically stout, sappy, purplish-brown cones.

1/300 acre Recruitment Subplots

In 2020, 84 recruitment subplots (three per transect) were completed and six recruitment subplots were not surveyed on the two transects that had snow cover. In these 1/300 acre recruitment subplots, we recorded the number of five-needle pines in four height categories (>0–15 cm, 15.1–61 cm, 61.1–140 cm, 140+ cm; note that trees in the 140+ cm category typically have tags already if they are within the 10 × 50 m transect boundary). All other tree species (lodgepole pine (*Pinus contorta*), fir (*Abies lasiocarpa, Pseudotsuga menziesii*), spruce (*Picea engelmannii*), and sometimes aspen (*Populus tremuloides*)) are recorded in two height categories (15–140 cm, 140+ cm). We examined each five-needle pine tree for signs of blister rust. In addition, we recorded ground cover, vegetation cover, and dominant and codominant vegetation species.

These data are under review and will be included in future data summary reports.

Learn More

These results are summarized in a resource brief for 2020. For more results from past years please visit the Greater Yellowstone Network website



Five-needle pine seedling a few years after sprouting.

Article 5.

Methods for the Interagency Whitebark Pine Monitoring Program in the Greater Yellowstone Ecosystem

This is the fifth article in the article series, *Whitebark Pine Monitoring in the Greater Yellowstone Ecosystem*.

This article summarizes the methods used by NPS Greater Yellowstone Inventory and Monitoring Network crews to track whitebark pine health in the Greater Yellowstone Ecosystem (GYE). Details of the sampling design and field methodology can be found by downloading the *Interagency Whitebark Pine Monitoring Protocol for the Greater Yellowstone Ecosystem Version 1.1* (GYWPMWG 2011).

[in-page navigation element added]

Study Area—The Greater Yellowstone Ecosystem

The GYE study area is geographically defined as the Yellowstone Plateau volcanic fields and the 14 surrounding mountain ranges (Marston and Anderson 1991). This area includes five national forests, three national parks, and Bureau of Land Management lands (Figure 1). Iconic Yellowstone and Grand Teton national parks (John D. Rockefeller Jr. Memorial Parkway is administered by Grand Teton National Park) are located at the center of this ecologically diverse region. The national forests are the Beaverhead-Deerlodge National Forest (MT), the Bridger-Teton National Forest (WY), the Custer Gallatin National Forest (MT), the Shoshone National Forest (WY), and the Caribou-Targhee National Forest (ID, WY).

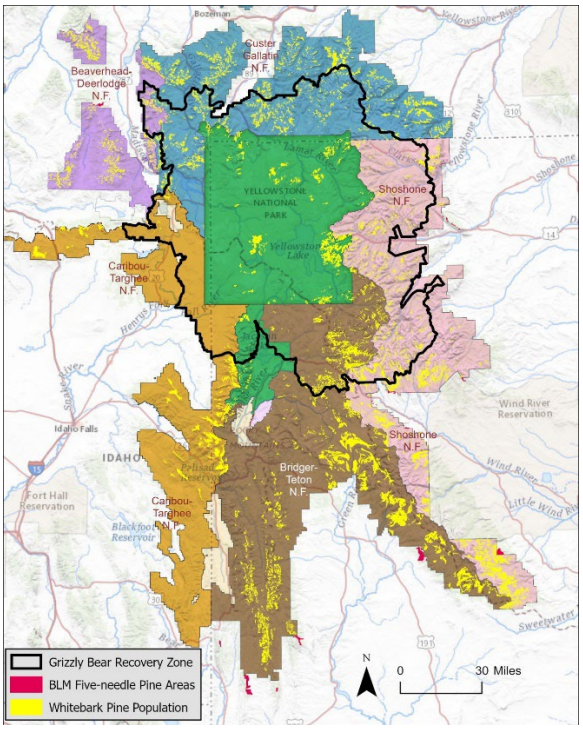


Figure 1. The Greater Yellowstone Ecosystem includes three national parks, five national forests, and Bureau of Land Management lands.

Sample Frame

Whitebark pine, in mixed and dominant stands, occurs in over 2.5 million acres of the 15 million acres+ of the GYE. The target population for this program is all whitebark pine trees found on NPS and US Forest Service lands in the GYE. The sample frame included stands of whitebark pine approximately 2.0 hectares (5 acres) or greater within and outside of the US Fish and Wildlife Service grizzly bear recovery zone (RZ). Whitebark pine stands were defined as a contiguous area of forest with whitebark pine as the dominant or codominant component. Stands were identified using photo-interpretation (Dixon 1997) and stand composition cover maps (GYWPMWG 2011). At the inception of the monitoring program in 2004, a total of 10,770 whitebark pine timber stand polygons 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 included whitebark stands mapped by each of the five US Forest Service 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.

In addition to the whitebark pine population sampled since 2004 on NPS and US Forest Service lands in the GYE, several additional five-needle pine timber stands have been sampled since 2013 in areas

administered by the Wyoming Bureau of Land Management (BLM) (Shanahan et al. 2019). The BLM monitoring data are not included in this data summary. Results from those surveys are available in *Monitoring Five-Needle Pine on Bureau of Land Management Lands in Wyoming: Summary Report for 2013, 2014, 2016, 2017*.

Sampling Design and Transect Establishment

The sampling design is a two-stage cluster design in which stands of whitebark pine are the primary units, and 10 meter wide by 50 meter long (10 × 50 m) transects within stands are the secondary units. The sample of transects is a probabilistic sample that provides statistical inference to the whitebark pine population in the Greater Yellowstone Ecosystem (GYE).

From 2004 to 2007, we established 176 permanent transects in 150 whitebark pine stands. All live, whitebark pine trees more than 1.4 meters (>1.4 m) tall (4,768 individual trees) located within the boundaries of transects were marked with a circular aluminum tree tag. Relocating and sampling each tagged tree every few years provides data useful for estimating changes in blister rust infection and survival rates over an extended period. Tree size (diameter at breast height in centimeters; DBH) was also recorded. We examined live trees for blister rust infection and recorded the location of blister rust infections (canopy or bole). A canopy canker was defined as any infection occurring within the branches of a tree ≥5 cm distal from the main bole. A bole canker was an infection on the main trunk of the tree or within 5 cm of the bole along branches. Bole cankers are considered more immediately lethal and therefore more severe than canopy cankers (McDonald and Hoff 2001; Schwandt and Kegley 2004).

Panel Assignment and Revisit Schedule

After 2007, stands were randomly assigned to one of four rotating panels. A panel is a grouping of about 44 permanent transects (Figures 2, 3). This is the number of transects that can be realistically visited in each field season by a two-person field crew. We conduct surveys from late June through mid-September each year, and each panel is revisited every four years. Four years is the approximate amount of time after initial infection with blister rust that visual signs become detectable (McDonald and Hoff 2001).

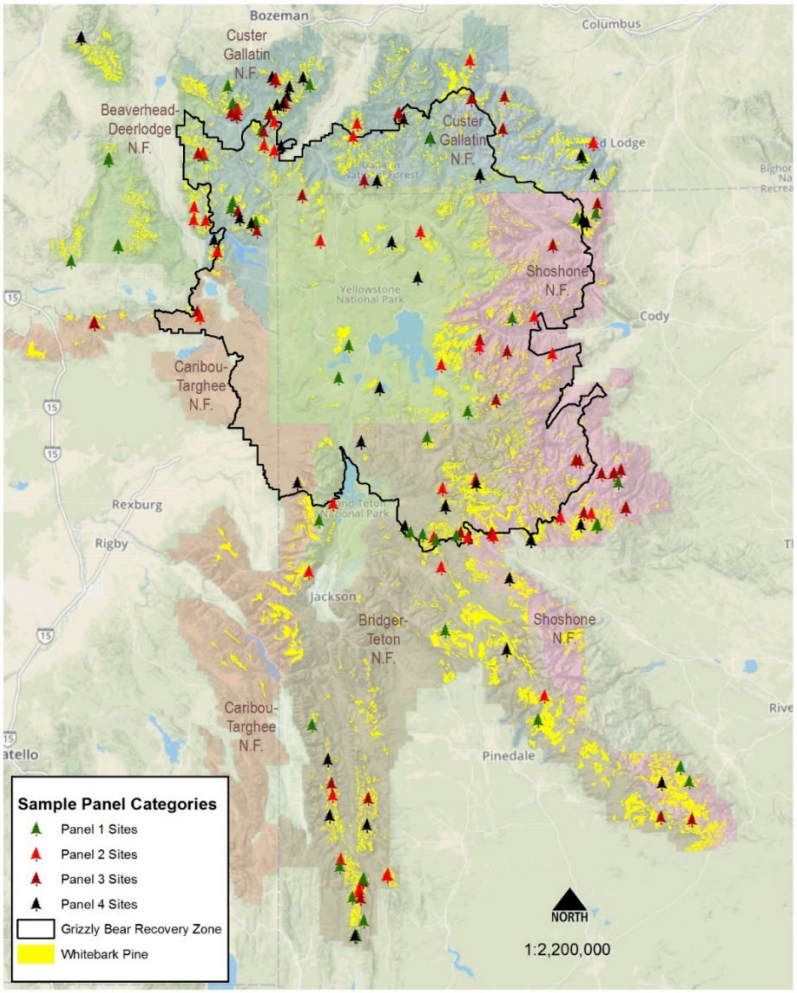


Figure 2. Location of whitebark pine survey transects within the Greater Yellowstone Ecosystem.

Figure 3. Panel sampling revisit schedule. The schedule includes full surveys of whitebark pine for blister rust and mortality, and surveys for mortality only conducted during the mountain pine beetle epidemic. 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, Time Step 5: 2020–2023).

Sample Panel	Transects per Panel	Time Step 1 (baseline)	Time Step 2				Time Step 3				Time Step 4				Time Step 5			
		2004 thru 2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020*	2021	2022	2023
1	43	Set up surveys and document initial health status	blister rust & mortality	–	mortality only	–	blister rust & mortality	–	–	–	blister rust & mortality	–	–	–	blister rust & mortality	–	–	–
2	45	Set up surveys and document initial health status	–	blister rust & mortality	–	mortality only	–	blister rust & mortality	–	–	–	blister rust & mortality	–	–	–	blister rust & mortality	–	–
3	44	Set up surveys and document initial health status	mortality only	–	blister rust & mortality	–	mortality only	–	blister rust & mortality	–	–	–	blister rust & mortality	–	–	–	blister rust & mortality	–
4	44	Set up surveys and document initial health status	–	mortality only	–	blister rust & mortality	–	mortality only	–	blister rust & mortality	–	–	–	blister rust & mortality	–	–	–	blister rust & mortality

*30 of 43 transects were visited in 2020 (due to COVID-19 restrictions).

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 any given year by panel 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 summary of data collected in a specific year should not be used to draw wide-reaching conclusions.

Documenting Whitebark Pine Health: Objectives 1–3

The first three protocol objectives track the condition of whitebark pine trees >1.4 m tall within the 10 × 50 m belt transects .

> *Objective 1: Estimate the proportion of whitebark pine trees >1.4 m tall infected with white pine 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 aecia or canker location) and estimate the change in severity over time.*
>
> *Objective 3: Estimate survival of individual whitebark pine trees >1.4 m tall, explicitly accounting for the effects of white pine blister rust infection, mountain pine beetle activity, and wildfire.*

Objective 1—Blister Rust Infection Status

During a survey visit, the presence or absence of blister rust infection is recorded for all live trees on the 10 × 50 m 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. Ancillary indicators of blister rust include flagging, rodent chewing, oozing sap, roughened bark, and swelling (Hoff 1992).



Examining a whitebark pine for evidence of white pine blister rust. The clusters of brown needles indicate potential infection. NPS photo

Objective 2—Blister Rust Infection Severity

To document the severity of infection, the location of a blister rust canker is recorded as occurring in the canopy (branches) or on the bole (trunk) of an infected tree. A canker located on a branch but within 5 cm or less from the bole of an infected tree is recorded as a bole canker. Bole cankers are more detrimental to the overall health of an infected tree and can be lethal. Although a tree can persist for decades after becoming infected, cankers situated on the lower portions of the bole will eventually lead to tree death.

Change in infection severity is assessed following subsequent surveys to live, tagged trees. Infections that initiate in the canopy have the potential to spread to the bole of infected trees. However, trees can also self-prune branches (uninfected or infected), rodents can consume cankers entirely, and blister rust resistant trees can separate or wall off infected areas, which eventually scar over. Tracking infection location change through time can provide important insight into the potential health trajectory of individual, live tagged trees and possibly impart information on canker transition dynamics.

It should be noted that a 2017 statistical analysis of canker location data collected by multiple observers to investigate observer error indicated moderate to low agreement between observers on location assignment (bole or canopy; Wright and Irvine 2017). While this investigation revealed limitations in our ability to confidently report on location transition status, it did indicate a high degree of agreement in

overall infection status among observers. Additionally, in 2020, only one observer collected infection data on all 30 transects surveyed. While this observer had over 20 years of experience identifying blister rust infection, observer subjectivity is always present regardless of the number of years of experience.



White pine blister aeciospores erupt from a canker caused by the nonnative fungus, *Cronartium ribicola*. Cankers on the bole of a tree cause more systemic, and therefore, severe damage than cankers on the branch of a tree. NPS photo.

Objective 3—Mortality



J-shaped groove underneath the bark of a pine tree, where mountain pine beetle eggs were laid. Note the slight hook at the bottom of the vertical excavation. NPS photo

For each tagged tree, observers identify if a tree is alive or dead. A tree with any green needles remaining on the tree is considered alive. Indicators of mortality influencing agents that may have impacted tree health are identified (i.e., mountain pine beetle, blister rust, animal damage, mechanical damage such as windthrow, fire scar, needle cast).

If mountain pine beetle activity is noted, observers record the type of indicator: pitch tubes and/or frass (boring sawdust). Pitch tubes are small, popcorn-shaped resin masses produced by a tree to stave off a mountain pine beetle attack. Frass is created during a mountain pine beetle attack and can be found in bark crevices and around the base of an infested tree. For all dead trees (no green needles observed), a section of bark is removed to expose any J-shaped galleries that might be present. The presence of J-shaped galleries indicates that adult mountain pine beetles and their larvae occupied the tree.

Over the course of the mountain pine beetle epidemic (2008–2013), all transects were surveyed every two years to document mortality. Trees with all brown needles or devoid of needles were classified as dead in the year this was observed (any year from 2008 to 2013). After the peak of the mountain pine beetle epidemic, we returned to the four-year rotation of visiting the transects.



Mountain pine beetle (black oblong insect) deterred from entering a boring hole that the tree has filled with pitch to fight off attacking beetles. This is a pitch tube. NPS photo

Documenting Whitebark Pine Health—Objective 4

Objective 4—Recruitment

The fourth protocol objective assesses recruitment of whitebark pine into the cone producing population:

> *Objective 4: Document the recruitment of understory whitebark pine into the reproductive population and assess the multiple factors that influence regeneration and recruitment success over time.*

We base this assessment on three different indices of recruitment within the 10 × 50 m belt transects, as well as additional metrics collected within 1/300 acre recruitment subplots. The recruitment subplots overlap the beginning, center, and ending points of the belt transects. Note that several measurements include the term “five-needle pine” species. This generalization is due to the presence of limber pine (*Pinus flexilis*), another five-needle pine species found in the GYE. Without the presence of female or male cones on a tree, limber pine and whitebark pine are indistinguishable.



Newly emerged five-needle pine seedling.

10 x 50 m Belt Transect

The three recruitment indices we measure within belt transects are

- The number of understory trees for any five-needle pine species ≤1.4 m tall (blister rust infection signs are noted).

- The number of whitebark pine trees (previously identified when <1.4 m tall), that grow to >1.4 m tall (blister rust infection signs are noted). These trees are tagged.
- The number of live, tagged whitebark pine trees, regardless of height, that show signs of reproductive activity (cones).

To approximate the average density of recruitment of five-needle pine trees per stand, we sum trees ≤1.4 m tall by stand (within the 500 m^2 transect area) and divide by the total number of stands. In the case where there are two belt transects per stand (26 cases), we average the count of small trees over the two belt transects for one stand total.

To investigate the proportion of reproducing whitebark pine trees, we conduct a visual assessment of all live, tagged whitebark pine trees on the transect for signs of current or past reproduction based on the presence of cones or cone scars. For reproducing trees, the 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. We divide the total number of positively identified live, cone-bearing trees by the total number of live trees remaining in the tagged tree sample at the end of the revisit time-step.

Recruitment Subplots

To assess the influence of competition and other factors on whitebark pine regeneration and recruitment, we collect the following data in 1/300 acre recruitment subplots associated with each belt transect:

- A count of all five-needle pine trees in four height categories (>0–15 cm, 15.1–61 cm, 61.1–140 cm, 140+ cm; note that trees in the 140+ cm category are tagged if they are within the 10 × 50 m transect boundary).
- A count of all trees by species, including lodgepole pines (*Pinus contorta*), fir (*Abies lasiocarpa, Pseudotsuga menziesii*), spruce (*Picea engelmannii*), and aspen (*Populus tremuloides*), in two height categories (15–140 cm, 140+ cm).
- Bare ground cover and vegetation cover.
- Dominant and codominant vegetation species.
- Evidence of blister rust status on five-needle pines.

Circular recruitment subplots have a radius of 2.08 m and are associated with the beginning, center, and end monument points of each belt transect (Figure 4). Subplot edges are separated by a distance of approximately 20.84 m (25 m – 2.08 m radius x 2 = 20.84 m). Five-needle pine trees ≤1.4 m tall are examined and documented for blister rust infection based on the presence of aecia and other indicator criteria as described in the monitoring protocol. Recruitment subplot data are collected only when the entire 10 × 50 m belt transect is free of snow to ensure visibility of the small trees.

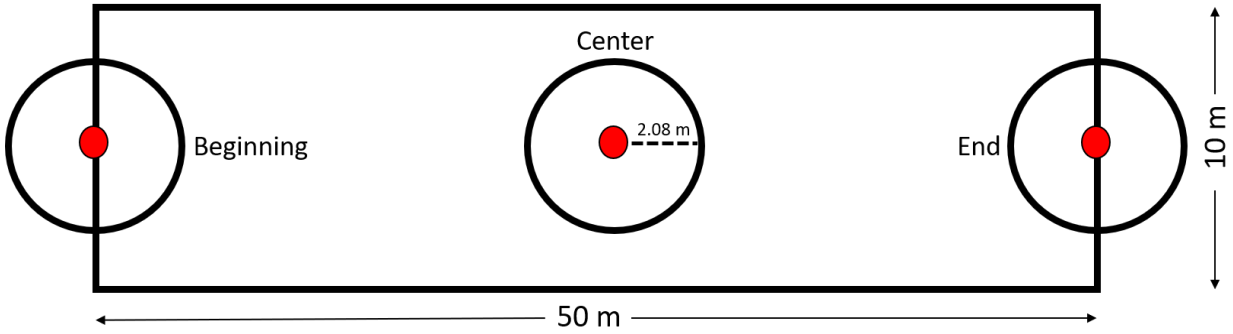


Figure 4. Layout of the three recruitment subplots within a 10 x 50 m belt transect.

Trees Transitioning from the Understory

To document the transition of ≤1.4 m tall five-needle pine trees as they advance from the understory population into the sample frame of tagged trees in the established monitoring program, all trees 61.1–140 cm tall within the subplot boundaries are marked with a recruitment-specific tree tag, which is different than the tags used for trees ≥1.4 m tall. The distinct number on tagged understory trees is recorded by subplot location. Blister rust infection status and location (canopy/bole) is also documented, if present. Five-needle pine trees that grow above 1.4 m tall and occur within both a recruitment subplot and a 10 × 50 m monitoring transect are retagged for long-term monitoring.

Understory Species Composition and Ground Cover

To investigate competition among trees in the understory, all other conifer species, as well as aspen (*Populus tremuloides*), that are 15–140 cm tall within the subplot are tallied by species. Trees >1.4 m tall are also counted if a portion of the bole is located within the subplot.

Using Daubenmire cover class codes (Daubenmire 1959), the percentage of bare ground and understory vegetation cover is documented. The dominant or codominant vegetation species are noted.

Data Management and Analysis

Prior to analysis, all data are subjected to rigorous quality assurance and quality control (QA/QC) procedures as outlined in the protocol. 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 the current year's data with 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).

Data for all years are available from the NPS Integrated Resource Management Applications (IRMA) portal: Summary Data from Greater Yellowstone Ecosystem Interagency Whitebark Pine Long Term Monitoring Program.

References (hidden inside collapsible panel):

Daubenmire, R. F. 1959. Canopy coverage method of vegetation analysis. Northwest Science 33:43-64.

Dixon, B. G. 1997. Cumulative effects modeling for grizzly bears in the Greater Yellowstone Ecosystem. Thesis. Montana State University, Bozeman.

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.

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.

Marston, R. A., and J. E. Anderson. 1991. Watersheds and vegetation of the Greater Yellowstone Ecosystem. Conservation Biology 5(3):338–346.

McDonald, G. I., and R. J. Hoff. 2001. Blister rust: an introduced plague. Pages 193-220 in D. F. Tomback, S. F. Arno, and R. E. Keane, editors. Whitebark pine communities ecology and restoration. Island Press, Washington, DC.

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/.

Schwandt, J. W., and S. Kegley. 2004. Mountain pine beetle, blister rust, and their interaction on whitebark pine at Trout Lake and Fisher Peak in northern Idaho from 2001–2003. R1-04-9. USDA Forest Service, Forest Health Protection, Missoula, Montana.

Shanahan, E., K. Legg, R. Daley, K. M. Irvine, S. Wilmoth, and J. Jackson. 2019. 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.

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.

Wright, W. J., and K. M. Irvine. 2017. Assessment of imperfect detection of blister rust in whitebark pine within the Greater Yellowstone Ecosystem. Natural Resource Report NPS/GRYN/NRR—2017/1457. National Park Service, Fort Collins, Colorado.

Article 6:

Whitebark Pine Conservation in the Greater Yellowstone Ecosystem

[insert photo of USFS person here]



Whitebark pine field crew.

This article ends the article series, *Whitebark Pine Monitoring in the Greater Yellowstone Ecosystem*.

Whitebark pine conservation in the Greater Yellowstone Ecosystem (GYE) has been a collaborative effort spanning an area greater than 24 million acres across three states. It includes three national parks, five national forests, Bureau of Land Management lands, and tribal and private lands. What started as a grassroots effort quickly transformed into a multijurisdictional endeavor. In 2001, the Greater Yellowstone Coordinating Committee's (GYCC) Whitebark Pine Subcommittee was established. The GYCC Whitebark Pine Subcommittee comprises members from the US Forest Service, National Park

Service, Bureau of Land Management, and US Fish and Wildlife Service whose mission is to help "ensure the long-term viability and function of whitebark pine in the Greater Yellowstone Area." After several years in development, in 2011 the GYCC Whitebark Pine Subcommittee published the *Whitebark Pine Strategy for the Greater Yellowstone Area* (WBP Strategy). The WBP Strategy offers detailed guidelines for conserving and restoring whitebark pine populations across the Greater Yellowstone Ecosystem. In 2015, the *Adaptive Action Plan: Whitebark Pine in the Greater Yellowstone Area* (Adaptive Action Plan) was developed as an action supplement based on the WBP Strategy recommendations.

An effort is currently underway to create a national restoration strategy. The Greater Yellowstone Whitebark Pine Subcommittee is contributing to this strategy, which is scheduled to be finalized in 2022.

Links to learn more:

Greater Yellowstone Coordinating Committee

Whitebark Pine Subcommittee: Greater Yellowstone Coordinating Committee

Whitebark Pine Strategy for the Greater Yellowstone Area

Whitebark Pine in the GYE – Adaptive Action Plan Nov 2015

National Whitebark Pine Restoration Plan

Whitebark Pine Proposed for Listing

Following data-driven support and petitioning from advocacy groups (Whitebark Pine Ecosystem Foundation, American Forest Foundation), in 2011 the US Fish and Wildlife Service designated whitebark pine as warranted but precluded for threatened or endangered listing under the Endangered Species Act (ESA). This labeling is often more emblematic of financial constraints within the agency rather than an indication of species listing importance.

Over the next decade, whitebark pine populations across their historical range continued to experience rapid declines due to multiple agents, including white pine blister rust (*Cronartium ribicola*), mountain pine beetle (*Dendroctonus ponderosae*), wildfire, and climate change. More data and expert opinion were gathered in 2019 and the plight of whitebark pine was addressed again for a final ESA listing decision. In December of 2020, whitebark pine was proposed for listing as threatened under the Endangered Species Act by the U.S. Fish and Wildlife Service. Public comments on this proposal were solicited and accepted through February 1, 2021. As of January 2022, the listing is still pending final designation.

View listing decision actions by the US Fish and Wildlife Service:

Whitebark Pine

Other Whitebark Pine Monitoring and Research Efforts

In addition to guiding whitebark pine monitoring led by the NPS Greater Yellowstone Inventory and Monitoring Network, elements of the *Interagency Whitebark Pine Monitoring Protocol for the Greater Yellowstone Ecosystem* have been used in other studies of status and trend estimates of other five-needle pine species (Mckinney et al. 2013; Perkins et al. 2016). The monitoring program data have also been requested by independent and university-affiliated researchers and were incorporated into the whitebark pine Species Status Assessment conducted by the US Fish and Wildlife Service as part of its listing determination for the whitebark pine under the Endangered Species Act.

Inside collapsing panel:

Perkins, D. L, R. E. Means, and A. C. Cochrane. 2016. Conservation and management of whitebark pine ecosystems on Bureau of Land Management Lands in the western United States. Technical Reference 6711-1. Bureau of Land Management, Denver, Colorado.

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. Starcevich. 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. National Park Service, Fort Collins, Colorado.

Learn More

Find National Park Service and external journal and collaborative publications tied to whitebark pine monitoring results on the Greater Yellowstone Network website.